The Effect of Stretching Regimes on Stride Length and Range of Motion of the Equine Trot.

Natasha Rose BSc (Hons), EBW.

A thesis submitted in partial fulfilment for the requirements for the degree of MSc by Research at the University of Central Lancashire in collaboration with Myerscough College

July 2008

For my much loved Granda, who sadly passed away
the day I finished this project.
Bob Dent 10th April 1923 - 19th September 2007.

Student Declaration

I declare that while registered as a candidate for the research degree, I have not been a registered candidate or enrolled student for another award of the University or other academic or professional institution

I declare that no material contained in the thesis has been used in any other submission for an academic award and is solely my own work.

Signature of Candidate ____________

Type of Award MSc by Research

Department The School of Natural Resources

Abstract

Kinematic studies quantifying the various influences on equine locomotion are widespread, however research on the effects of stretching on equine movement is limited and lacks in comparison to human medicine. Equine trainers should be aiming to facilitate movement that is natural, aesthetic and rewarding for the horse and rider. Injury prevention is also critical for equine welfare and career longevity. The use of stretching regimes as part of manual therapy is becoming a widespread procedure within the performance horse industry. This is most likely due to extrapolation of the positive findings from human research. The aim of the investigation was to quantify the effects of two eight-week stretching regimes on stride length (SL) and range of motion (ROM) in the equine trot. Eighteen horses were divided into three matched groups according to age, conformation and breed. The groups were assigned to a 6-day stretching regime (6DSR), 3-day stretching regime (3DSR) and a control, no stretching regime (NSR). Baseline measurements of SL and ROM in trot (in hand) were obtained prior to treatment using two-dimensional video analysis. The two stretching regimes were applied for eight weeks. SL and ROM data were collected at weeks 0, 2, 4, 6, 8, 9, 10 and 11 for the trot in hand. Subjects were analysed in ridden extended trot at week 8 and 16. The results were analysed by a two-way analysis of variance (ANOVA). There were no significant effects of stretching on the in hand or ridden SL ($P>0.05$). Some significant differences were found in joint ROM between the 6DSR, 3DSR and NSR, the 6DSR generally produced lower ROM than the other two treatments. In conclusion SL was not altered by the two eight-week stretch regimes, however the 3DSR was more beneficial than the 6DSR on increasing joint ROM. Further research is required to investigate whether the ROM differences are due to stretch hold times and frequencies.

CONTENTS **PAGE NUMBER**

List of Plates **Page Number**

List of Figures **Page Number**

List of Tables **Page Numbers**

Acknowledgements

Without the continuing help and support from the following people, my positive attitude, determination and sanity would not have been possible and I am eternally grateful to everyone for this. I would like to thank:

My supervisors, Alison Northrop and Charlotte Brigden for their valuable help, support and belief in me throughout all my years at Myerscough College.

My UCLAN supervisor, Peter Lumsden for keeping me on the right track and for all his technical advice.

Jamie Martin for his superior statistical brain, valuable input into the project and for general comedy value!

David Elphinstone, Myerscough's Research Coordinator for putting up with me in his office and for his wealth of knowledge.

Katherine Fidler, my co-worker and friend, thank you for the many early mornings on the yard and hours of leading horses past the camera. I would also like to thank Charlotte Lyons, Jenny Crabb, Rose Thornton and Stan Power for all their fantastic help with film days.

The yard manager, Kirtsy Owen and the yard staff, Simone Collinge, Melissa Wilson, Emma Cooper and Jo Skingsley. It was a pleasure to work with you all and be with the horses every day; the project ran smoothly because of your fantastic help and cooperation. I would also like to thank Kirsty, Simone, Adam Cummings and Nicky Jennings for riding horses in all weather conditions! Not forgetting the horses, without this project wouldn't have existed, for their patience and good behaviour (most of the time).

Last but not least I would like to thank Bob and Christine Rose (my parents) and Stan Power, for their never-ending love, support (mentally and financially!) and continuing encouragement to reach for the stars.

1.0 INTRODUCTION

The horse has become one of the most elite animal athletes and is used at both amateur and professional levels in a number of sporting events (Goodship and Birch, 2001) that require many different talents (Clayton, 2001). Sprinting sports require rapid acceleration and the ability to produce a high maximum speed, middle distance and endurance call for stamina, while other disciplines depend on different levels of technical skills such as visual acuity, fast reflexes or aesthetics of movement (Clayton, 2001). Attributes of effective and high-quality equine motion are movements that are unrestricted, smooth and well coordinated (Denoix and Pallioux, 2004); in Germany one of the most important requirements for dressage horses is to demonstrate 'Lossgelassenheit', which means looseness and suppleness (Dyson 2000). Competition in equine sports is becoming increasingly intense, and so time must be set aside to ensure suitable preparation and careful aftercare of the horse; the aim should be to produce movement that is natural, aesthetic and rewarding for the horse and rider (Denoix and Pallioux, 2004).

Strained muscles, tendons and ligaments are common occurrences to the equine (and human) athlete while participating in intense training or competition (Zebarth and Sheard, 1985; Dyson, 2000 and Meershoek *et al.,* 2001). Pain and stiffness can often lead to restriction in the range of movement and alter the coordination and balance of the gait, often displayed as unnatural, jerky or hampered movement (Denoix and Pallioux, 2004). Strained muscle fibres are held in a greater state of contraction and cannot release completely or as quickly thus reducing flexibility (Meagher, 1985). Stretching before participation in athletic activities is standard protocol for all human sports and training sessions (Shellock and Prentice, 1985 and Thacker *et al.,* 2004), often used to reduce the risk of injury (Best, 1995) and increase performance (Sharma *et al.,* 2004). The use of stretching in sport, however, has often been based more on myth than on scientific evidence (Knudson, 1998). The origins of stretching human soft tissue are traced back through archaeological findings to the ancient Greeks, who employed flexibility training and gymnastic programmes to enable them to perform acrobatics, wrestling and various other sports (Lardner, 2001).

'Asanas' (stretching postures) have been in use for thousands of years to improve skill and flexibility as well as an aid to alter an individual's state of mind. Chandler *et al.,* (1990) defines flexibility as the ability to move a joint through a normal range of motion (ROM) without undue stress to the musculoskeletal system. Stretching procedures for humans aim to avoid injury and stiffness (Best, 1995; Weldon and Hill, 2003), increase flexibility (Sharma *et al.,* 2004) and ROM (de Weijer *et al.,* 2003; LaRoche and Connolly, 2006) and thus produce effective and aesthetic movement. The purpose of stretching for the equine is twofold; it forms part of preparatory training for the athletic horse so that movement is full and effective; it also plays a therapeutic role, aiding the prevention of stiffness in painful areas (Denoix and Pallioux, 2004). Shannon *et al.* (2005) describes stretching as techniques used to lengthen shortened soft tissues at the musculotendinous units to facilitate and increase ROM. Stretching is of fundamental importance to the equine athlete (Denoix and Pallioux, 2004). It brings the proprioceptors in the ligaments and tendons to a state of readiness and increased elasticity, it improves balance and frees up movement without risking premature effort from muscles which are in an inappropriate state of tonus, such as cold muscles that have not been warmed-up (Hourdebaigt, 1997; Denoix and Pallioux, 2004). Human studies have also demonstrated increases in the elasticity of tendon structures (Kubo *et al.,* 2001).

The application of preparatory stretching and stretch routines to horses is starting to become a widespread procedure. This is most likely due to extrapolation of the positive findings from research on human athletes to the athletic horse; indicating potential increases in muscle force, jump height, speed, ROM, muscle length and flexibility (de Weijer *et al.,* 2003; Sharma *et al.,* 2004; Shrier, 2004 and LaRoche and Connolly, 2006). Currently there is no simple and scientific method to evaluate the results from horses undergoing stretching (Giovagnoli *et al.,* 2004) and therefore it is an unsubstantiated area within equine training and performance (Buchner and Schildboeck, 2006; McGowan *et al.,* 2007). Physiotherapy and complimentary therapies such as stretching are commonly used for injury recovery and rehabilitation in horses (Denoix and Pallioux, 2004). Scientific research into the effects on movement and performance is however relatively untouched; in contrast to human or small animal physiotherapy there is no comprehensive academic literature or scientific research about equine physiotherapy (Buchner and Schildboeck, 2006). Despite the high profile of equine physiotherapy it is still an emerging area and limited information is available about its definition and where it is positioned alongside the veterinary profession (McGowan *et al.,* 2007). The majority of published information regarding stretching in horses appears in rehabilitation and therapy texts (Bromiley, 1993; Denoix and Pallioux, 2004), therefore evidence from scientific studies performed on human athletes will be reviewed and extrapolated to the horse in terms of effects on equine performance.

1.1 The use of stretching, its limitations and benefits

Several studies involving human athletes have investigated the effects of stretching when used alone (Power *et al.,* 2004), within various warm-up routines (de Weijer *et al.,* 2003; Sharma *et al.,* 2004; Little and Williams, 2006; McMillian *et al.,* 2006), pre and post-exercise (Herbert and Gabriel, 2002; Behm *et al.,* 2004) and incorporated within long term programmes (Gajdosik *et al.,* 2005; LaRoche and Connolly, 2006; Roberts and Wilson, 1999). Stretching is widely used and reported by professionals, coaches and researchers, however there are contradictory findings within the literature (Witvrouw *et al.,* 2004). The contradictions include conflicts on whether stretching is beneficial to injury prevention (Herbert and Gabriel, 2002; Shrier, 2004; Thacker et al., 2004; Witvrouw *et al.,* 2004) type of stretching to be used, long term or pre-exercise (de Weijer *et al.,* 2003; Shrier, 2004; Zakas, 2005; LaRoche and Connolly, 2006), hold time per stretch (Bandy *et al.,* 1997; Bandy and Irion, 1994) and sport specific benefits (Thacker *et al.,* 2004; Reaburn, 2006).

1.11 Stretching and injury prevention

Stretching a muscle prior to concentric action can enhance force production during the subsequent contraction; the increase in force production is called the stretch-shortening cycle (SSC) (Baechle and Earle, 2000). Studies have shown that stretching programmes can significantly influence the viscosity of the tendon and make it considerably more compliant and when a sport demands SSC of a high intensity, (such as football or sprinting) stretching may be essential for injury prevention (Witvrouw *et al.,* 2004). Witvrouw *et al.,* (2004) suggests sports that require low intensity SSC (jogging, cycling or swimming) have no need for such a compliant muscle-tendon unit and thus stretching (making the tendon more compliant) may not be advantageous. Recently investigators have questioned the practice of stretching and challenge that there is little evidence that pre or post performance stretching prevents injury; it may even negatively affect performance (Thacker *et al.,* 2004). Thacker *et al.,* (2004) also suggested that although stretching before activity might improve performance for sports that require increased ROM (for example, gymnastics), increased flexibility might compromise muscle performance for up to an hour, which could have detrimental effects on sports that do not primarily require an increase in flexibility (for example sprinting). Herbert and Gabriel (2002) reported similar findings in a systematic review of literature; conclusions from five studies of nominally moderate quality that stretched pre or post exercising had no effect on delayed onset of muscle soreness and did not produce significant reductions in the risk of injury. A problem with drawing such conclusions about the five studies is that often a report did not clearly specify that a criterion was met, thus Herbert and Gabriel (2002) consequently questioned overall outcomes and quality of the studies. Research and stretching methods varied from study to study, making exact result comparisons difficult. Definitions of injury also varied between studies and the authors may have been influenced by publication bias or by inclusion only of studies reported in English (Herbert and Gabriel, 2002). The problems previously mentioned could be applied to all studies. No two studies are exactly identical, as participant's muscle structure, individual ability and circumstances may be different, causing difficulties when extrapolating data.

Stretching and prevention of injury is dependant on the intended sport and the individual; when an individual's muscle-tendon unit is less flexible in a gymnastic type of sport a predisposing factor for exercise-related injuries exists (Thacker *et al.,* 2004; Witvrouw *et al.,* 2004). Stretching would therefore be of benefit to increase flexibility and reduce this risk. On the other hand, if the sport does not need enhanced flexibility, stretching may be of no benefit to injury prevention at all (Witvrouw *et al.,* 2004) and may impair muscle performance (Thacker *et al.,* 2004). In relation to equine sports, dressage, show jumping and eventing could be assumed to be gymnastic type activities, performing intricate and/or full range of motion movements that could require flexible muscle-tendon units. Endurance, middle distance or sprint racing may not require increased flexibility if there is a possibility of impaired muscle function in terms of power output and muscle strength for up to an hour (Thacker *et al.,* 2004).

1.12 Sport and individual specific stretching

Stretching to improve performance is very sport specific, which may partly explain the reason why there is currently no standard stretch protocol and may even mean there will never be a standard stretch protocol. Stretching would also be assumed to be specific to the individual athlete. Caution should be taken when generalising the results of studies to other populations, for example McMillian *et al.,* (2006) found performance improvements using a dynamic warm-up in young athletes accustomed to vigorous athletic and military training. This may vary compared with older or less-athletic populations due to differing responses to the warm-up protocols used. Caution must also be taken when comparing human results to that expected of horses. Hypotheses that have been accepted within human studies must not be assumed to be applicable to equine studies without vigilance.

At elite sport level, milliseconds and millimetres can mean the difference between winning and losing in humans and horses. Even small changes in reaction time, movement time and balance can have a dramatic impact (Behm *et al.,* 2004). Performing statistical analysis on results demonstrates whether an effect or change is statistically significant. Results not statistically significant, however, could be significant in the field. A statistically significant difference is not automatically one that is of clinical significance (Doll and Carney, 2007). Hinchcliff (2004) identified that failure to detect an effect of a drug does not mean that the drug does not have an effect; it simply means that in almost all cases the statistical power to detect a meaningful difference is inadequate. An increase in stride length (SL) by millimetres may not create a statistically significant p value but could mean the difference between winning and second place. Winning margins in many athletic events are small compared to the duration of the event (Hinchcliff, 2004). Behm *et al.,* (2004) emphasised that considering the minute differences between winning and losing in individual and team sports, the low but significant percentage changes in factors such as reaction time, movement time and balance (all affected by stretching) could result in serious consequences. Studies that did not find effects that were statistically significant should therefore not necessarily be dismissed, but should be considered regarding methods and type of subjects used. A systematic review conducted by Thacker *et al.,* (2004) highlighted that a simple factor such as a positive attitude toward warm-up was associated with a significant improvement in performance. There is a difficult line to be drawn as to what factor improved the performance; the attitude, the warm-up or the stretching. This psychological influence is difficult to assess in animals and may not be as significant in horses, but could possibly still have an effect. Psychological influence could also have a significant effect on the rider in competitions, anxiety is considered an important factor influencing sport performance (Kleine, 1990) and the level of pre-competition anxiety can have positive and negative effects (Raglin, 1992).

1.13 Hold time per stretch and timing of exercise

A standardised method by which to achieve the benefits of stretching still remains to be found, as it appears that stretching recommendations are ambiguous, caused by misconceptions and conflicting research reports (Witvrouw *et al.,* 2004). There is very little literature suggesting how to optimise a stretch (Zakas, 2005) and there are many important and unanswered questions within the area of stretching. The most effective timing, duration and repetitiveness of stretches to improve performance remain unclear. Zakas *et al.,* (2006) consider that some researchers' recommendations are questionable because the stretching protocols investigated were not representative of routines commonly used by athletes. Shrier (2004) states that due to the nature of research, testing actual competition performance with appropriate scientific rigor is challenging. Researchers rely on tests of performance that relate directly or indirectly to sport performance; the closer the test to performance the more valid the test (Shrier, 2004). Results from studies that do not relate to performance have to be interpreted with caution (Shrier, 2004) because direct links from the results to performance cannot be made without further testing of adaptation to methods. 'The stretching debate' assembled by Beam *et al.,* (2003) created controversy around stretching benefits (or lack of benefits) and highlighted interesting issues with regards to one particular study (Herbert and Gabriel, 2002), some of which could be applied to other published articles. Beam *et al.* (2003) questioned the means by which the researchers (Herbert and Gabriel, 2002) arrived at the conclusions and highlighted that critical factors are often not clear in the evidence provided and several are debatable.

Reasons that the evidence available about stretching is controversial could be attributed to the fact that the methods used and factors measured are variable. There is no scientifically based prescription for stretching exercises (Witvrouw *et al.,* 2004), thus there is no strong evidence to draw a useful conclusion. An example of such variability is hold time per stretch. Several studies have concluded 30 seconds hold time per stretch to be an optimal time to increase ROM (Bandy *et al.,* 1997 and LaRoche and Connolly, 2006) and flexibility (Bandy and Irion 1994; de Weijer *et al.,* 2003 and Sharma *et al.,* 2004) however many other studies have used a variety of stretching hold times. The hold times range from five, 15 and 30 seconds (Roberts and Wilson, 1999 and Zakas, 2005), 45 seconds (Kubo *et al.,* 2002a; Behm *et al.,* 2004 and Power *et al.,* 2004) up to 20 and 30 minutes (Fowles *et al.,* 2000; Behm *et al.,* 2001). With such a variety of methods, drawing sound conclusions about how to stretch and the proposed benefits remains challenging. Researchers who conclude stretching to be ineffective could be unjust because inappropriate techniques to stretch (such as hold time) or to measure the effects were used. Bias could be a problem if the researcher applying the stretches is the same person analysing the results, also the experience and knowledge of the physiotherapist is largely unknown and difficult to quantify. Thacker *et al.,* (2004) recommends neither the endorsement nor the discontinuation of stretching based on a review of literature, highlighting the need for more research. The 'correct' or standardised way to stretch to achieve maximum benefits is still largely unknown after nearly half a century of research in stretching.

Little and Williams (2006) investigated the effects of stretching and warm-up protocols and found no significant difference between static-stretch and no-stretch warm-up protocols. The data did not support the hypothesis that static stretching has a detrimental effect on high-speed performance. Reasons that this study did not record detrimental effects after static stretching could be related to the methods used. Previous protocols have often stretched muscles for greater durations than those used in common pre-competition warm-ups (Fowles *et al.,* 2000; Behm *et al.,* 2001). The long stretch times previously used (up to 20 minutes hold time) are not true representations of a warm-up before exercise or competition. The hold time of 30 seconds appears to be a true or common representation, based on previous research (Bandy and Irion 1994; Bandy *et al.,* 1997; de Weijer *et al.,* 2003; Sharma *et al.,* 2004 and LaRoche and Connolly, 2006). Little and Williams (2006) highlight that such stretching durations (up to 20 minutes) may cause neural and excessive mechanical force inhibitory mechanisms that are not apparent during common pre-competition warm-ups. Using stretch durations around the 30-second threshold, the mechanism that may be responsible for the decrease in performance could be avoided. Little and Williams (2006) and Behm *et al.,* (2001) also highlighted that performance analysis has often been conducted immediately after stretching, whereas in practice, there is often a further warm-up activity after stretching. Extra muscle activity after stretching may reverse any decrease in muscular compliance and associated decrease in neural drive initiated by stretching. It is not clear the exact cause of this, whether it is the extra activity or time delay before performance is measured (Little and Williams, 2006). The time delay and the extra activity before performance could both have an effect on the reverse of decrease in muscular compliance; it might not necessarily be just one factor having an effect. The magnitude of the effect however is probably dependent on the type of sport being performed. If the sport being performed is gymnastic in nature, it could be assumed that extra activity would be of benefit to reverse any decrease in muscle compliance. Keeping the muscles moving and 'warm' could potentially increase muscular compliance. If the sport being performed requires shorter more powerful bursts such as sprinting, the time delay may be more effectual as increased flexibility (as a result of stretching) has been found to have a negative impact on muscle performance in high power sports (Reaburn, 2006). The rest could possibly reverse the effect of this. It is clear that further research is needed, to investigate additional aspects of performance and injury after differential stretching on specific areas of muscle flexibility, compliance and performance.

1.14 Stretching benefits

The benefits of stretching are claimed in the following areas; increases in speed (Little and Williams, 2006), ROM (LaRoche and Connolly, 2006), muscle length (deWeijer *et al.,* 2003), flexibility (Sharma *et al.,* 2004), injury prevention, muscular relaxation, improved posture, mental relaxation and pain relief (Lardner, 2001; Shrier, 2004). Baechle and Earle (2000) identify that a plausible reason for improvements in ROM could be primarily due to the connective tissue adaptations. Stretching exercises most significantly affect connective tissues by taking advantage of the plastic potential (the tendency to assume a new greater length after a passive stretch) (Baechle and Earle, 2000). Increases in length of connective tissue could be assumed to be a contributing factor to increases in muscle length, flexibility and improved posture (Baechle and Earle, 2000). LaRoche and Connolly (2006) identified four weeks of stretching increased ROM, with no change in muscle stiffness, work absorption or delayed onset of muscle soreness. The increase in ROM was probably a result of enhanced stretch tolerance rather than changes in muscle elasticity. Exactly how improved tolerance to muscle force is achieved is unclear but most likely involves changes in peripheral or central nervous system operation (LaRoche and Connolly, 2006). The concept that there are no long-term adaptations in the elastic properties of muscle after a moderate duration (four weeks) stretching programme is supported by LaRoche and Connolly (2006). These adaptations are thought to be relatively short lived, often subsiding within the hour (Magnusson *et al.,* 1998 de Weijer *et al.,* 2003), potentially removing the need for a daily programme; this is still an area of interest today.

A probable factor for the increase in force, jump height and speed could be the stretch-shortening potentiation, commonly called the stretch-shortening cycle (SSC) (Baechle and Earle, 2000). The force enhancement is probably caused by the combined effects of the use of elastic energy in the muscle (primarily from stretching the myosin cross bridges) and stretch-reflex potentiation (activation of the myotatic stretch reflex caused by a rapid stretch) of muscle (Baechle and Earle, 2000). Recent studies have indicated that stretching programs can influence the viscosity of the tendon (Kubo *et al.,* 2002a; Kubo *et al.,* 2002b) and make it significantly more compliant, and when a sport demands SSC of high intensity, stretching may be important for injury prevention (Witvrouw *et al.,* 2004). Baechle and Earle (2000) highlight the importance of the SSC in many activities such as running, jumping and throwing, also that stretching a two-joint muscle (for example the hamstring) at one joint may increase the muscle's ability to generate force at the other joint. Significant improvements have been found in hamstring flexibility (Sharma *et al.,* 2004) and hamstring length (de Weijer *et al.,* 2003) with stretching treatment combined with a warm-up. Static stretching was also found to not be detrimental to high-speed performance when included in a warm-up and dynamic stretching produced better performance than did static stretching (Little and Williams, 2006).

Rose *et al.,* (2007) investigated the effects of stretching alone and combined with a warm-up and found no significant differences between the two treatments on SL and ROM of the horse. It must be noted that the stretching techniques were applied to the whole body, not just to the limbs, and took approximately 45 minutes to apply to each subject, thus if maximal muscle length gains decline within 15 minutes (de Weijer *et al.,* 2003) then minimal effects would have been recorded. It is more difficult to apply warm-up and stretching procedures to the horse in a regular routine due to possible time constraints and the difficulty to control the horse's movements. A dynamic warm-up for example, including dynamic stretching (stretching while performing movements) would be almost impossible to apply to the horse, thus is why stretching and warm-up was not investigated in this study. Improvements in ROM, flexibility and muscle force production would be of great benefit to equine motion. Considerable muscular force and increased ROM is needed to propel the horse's hindlimbs forward for efficient, smooth and positive movement. It is also needed to increase stride length to cover related distances and for increased clearance of height over a fence, therefore the most suitable method of applying effective stretches must be found.

1.2 Pre-exercise stretching versus long term routine stretching

A number of reports regarding stretching have been investigated by systematic and critical reviews (Shrier, 2004; Thacker *et al.,* 2004; Herbert and Gabriel, 2006). A review of clinical evidence strongly suggests that pre-exercise stretching (immediately before exercise) decreases force production and velocity of contraction for joint ROM, whilst running economy is improved in the human athlete (Shrier, 2004). The effects of regular routine stretching are exactly opposite. Regular stretching improves force production and velocity of contraction but has no effect on economy of motion (Shrier, 2004). The mechanism by which regular long-term stretching improves performance is likely to be related to stretch-induced hypertrophy (Shrier, 2004). Stretching a muscle group for 30 to 60 seconds per day over several months could potentially result in hypertrophy and an increase in force and contraction velocity could be predicted. This was observed in every study within the review conducted by Shrier (2004). Thacker *et al.,* (2004) reviewed 27 studies published since 1962 and concluded that stretching demonstrated increases in flexibility in a variety of human joints. It was highlighted that 15 or 30 second stretches are more effective than shorter durations and just as effective as stretches of longer durations (Thacker *et al.,* 2004). The duration of increased flexibility after stretching is from six to 90 minutes, although an extensive program of several weeks duration has produced increased flexibility that persists for several weeks (Thacker *et al.,* 2004).

Pre-exercise stretching can produce negative effects on some aspects of performance. Shrier (2004) reviewed 20 studies that found an acute stretching session diminished immediate performance in terms of force, torque and jump ability and there were no studies that reported stretching to be beneficial for these aspects. Thacker *et al.,* (2004) found similar results, the adverse effects that stretching produced was a temporary decrease in strength, increased arterial blood pressure and decrease in jump performance. This has been a common finding for pre-exercise stretching and the decrease in strength has negative effects on sports requiring power generation (Thacker *et al.,* 2004; Reaburn, 2006). If the muscles have reduced strength and a decrease in how high an athlete can jump, performance in sports such as sprinting, hurdling, high jump and long jump would suffer. An increase in arterial blood pressure would potentially cause the heart to work unnecessarily harder than it should, thus the body would not be working efficiently, causing a greater energy out put. Shrier (2004) on the other hand reported seven studies suggesting regular stretching improves performance and perhaps more interestingly no studies suggested regular stretching diminishes performance. Shrier (2004) advised that if one stretches, it should take place after exercise or at a time not related to exercise. This is due to the negative aspects that pre-exercise stretching can cause such as decreases in strength, torque, jump ability and increase in arterial blood pressure (Shrier, 2004; Thacker *et al.,* 2004).

Research that has been conducted on long term stretching regimes focused on time periods of four weeks (LaRoche and Connolly, 2006), five weeks (Roberts and Wilson, 1999), six weeks (Bandy and Irion, 1994; Bandy *et al.,* 1997) and eight weeks (Kubo *et al.,* 2002a). All studies had varied methods of stretching frequency, type and hold time per stretch. Bandy and Irion (1994) applied stretches for 15, 30 and 60 seconds for five days per week. The results suggested that duration of 30 seconds is an effective time of stretching for enhancing the flexibility of the hamstring muscles. Interestingly no increases of flexibility of the hamstring muscles occurred by increasing the duration of stretching from 30 to 60 seconds (Bandy and Irion, 1994). Bandy *et al.* (1997) also found similar results, plus no increase in flexibility when the frequency of stretching was increased from one to three times per day. Roberts and Wilson (1999) found a five week programme, stretching three times per week, applying three stretches of 15 seconds significantly increases active and passive ROM in the lower extremity of university sport players and a stretch duration of 15 seconds produces significantly greater improvements in active ROM than stretching for five seconds. LaRoche and Connolly (2006) carried out a protocol of ten sets of stretching held for 30 seconds per stretch. Stretching was completed three times per week over a four week period. The results found that after four weeks of stretching ROM had increased significantly. LaRoche and Connolly (2006) commented that stretching programmes lasting longer than four weeks, with an increase in intensity and volume of stretching applications to participants could produce changes in the stiffness and work-absorption capacity of skeletal muscles, possibly decreasing muscular stiffness. The majority of research studying the effects of stretching on material properties of muscle have been four to eight weeks in duration, and thus may have not been long enough to elicit histologic (microscopic tissue) changes in the muscle (LaRoche and Connolly, 2006).

1.3 Equine Body Worker methods of stretching

Equine Body Worker (EBW) is a name used for a person qualified in the field of equine sports massage, who trained under an Equinology instructor and passed all the relevant course material. An EBW is qualified with skills to carry out a full assessment of a horse's muscular state and fitness. Sports massage allows subtle changes to be detected at the early stages for intervention and care in the performance horse. This knowledge is invaluable. Knowledge of how to stretch and massage a horse allows discovery of when the muscles feel 'normal'. Changes to this can be detected and thus prevention is better than cure. An EBW applies various massage and stretching techniques to form a complete bodywork session. The EBW methods of stretching are as follows (Pattillo, 2005); prior to stretching, the horse must be warmed up by either massage, heat lamps or walking for approximately ten minutes to warm the muscles, increase their state of tonus and prepare them to be stretched. The EBW begins with the forelimbs, and then moves onto the hindlimbs. The techniques are applied side to side as this is more effective. The stretch should be applied slowly and often a relaxation technique (plate 1) can be applied first if the horse is tense. The stretch is often repeated twice and a support stance is adopted to protect the EWB's back.

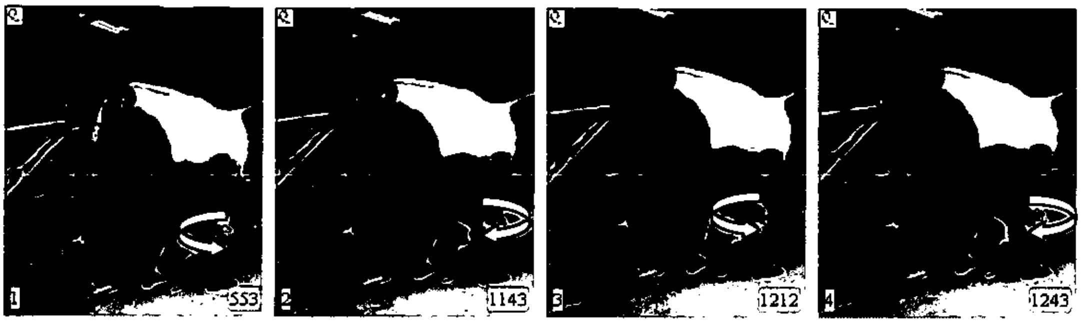

Plate 1: Relaxation technique to the forelimb; picking up the horses hoof and applying small circular movements in a clockwise or anti-clockwise direction, repeated for several circles.

When stretching the limbs, each one should be in a slightly flexed position to avoid hyperextension, the limb should be held with two hands, which should not be placed upon the tendons. Stretching should always be in the natural line of movement and allow the horse to square the rest of its hooves for maximal balance. The time to hold the stretch is referred to as 'hold times'. EBW methods (Pattillo 2005) recommend that when a horse is new to stretching and learning to become familiarised with the stretch procedure, the stretch should be held for approximately ten seconds. At intermediate level (horses who have been accustomed to stretching) the recommended hold time is 15 seconds and advanced level (horses who have received stretching on a regular basis for a long period) the hold time is increased to 30 seconds. A limitation to the recommendations given by Pattillo (2005) is that no published research has been produced to evaluate the efficacy and effects of the stretching methods upon the horse. This makes drawing conclusions about work that adopts these methods difficult, as there is no work to compare it to.

Giovagnoli *et al.,* (2004) produced one of the limited investigations into stretching effects on the horse, in this case the variation of wither height. The wither height measurement is not directly related to performance however the methodology is still worth considering. While measuring the wither height, temperature was constant. This is important as temperature can affect mechanical performance of muscle (Bennett, 1985) and joint stiffness (Lloyd, 1994; Hunter and Whillans, 1951; Hunter *et al.,* 1952), muscle contraction frequency and stride length (Bergmann and Irschick, 2006). Stretching was performed on the left and right forelimbs only and included over-protraction (lengthening/extension), over-retraction (to draw back) and over-abduction (moving away from the mid-line). When performing over-protraction and over-retraction only the hoof was handled, however Pattillo (2005) disagrees with this; the limb should be supported at all times when being stretched for safety of the horse and manipulator. Giovagnoli *et al.,* (2004) explained that each stretching position of the largest amplitude (also called over-stretching) was obtained gradually depending on the reactions of the individual horse. Individual differences must be taken into account; nevertheless this method appears variable with no way of knowing to what degree each horse was stretched. Care must also be taken with over-stretching to avoid strain and injury. Giovagnoli *et al.,* (2004) did not clarify whether the person stretching was qualified to do so which warrants caution, especially when applying over-stretching methods.

1.4 Potential benefits of stretching to the horse and its performance

Denoix and Pallioux (2004) suggest the benefits to horses of active and passive mobilisation arise from the lengthening and stretching of the soft tissues of the areas involved in locomotion. Lengthening allows the muscles to increase in ROM, improving coordination and athletic performance (Denoix and Pallioux, 2004). Lengthening of the muscles as a result of stretching can enhance a multitude of factors. Denoix and Pallioux (2004) identify these factors as stride length, engagement and propulsion of the hindlimbs, protraction and propulsion of the forelimbs, support of the thorax by the forelimbs, equilibrium when moving at speed, better positioning of the limbs when in relation to the centre of gravity, tonicity of and spring in the muscles and proprioception. Prolonged lengthening of these structures improves elasticity allowing them to increase tolerance of the pressures induced by locomotion and competition (Denoix and Pallioux, 2004).

The physiological pressures currently exerted on the horse, for example, to jump higher and gallop faster are pushing the standard of ability to perform to its physiological limits, which is demonstrated by the frequent appearance of injury. Tendon injuries, especially injury to the superficial digital flexor tendon (SDFT) of Thoroughbred racehorses results in significant losses to the racing industry every year (Patterson-Kane *et al.*, 1997; Williams *et al.*, 2001 Kasashima *et al.*, 2002; Lam *et al.*, 2007). It has been estimated that 30% of horses in race training in Europe suffer from SDFT injury at some stage (Patterson-Kane *et al.*, 1997). In the UK Williams *et al.*, (2001) reported 0.078% tendon or suspensory ligament injuries per 1000 starts. The situation also raises concern; as such lesions are far less common in animals not used for competition (Patterson-Kane *et al.*, 1997). Stretching, as a practical method by which to aid improvement of athletic performance, could be considered beneficial to the horse, rider, and trainer and potentially reduce injury and raise competition standards. Giovagnoli *et al.*, (2004) found that after passive stretching was applied to a group of horses for no more than 30 seconds at least 60% of horses wither height was reduced. Reasons for this were hypothesised to be caused by a neuro-muscular relaxation (probably due to a temporary reduction in motorneuron excitation), as reported in human medicine (Guissard *et al.*, 2001), hence decrease in wither height (Giovagnoli *et al.*, 2004). Giovagnoli *et al.* (2004) concluded that further research is needed to explore the physiological basis and the consequences of stretching in horses and to provide further evidence to support the neuro-muscular relaxation hypothesis. If this theory is validated, it could be assumed that the neuro-muscular relaxation could also elicit a positive effect on increasing ROM and SL due to the muscles being loose and relaxed and it could reduce the risk of strains and injury. Kinematic techniques such as gait analysis may help in the quantification of stretching effects, possibly detecting differences in SL and ROM before and after stretching treatments.

1.5 Gait analysis of the horse

The increasing interest for equine sports has stimulated development of the scientific research in equine locomotion (Barrey, 1999). Gait analysis is becoming increasingly common among biomechanical researchers, veterinarians and farriers, due to improved availability of economical and simple equipment (Colborne, 2004). Gait analysis allows investigation of lameness and abnormal movement, and improves understanding of factors that may affect equine motion. Clayton (1991) identified that time magnification in motion photography allows observation of events in a stride pattern that are beyond the capabilities of the human eye. Quantitative analysis permits the stride to be investigated in detail for example timing of the stride (how long the limbs remain at different phases of the stride), vertical and horizontal (SL) distance travelled by the limbs, and angular variables (minimum, maximum joint angles and ROM) (Clayton, 1991). Two and three-dimensional kinematic gait analysis have been used in a multitude of equine studies (Back *et al.,* 1993; Clayton, 1994; Leleu *et al.,* 2002; Sha *et al.,* 2004; Chateau *et al.,* 2005 and Forsyth *et al.,* 2006). The modern and commonly used application of investigating locomotion is to use anatomical markers attached onto specific points on the horse, which are filmed by a video camera (Clayton, 1990 and Clayton, 1994). The images are then downloaded and computer software is used for subsequent analysis.

A number of kinematic studies of equine locomotion have involved two dimensional (2D) motion analysis, describing flexion and extension which are the primary movements at most of the horse's joints (Clayton, 2006). In 2D motion analysis, the limb segments are treated as inflexible rods that rotate around hinge joints between the adjacent segments. Errors are greater for joints nearest to the carpus and tarsus due to movements of the soft tissue of the underlying bony landmarks (Clayton, 2006). Clayton and Schamhardt (2001) suggest that the results gained from 2D motion analysis studies could be adversely affected by image distortion due to out-of-plane image movements of the body segments; three-dimensional (3D) motion analysis overcomes this. 3D motion analysis however, requires considerably more sophisticated equipment, four or more video cameras are needed to reconstruct the motion in three dimensions and to analyse the limbs on both sides (Barrey, 1999). Clayton and Schamhardt (2001) noted that it is not possible to have markers coincide with the joint centre in 3D motion analysis; three markers must be attached in order to gain all six degrees of freedom, also soft tissue movements may create more of a problem.

The use of anatomical markers is common in 2D and 3D gait analysis (Holmström *et al.,* 1990; Holmström and Drevemo, 1997 and Leleu *et al.,* 2002). The positioning of the anatomical markers has evolved from previous studies; however there is no set standard model as marker locations are chosen in accordance with the purpose of the analysis for the study. The disadvantages of using anatomical markers are from subjective error incorrectly placing the markers onto the body and from displacement from the skin (Van Weeren *et al.,* 1990a). Van Weeren *et al.,* (1990a) studied displacement of the skin over the underlying skeletal structures in the proximal parts of the limbs and found consistent displacements of a large magnitude, highlighting a factor of considerable importance when interpreting results from modern gait analysis techniques. Back *et al.,* (1993) highlighted that if the kinematic data is predominantly used to compare the kinematics of subjects where the horse can act as its own control, trying to correct skin displacement is not entirely necessary.

Important considerations when studying gait analysis include consistency of maker placement, accuracy of calibration of the data collection volume, and controlling the speed and straightness of the horse's movement (Clayton, 2006). Leach (1987) highlights that evaluation of performance capability of the horse requires understanding of the interrelationships between velocity, SL and stride frequency (SF). Velocity is calculated by multiplying SL with SF, both SL and SF increase with increasing velocity. At velocities less than 12m/s, for example the trot, velocity increases may be due more to SL increases because of the limited changes in SF, which occur only with increasing speed. To obtain biomechanical data, the horse is often trotted in hand or ridden past the cameras; trot is the gait used most extensively to assess gait quality and has the most information on it (Clayton, 2001). Mean trotting velocities have been recorded between 3 and 4m/s (Back *et al.,* 1994; Clayton, 1994; Back *et al.,* 1996a). It has been suggested that between three and five strides of trot is sufficient for reliable gait analysis (Clayton and Schamhardt, 2001) to obtain an average of these strides.

Today the most popular techniques used for studying equine kinematics are videographic analysis combined with a commercial software package (Back and Clayton, 2001). Equinalysis is a 2D motion analysis computer software programme that allows video footage of the horse motion to be analysed. Equinalysis was designed specifically for the equine industry to be used by farriers, veterinarians, trainers and riders, it is portable, relatively easy to use and can capture digital images for on the spot analysis via a laptop computer. A validation study for Equinalysis will be in process during the study to ensure the data it provides for the SL and joint ROM measurements are correct.

1.6 Conformation, stride length (SL) and range of motion (ROM) in the horse

Equine conformation is an important factor in movement and performance (Holmström *et al.,* 1990; Back *et al.,* 1996b; Dyson, 2000; Holmström, 2001) (and breeding (Mawdsley *et al.,* 1996)). Overall body shape defines the limits for range of movement and function of the horse and ultimately its ability to perform (Mawdsley *et al.,* 1996). Correct hoof trimming and shoeing are of equally fundamental importance in keeping the equine athlete sound and injury-free (Clayton, 1990). Exogenous factors such as farriery can greatly affect evaluation of lower limb conformation (Belloy and Bathe, 1996) and thus potentially limb movement such as SL. Clayton (1990), however, concluded that there were no significant differences between two farriery treatments, normal and acute (toes longer than the heels) on SL or duration of the suspension or stance phase in the limbs. This indicates that if a subject's toes have grown significantly longer, this should not affect the SL and ROM results, however records of individual subject's farriery records would be useful to have when carrying out kinematic studies to possibly relate any significant changes in the stride.

The knowledge of each individual's conformation and baseline data is integral to kinematic studies. A linear assessment trait evaluation system is suitable to allow quantitative description of the static conformation of the horse. The system, devised by Mawdsley *et al.,* (1996) evaluates 27 traits by linear evaluation score (from one to seven) or measurement (often in centimetres). The system was not devised to define good or bad characteristics, but to describe where the individual being assessed is placed between the biological extremes for a particular conformational trait (Mawdsley *et al.,* 1996). Evaluation of the conformation of the horse is usually subjective and based on experience (Holmström *et al.,* 1990). Rossdale and Butterfield (2006) highlight that subjective evaluations have the merit of allowing expression of opinion relating to practical experience using tried, tested and trusted methodology. Objective conformation evaluation methods provide a reliable and quantitative assessment of the horse but traditional subjective methods such as Mawdsley *et al.,* (1996) will always be important (Holmström, 2001). It must be kept in mind that there are aspects of conformation that cannot be measured by objective methods and the reliability of the evaluation is dependant on the experience and skill of each individual judge (Holmström, 2001). Subjective assessments are relatively simple, commercial and practical, however scientific advances mean that a quantifiable assessment will be more appropriate in the future (Rossdale and Butterfield, 2006). The objective approach to conformation assessment (such as Holmström *et al.* (1990)) is based on exactitude backed by statistics, but involves a corresponding basis of expensive and time-consuming methodology (Rossdale and Butterfield, 2006). In a time when 'evidence-based veterinary medicine' stands at the forefront, 'evidence based' assessment of conformation should not be left behind (van Weeren and Crevier-Denoix, 2006).

Previous researchers have found correlations between specific conformational traits and locomotion (Clayton, 1990; Holmström and Drevemo, 1997), highlighting the importance of investigating both static and dynamic conformation. Various aspects of conformation play a role in gait quality (Clayton, 2001). In Warmblood sport horses, the stride kinematics associated with a subject assessment of good movement have been studied (Back *et al.*, 1994; Mawdsley *et al.*, 1996; Holmström *et al.*, 1994). Shoulder conformation (wide ROM in the scapula) has been correlated with SL, greater flexion of the tarsal joint and large extension of the fetlock in swing phase, all contributing to suppleness of movement (Back *et al.*, 1994). Limb and toe deviations from the straight axis have been considered a weakness, however not all deviations from 'desired conformation' should be judged as abnormal; 80% of Warmbloods have outwardly rotated hindlimbs, thus the frequency suggests it is normal (Holmström, 2001). Bench knee and toe in conformation is a common finding in riding horses, of which bench knee conformation does not have any documented negative effects on long term performance, but a higher incidence of splints (Holmström, 2001). For most biological systems there is a limited capacity for adaptation to achieve an optimal state when conditions are forced upon the system (Goodship and Birch, 2001), thus it must be taken into account, no matter how much stretching treatment is applied to the horse, its phenotype will limit the amount the SL and ROM can change and adapt.

Barrey (1999) defines a stride as a full cycle of limb motion. SL can also be defined as the horizontal distance travelled in the plane of progression during a single stride, or between consecutive footprints of the same foot (Back and Clayton, 2001). SL at the trot depends on the diagonal distance (distance between the diagonal pair of limbs during their stance phase) and the tracking distance (distance between the fore hoof and the next contact of the ipsilateral hind hoof) (Clayton, 2001). SL is a result of increasing muscular power, propelling the limbs across a greater area of ground. ROM is the difference between the joint angles when the joint is maximally extended and maximally flexed, joint ROM (measured in degrees of a circle) is commonly investigated in equine biomechanical studies (Back *et al.*, 1996a; Back *et al.*, 1996b). SL and ROM are integral characteristics of many equine sports. A long stride is valued for its aesthetic qualities in dressage, for the horse to cover related distances between fences easily in show-jumpers and for increased velocity in racehorses (Clayton, 1990). An increased SL and ROM of the limbs results in an effective and efficient performance in terms of quality, energy expenditure and aesthetics. In the highest scoring Olympic dressage horses the speed of the extended trot was strongly influenced by the stride length (Deuel and Park, 1990), this indicates greater reliance on changes in SL in elite dressage horses.

Back and Clayton (2001) suggest that lateral flexion of the vertebral column may enhance SL, thus the benefits of measuring SL along with ROM is that it shows suppleness and flexibility throughout the equine body. Horses that elicit high-quality movement achieve a particular trotting speed using a long SL (Holmström *et al.,* 1994). Lewczuk and Pfeffer (1998) found that endurance horses' SL increased over the course of a race, it was suggested that the increase in SL was due to warming-up during the course of the race, indicating possible muscular changes. Other desirable gait qualities include a wide range of motion in the scapula, which is correlated with SL, greater flexion of the tarsal joint and a large extension of the fetlock joints during the stance phase, which is correlated with suppleness of movement (Back *et al.,* 1994) and thus ROM. Many elite human athletes participating in gymnastic type sports require stretching procedures (Gremion, 2005) to alter the muscle fibre composition and thus increase their SL and ROM. Human and equine muscle structure is very similar, therefore if stretching is applied to the horse it is hypothesised that there will be an increase in the SL and ROM.

1.7 Aim

The study aims to quantify the effects of two eight week stretching regimes, 6-day stretching regime (6DSR) and 3-day stretching regime (3DSR) on stride length (SL) and range of motion (ROM) of the equine trot.

The objectives are:

- To obtain baseline measurements (SL and ROM) of all 18 horses pre treatment.
- To apply a 6DSR to one of the groups of matched horses.
- To apply a 3DSR to one of the groups of matched horses.
- To apply a NSR to one of the groups of matched horses.
- To compare SL and ROM pre and post the stretching regimes in all three groups of matched horses.
- To record ambient temperature during data collection and to quantify any temperature effects.
- To identify potential areas for further research and provide knowledge and scientific evidence of the effects of a stretching regime on SL and ROM of the equine trot.

1.8 Null Hypothesis H_0:

The null hypothesis is that the two differing stretch regimes 6-day stretch regime (6DSR), and 3-day stretch regime (3DSR) will have no significant effect on SL and ROM compared to the control, no stretch regime (NSR).

2.0 VALIDATION OF EQUINALYSIS:

Equinalysis is a two-dimensional (2D) motion analysis computer software program that allows video footage of equine motion to be analysed such as SL, joint angles, ROM and horizontal and vertical velocity data. Equinalysis was designed specifically for the equine industry to be used by farriers, veterinarians, trainers and riders. It is portable, relatively easy to use and can capture digital images for on the spot analysis via a laptop computer. Equinalysis has been used in a limited number of equine kinematic studies (Forsyth *et al.,* 2006); its primary use is a teaching tool. Its low cost and easy to use design makes it valuable equipment for undergraduate dissertations, however published scientific research more commonly uses accurate and expensive systems that have been rigorously tested and validated. Cost is an issue; most gait analysis systems consist of expensive cameras, force platforms and large dedicated indoor labs and these systems remain largely the domain of research laboratories and universities (Colborne, 2004).

It is essential to validate the analysis system prior to subject testing (De Luzio *et al.,* 1993; Klein and DeHaven, 1995) to confirm its accuracy and reliability in the measurements it produces. Validity is a complex notion; measurement validity reflects the extent to which a device measures what it is proposed to measure (Klein and DeHaven, 1995). The definition of the upper limits of accuracy of a particular motion analysis system provides the researcher with critical information to aid in making judgments regarding the degree to which conclusions can be drawn from the measurement data (Klein and DeHaven, 1995). Various validation methods have been used for human motion analysis (De Luzio *et al.,* 1993; Klein and DeHaven, 1995; Lovett, 2006 (unpublished)), however the methods were specific to the particular systems (Klein and DeHaven, 1995). It is difficult to find literature on validation of equine motion analysis systems. Authors often do not comment on the procedures used for validation, it is more routinely conducted by the manufacturing software company.

The purpose of this study is to quantify the effects of two stretching regimes on SL and ROM of the equine trot. Equinalysis will be used to analyse SL and

ROM, thus the methods used to validate Equinlaysis need to be closely designed with the intended purpose. The purpose of this study is to monitor possible changes in SL and ROM, therefore its essential to be certain that Equinalysis provides consistent results. To measure ROM a range of joint angles must be obtained, however without validation it is unknown whether the angles produced are correct. Accuracy of the system could be ascertained by digitisation of video footage of a moving fixed angle of a known value.

2.1 Aim of the replication study:

This chapter aims to report preliminary validation results of Equinalysis software and quantify the magnitude of human error when digitising video footage. To validate Equinalysis a pendulum will be filmed in motion with anatomical markers attached to specific points, the same video footage will be digitised ten times by a research assistant familiar to Equinalysis software. The angle data will be analysed for accuracy against the actual angles and for human error repetition discrepancies.

2.2 Null Hypothesis H_0:

The null hypothesis is that Equinalysis will not produce significantly different angles each time the pendulum digitisation process is repeated; also the Equinalysis angles will not be significantly different from the actual angle of the pendulum.

2.3 Equinalysis replication trial:

Three anatomical markers (similar to markers used in equine kinematic studies) were attached to a pendulum (plate 2, page 26) The pendulum was set in motion and filmed with a digital camera (recording at 125 frames per second). The video footage was downloaded onto a laptop, calibrated and digitised ten times by a research assistant. The digitisation process involved selecting the three anatomical markers in the order, pivot, right marker, left marker, pivot; this was done for 100 frames (plate 3, page 26) ten times. The angle data produced by Equinlaysis was transferred to Microsoft excel for subsequent analysis. The angle of the pivot would be used validate Equinalysis due to its clarity during all frames of the video footage. The actual angle of the pivot of the pendulum was

13.99°. The pivot angle at frames 0 to 100 were recorded from the ten sets of angle data and analysed for accuracy using a Chi-Squared test.

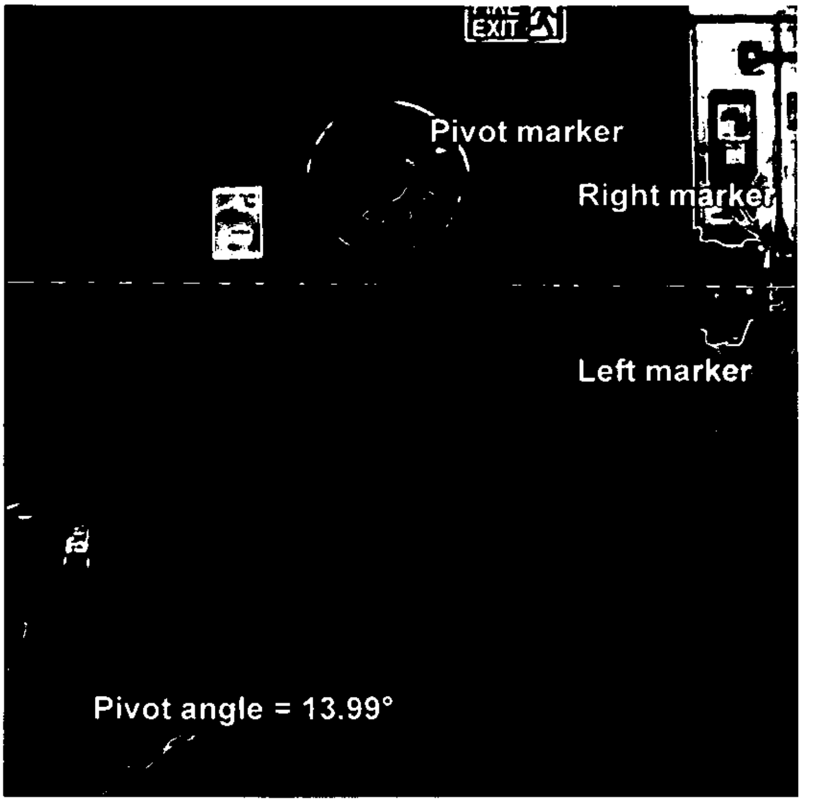

Plate 2. Pendulum with attached anatomical markers.

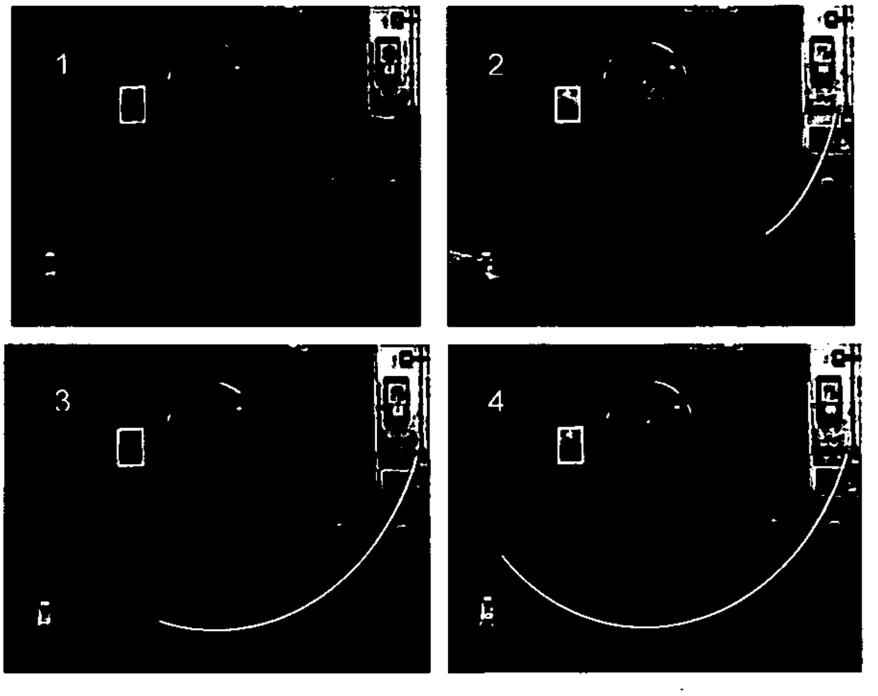

Plate 3. Digitisation of one swing (100 frames) of the pendulum in numerical order 1-4.

2.4 Results and conclusion

The goodness of fit test using Chi-Squared (X^2) indicated that there was no significant difference between the ten sets of Equinalysis produced pivot angles to the actual angle of the pivot. The actual angle of the pivot was 13.99° and the mean Equinalysis angle was 13.98°, the X^2 value (Chi-squared value) was 0.5248 (at 9 df) indicating no significant differences between the two ($P>0.05$). The results demonstrate Equinalysis produces consistent and repeatable angular results, this also highlights minimal human error when one person digitised each frame ten times. The results accept the null hypothesis, the digitised Equinalysis angles were not significantly different from the actual mean angle and minimal human error occurred during digitisation of 10 repetitions of the video footage.

To conclude, replication of Equinalysis was successful. Equinalysis is a repeatable and effective 2D motion analysis system. It must be highlighted that although successful, this is a preliminary replication study. Further validation work is needed to investigate the reliability of multiple researchers, and the use of Equinalysis in other applications, for example lameness quantification, looking at multiple angles and the automatic tracking feature.

3.0 METHODS

The investigation was carried out at Myerscough College between January and June 2007. Prior to the commencement of the eight-week stretching study a pilot study was carried out to determine whether the stretching methods were deemed practical, safe and achievable. It was essential that one person performed all the stretches in the pilot study and the eight-week stretching regime. A small group of subjects (n=2) (not included in the eight week stretch regime) were used to establish an estimation of how long each stretch session would take per subject. The stretches that were identified for use in the study were assessed and timed. It was discovered that the use of a maximum of six horses per group allowed sufficient time to stretch the subjects during the course of the day. Figure 1 (page 29) outlines a basic overview of the study; 18 subjects were split into three groups of six, group A, 6-day stretching regime (6DSR), group B 3-day stretching regime (3DSR) and group C, control, no stretching regime (NSR) by a group matched design. Prior to the commencement of the stretching procedures all subjects were filmed in trot (in hand) to gain baseline measurements of SL and ROM. The subsequent groups received their assigned treatments and were filmed at regular intervals during and post the stretching regime to measure SL and ROM. During the last week of the stretching (week 8) and eight weeks post stretching (week 16), subjects were also ridden in extended trot to measure ridden SL.

3.1 Subjects

The subjects consisted of six mares and 12 geldings (n=18), breeds varied, age ranged from six to 17 years (mean age 11) and height ranged from 14.2hh to 18hh (mean 15.2hh). All subjects previously received similar workloads on a daily basis and had suffered no serious previous injuries that may restrict movement. This information was gained from the yard manager, however depending on the age of the horse and number of owners, this could have been distorted over the years. A conformation assessment (Mawdsley *et al.,* 1996) was carried out prior to the study to gain an overview of all subjects' conformation type, highlighting any abnormalities that could have affected movement. If any subjects were found to have any extreme differences in conformation (or any movement restricting injuries), the decision to exclude them would have been made. No horses had any extreme 'abnormal' conformation characteristics or existing injuries. A profile table of all subjects' conformation scores were recorded (appendix 4, page VIII). Selection of subjects was based on horses available at the time, that were owned by Myerscough College and that could be matched together in the groups A, B and C, (horse summary profile, appendix 3, page VII). Horses were matched as closely as possible in terms of age, breed, height and conformation/build. Farrier, veterinary and general records were kept of each subject to identify possible reasons for different behaviour, movement and for general observation reasons.

3.2 Experimental protocol

Figure 1 (below) illustrates the basic experimental protocol. This is explained in more detail in each section.

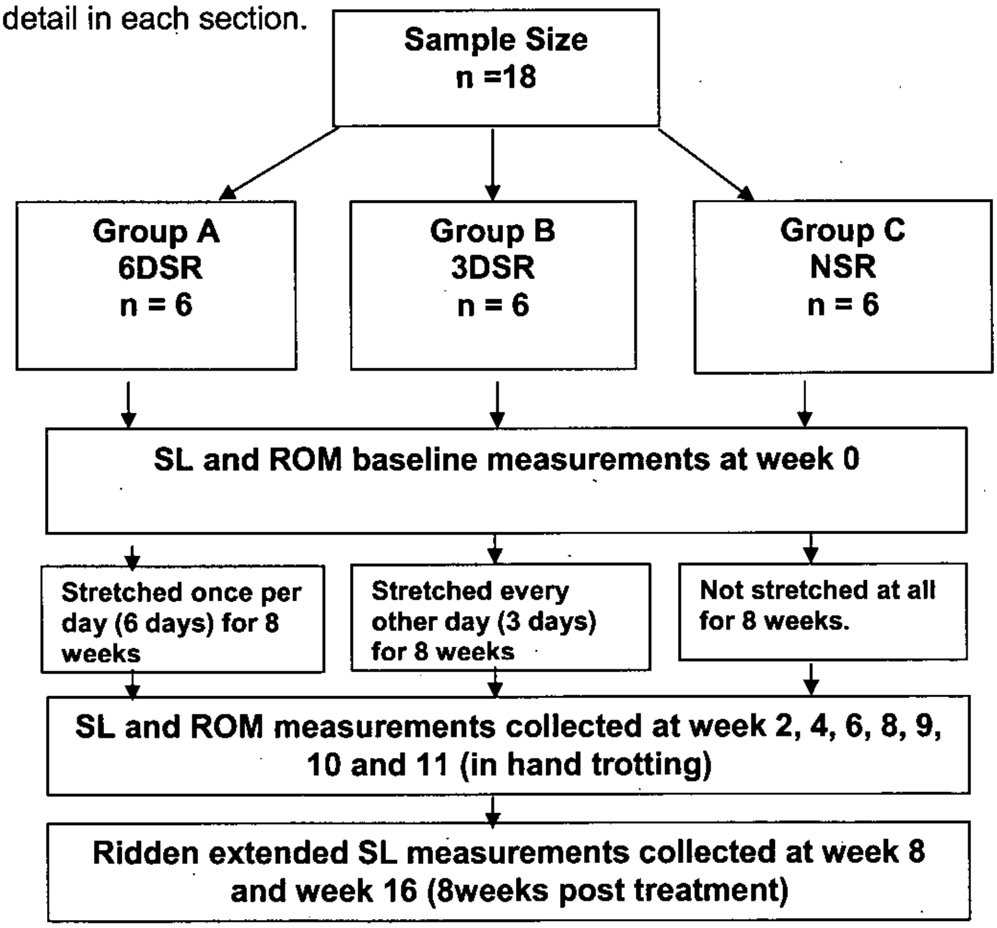

Figure 1. Basic experimental protocol indicating the treatments and assessments applied to each group. 6DSR= 6 day stretching regime, 3DSR= 3 day stretching regime, NSR= no stretching regime.

3.21 Anatomical Markers

The 18 subjects were divided and matched equally into three groups A, B and C. Subjects were matched in order to eliminate covariate effects and reduce potential bias (Nam, 1997). Baseline data (SL and ROM measurements) were obtained for each horse at week 0 prior to stretching treatments. To obtain the baseline SL and ROM, anatomical markers were applied to the horse (plate 4). The use of anatomical markers is a common procedure used in kinematic studies (Back *et al.,* 1995; Holmström and Drevemo, 1997; Leleu *et al.,* 2002). Locations of the anatomical markers were chosen in accordance to the joints analysed in the study. The joints being investigated were the shoulder, elbow, knee, fore fetlock, hip, stifle, hock and hind fetlock, illustrated in plate 4 and table 1 (page 31)

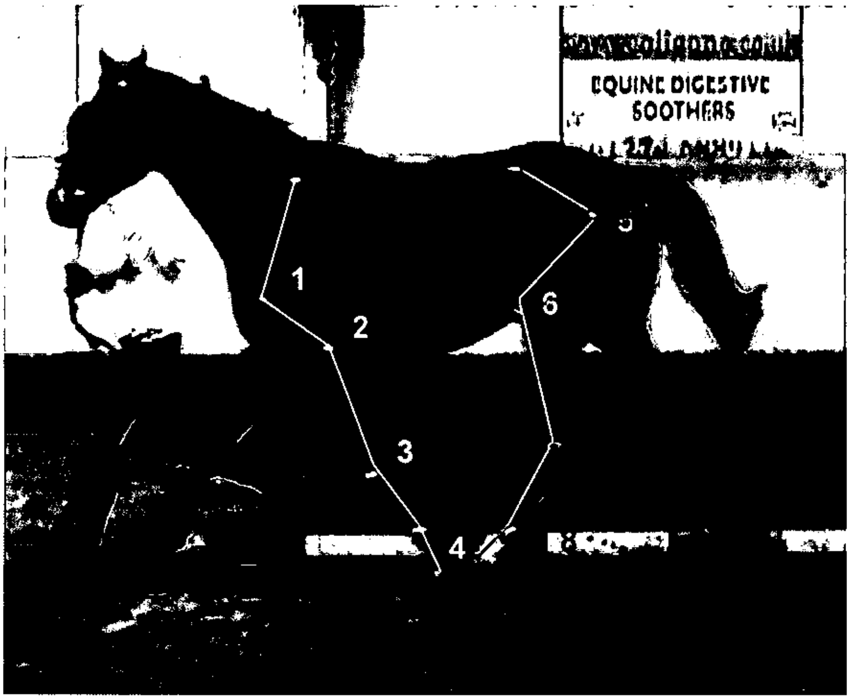

Plate 4. Anatomical marker and joint locations; 1=shoulder, 2= elbow, 3=knee, 4=fore fetlock, 5=hip, 6=stifle, 7=hock and 8=hind fetlock.

Table 1: Location of the anatomical markers (description from top to bottom of the limb) in conjunction with figure 2. Adapted from Back *et al.*, (1995) and Holmström *et al.*, (1990).

Location on the foreleg	Location on the hind leg
The proximal end of the spine of the scapula.	The proximal end of the lateral angle of the ilium.
The posterior part of the greater tubercle of the humerous.	The centre of the anterior part of the greater trochanter of the femur.
The transition between the proximal and middle thirds of the lateral collateral ligament of the elbow joint.	The proximal attachment of the lateral collateral ligament of the stifle joint to the femur.
Proximopalmer guardant of the ulnar carpal bone.	The centre of the lateral aspect of the tarsus.
The proximal attachment of the lateral collateral ligament of the fetlock joint to the distal end of the third metararpal bone.	The proximal attachment of the lateral collateral ligament of the fetlock joint to the distal end of the third metatarsal bone.
Coronet band.	Cornet band.

The anatomical markers used in this study were white or black (contrasting to the colour of the horses coat colour to improve visualisation when digitising) circular velcro adhesive stickers approximately 2cm in diameter, applied by only one researcher to increase reliability. Small patches of hair were trimmed at the elbow, knee, fetlock, stifle, hock and hind fetlock areas of the horse where the anatomical markers were attached, primarily to increase the accuracy of applying the markers to the same point on the horse each time SL and ROM measurements were taken and also, so the glue on the markers would stick to the horse securely. Once the anatomical markers were applied, the filming procedure took place to obtain the video footage of the SL and ROM.

3.22 In-hand Filming: Myerscough International Arena

The SL and ROM measurements were collected at week 0 (baseline) and weeks 2, 4, 6, and 8, of the eight-week stretching regime and 9, 10 and 11 post the stretching regime. The SL and ROM measurements were collected by trotting the subject in hand (as a rider can influence a horse's stride (Peham *et al.*, 2004) in front of a camera four times to obtain four or more strides. An average of three to five strides are suggested as a suitable amount for kinematic analysis (Clayton and Schamhardt, 2001). The in hand filming took place in the Myerscough International indoor arena; this was a suitable place to trot the subjects in front of the video analysis equipment. The surface consisted of stone washed silica sand with rubber fibre. Each subject had the anatomical markers attached to specific landmarks (plate 4, page 30) when trotting past the camera. Figure 2 illustrates the camera set up. All video footage was recorded using a Sony DCV-TRV60E digital camera, recording at 25 frames per second. The software records two fields per frame to produce an effective capture rate of 50Hz. The biomechanical video footage was downloaded onto a laptop, calibrated and digitised using Equinalysis software. Temperament and general behaviour observations of the subjects were noted on all days the filming took place. Ambient temperature was also recorded.

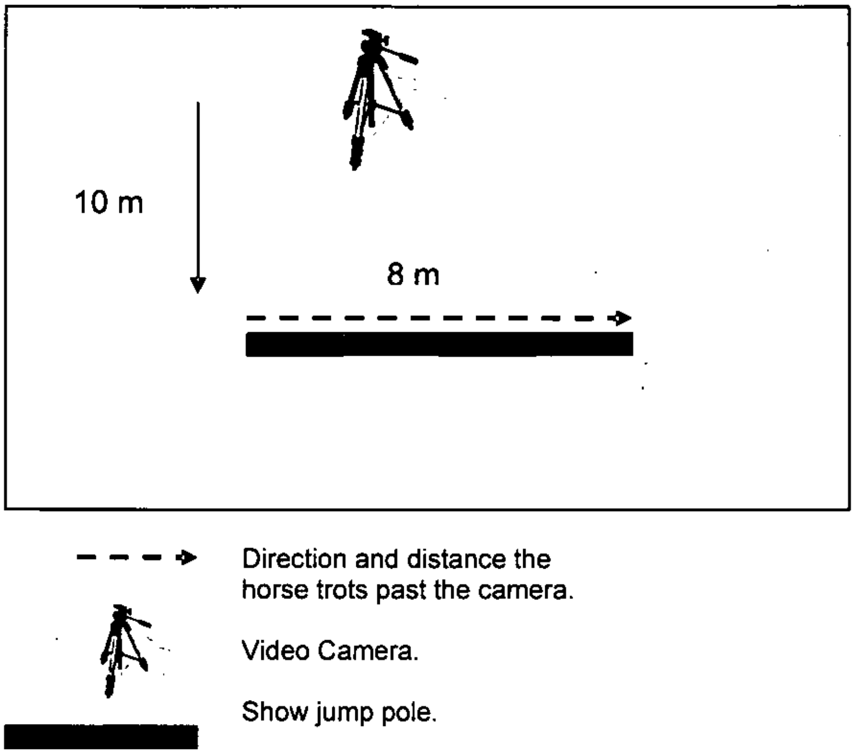

Figure 2. Camera set up in Myerscough College International Arena.

3.23 The stretching procedure

All subjects in groups A and B were warmed-up for a set period of time (ten minutes) prior to the stretch procedure on the horse walker at Myerscough College, the horse walker was set at a medium walk. This type of warm-up can be standardised and all subjects were familiar with this environment. Denoix and Pallioux (2004) and Pattillo (2005) suggest that stretching techniques should be applied after the horse has had approximately 10 minutes of warm up such as walking. The control horses (NSR) did not go through a warm-up because they were not being stretched. The stretches were applied once daily for six days per week to group A and once a day for three days per week to group B. The stretches were applied in the morning and at a time that fitted around each subject's exercise schedule. The stretches were employed by a qualified Equine Body Worker (EBW) level 1. The stretches aimed to increase the flexibility, SL and ROM of the shoulder, elbow, hip, knee, and hock joints. See page 34 to page 37 for a full diagrammatic explanation of the stretching movements. Before stretching the limb a relaxation technique was applied to the legs, this involved loose circles to familiarise the horse to the therapist and the situation (plate 5, page 34). The forelimb stretches used were; modified girth stretch (plate 6, page 34) full girth stretch (plate 6, page 34) leg flexor lift (plate 7, page 35) and triceps release (plate 8, page 35). The hindlimb stretches used were; hamstring stretch (plate 9, page 36) farrier stretch (plate 10, page 36) stifle and hip flexor stretch (plate 11, page 37) and lateral quad stretch (plate 12, page 37.) It must be noted that not all the stances of the EWB are correct, for example plate 6 (page 34) illustrating the modified girth stretch, the EBW's hands should be supporting under the knee and the fetlock, however the researchers position was altered to make the picture clear, so the position of the horses leg and direction of movement could be seen unmistakably. The stretches were applied twice and held for 10 seconds for the first time and then the following stretch was held for 20 seconds, similar to the recommended hold times of Pattillo (2005). The control group (NSR) did not go through the warm-up or the stretching routine, however SL and ROM were taken at the same time as the stretch subjects each week (filming was on a separate day to the stretching). To ensure all groups had the same amount of human contact the control subjects had approximately ten minutes of human contact time, daily, where a research assistant stroked, brushed and gave attention to the horse.

Plate 5. Relaxation technique (1-3) to the first fore limb stretch, the modified girth stretch (4-6).

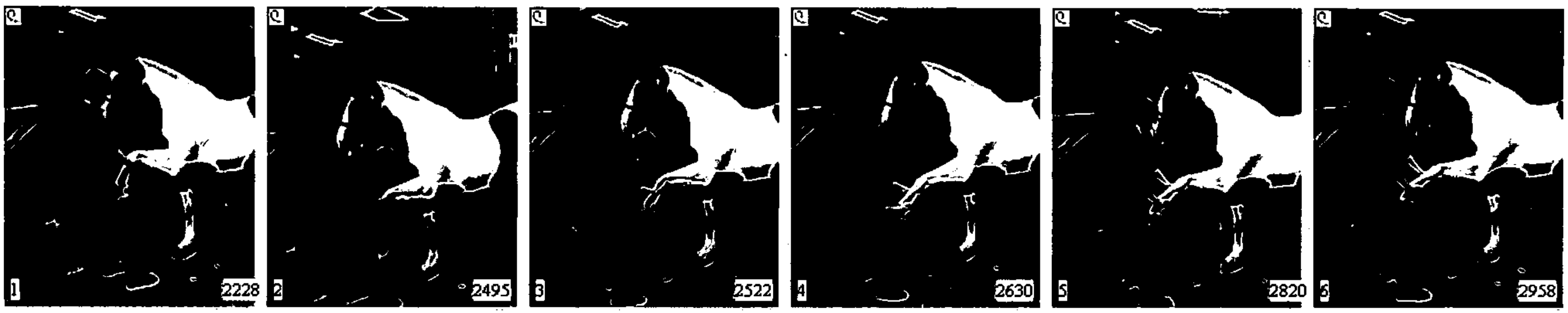

Plate 6. Modified girth stretch (1-2) to the second fore limb stretch, the full girth stretch (3-6).

Plate 7. The third fore limb stretch, the leg flexor lift.

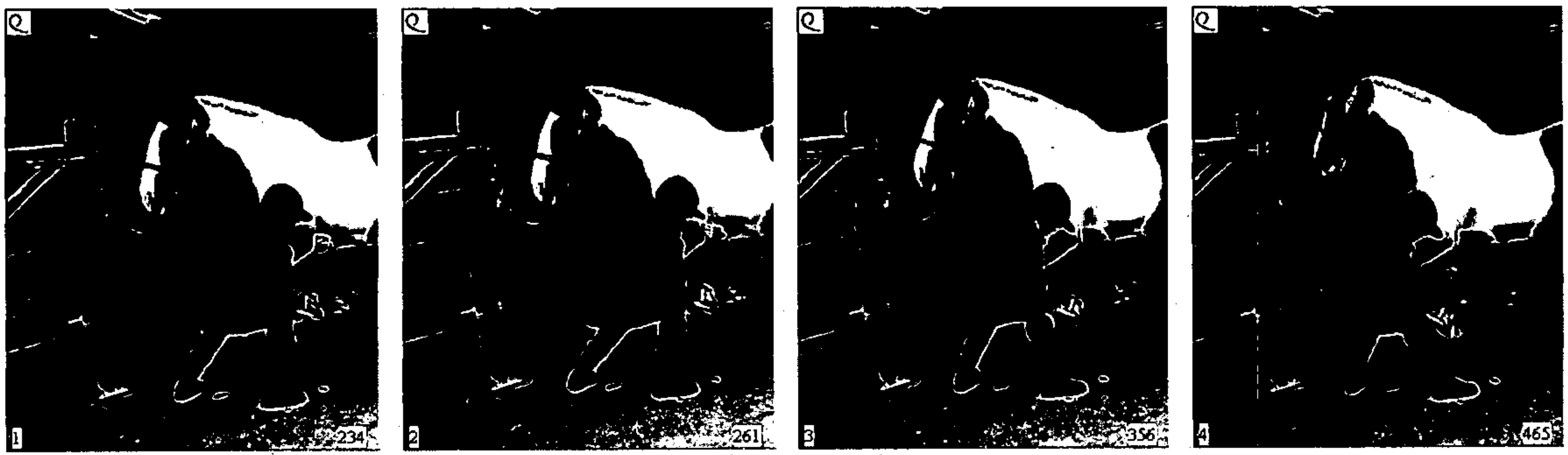

Plate 8. The fourth and final forelimb stretch, the triceps release stretch.

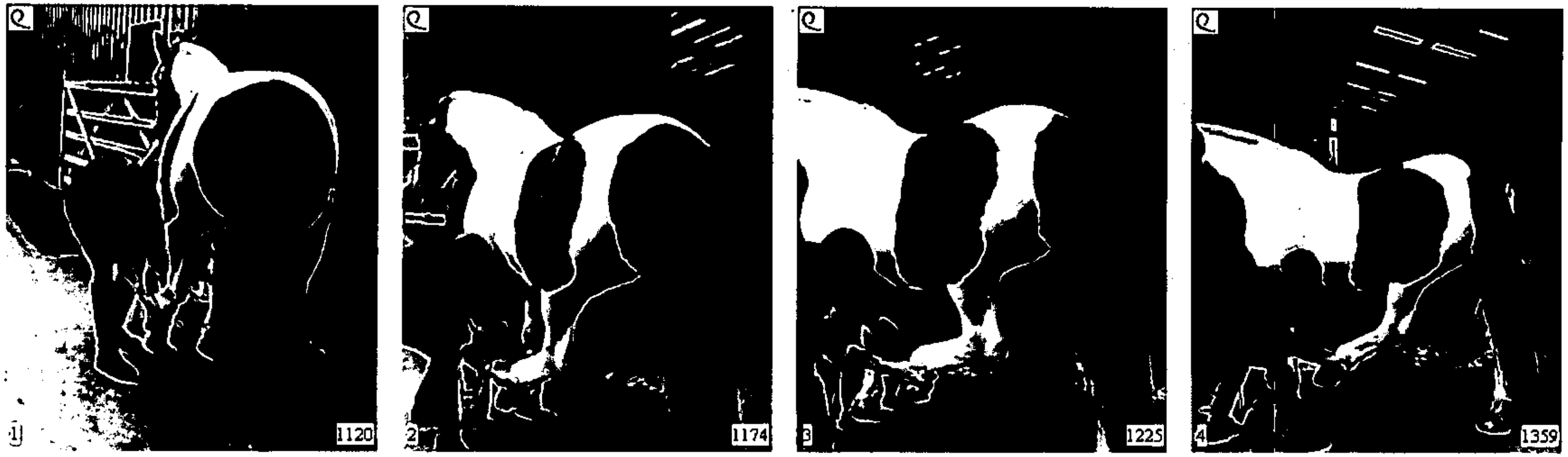

Plate 9. The first hind limb stretch, the hamstring stretch.

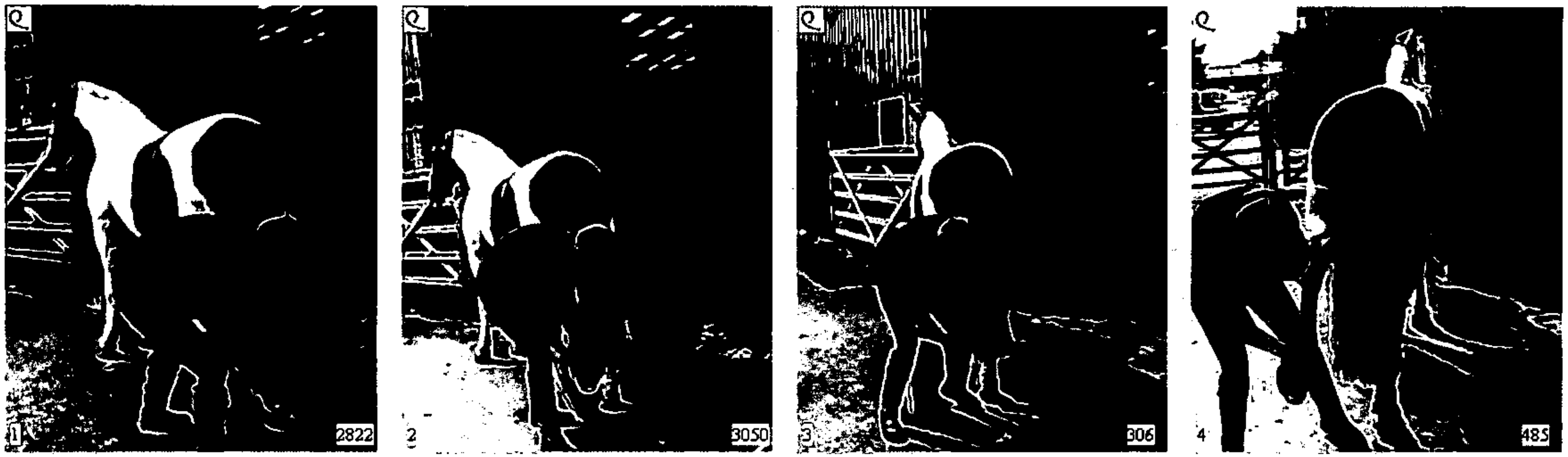

Plate 10. The second hind limb stretch, the farrier stretch.

Plate 11. The third hind limb stretch, the stifle and Hip flexor stretch.

Plate 12. The fourth and final hind limb stretch, the lateral quadriceps stretch

3.24 Ridden filming: Myerscough International Arena

During the study it was thought that riding the horses in extended trot during the stretching regime and after a period of time when stretching had ceased, may also elicit changes in the SL between the different treatment groups. This idea was developed near to the end of the stretching regime, thus the ridden data was not collected throughout the eight weeks of stretching. Week 8 of the study and 8 weeks post the study (week 16), all subjects were ridden in extended trot by four qualified riding instructors; one SMBHSII (stable manager, British Horse Society Intermediate Instructor), one BHSAI (British Horse Society Assistant Instructor), one BHSAI&IT (British Horse Society Assistant Instructor and Intermediate Teaching) and one BHSPI (British Horse Society Preliminary Instructor). Horses were ridden in extended trot in an attempt to elicit each subject's maximum SL, not just a 'normal' working trot SL, which was measured by the in-hand trotting. It would not be likely to achieve a maximal SL when a horse is trotted in hand; the horse needs to be pushed by the riders' aids to gain a maximum extension. The riders trotted the horse four times past a camera set up (figure 3, page 39) in extended trot. The distance between the pole and the camera was increased to 20m, to be able to fit enough strides in the camera view. The pole and line the horses were trotted on was set at a diagonal so to use maximum space for the rider to push the horse into extended trot. The filming took place in Myerscough's Large Outdoor Arena; the surface is similar to that of the International Arena (stone washed silica sand with rubber fibre) however, with the addition of felt pieces. SL was measured on both occasions to identify any potential difference in SL once the stretching routine had desisted.

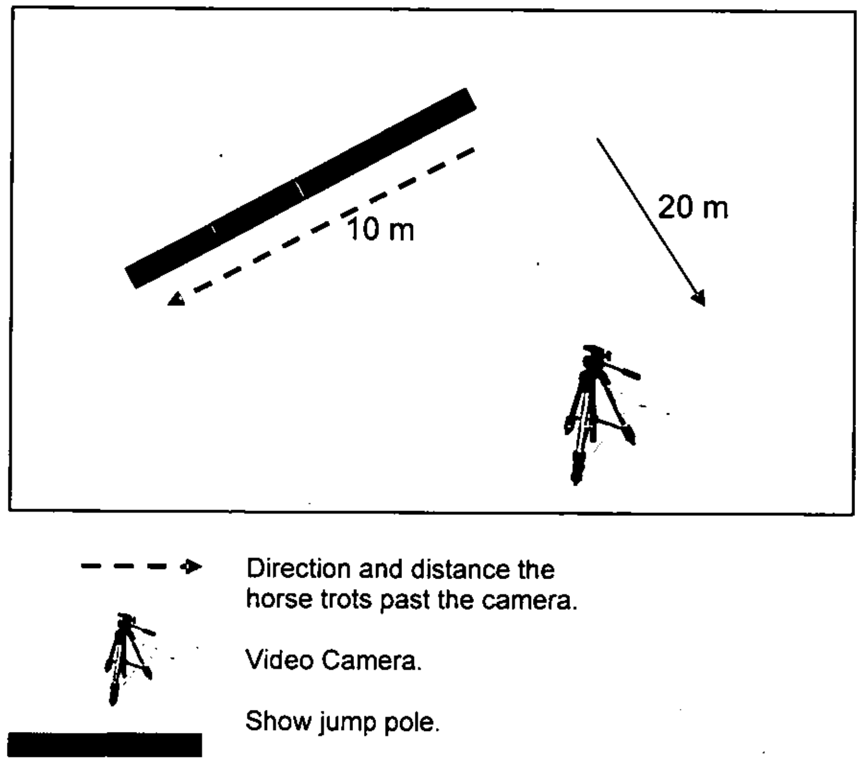

Figure 3. Camera set up in Myerscough College Large Outdoor Arena.

3.25 Video footage analysis

The video footage was analysed and digitised using Equinalysis software to measure SL and ROM in the shoulder, elbow, knee, hip, stifle, hock and fetlock joints. At the beginning of the study eighteen horses were used, however during the period the research took place three horses were discarded. From group A, Dudley, a seven year old Cob gelding (15.1hh), and from group C, Snowflake, a 13 year old Appaloosa mare (15.2hh) and Tiny, a nine year old Thoroughbred cross Clydesdale gelding (18.1hh). Dudley was considered unsafe to stretch, Snowflake was retired to a different yard and Tiny was considered not to be representative of the group of horses he was matched to in the study due to his size (18.1hh), he was producing larger SL than any other horse in the study. An unavoidable constraint was that horses available to be used in the study were limited, thus some had to be discarded due to their unsuitability to be matched. The number of subjects data that was analysed equated to 15. The digitisation and SL measurement process involved calibrating each video file; before filming the subjects a metre ruler was filmed at the same distance from the camera that the horse would be trotting (plate 13, page 40). Calibration using Equinalysis software involves drawing a line onto the ruler and entering the exact length

(1m) and saving this data with each video file of each horse trotting past the camera, this was so the software could recognise correct distances.

Plate 13. Filming the calibration clip.

The next step was to digitise the horse's limbs, the process entails selecting anatomical markers to produce a 'limb line' (plate 14 and 15); this was done for one whole stride (plates 16 and 17, page 41) to produce sufficient data to measure ROM. The starting and finishing points for digitising were established when the fore limb was vertical and the hind hoof first made contact with the ground (plates 14 and 15).

Plate 14.

Plate15.

Starting and finishing point for digitisation of the fore (14) and hind limb (15).

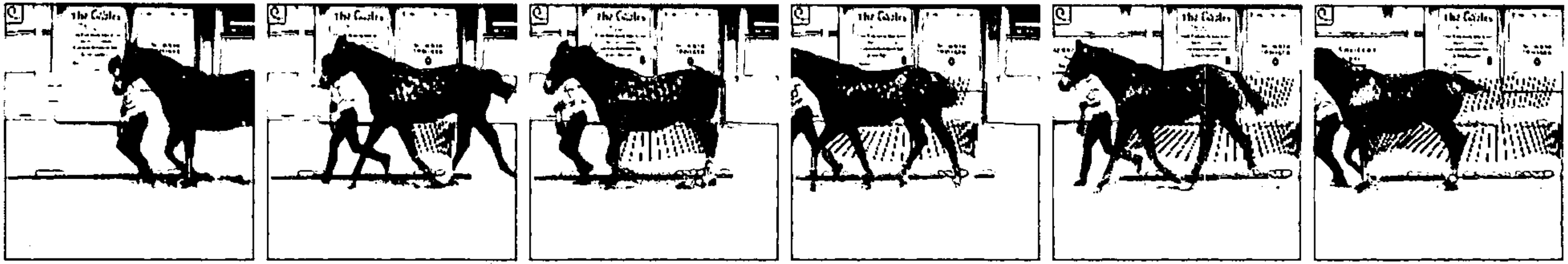

Plate 16. Digitisation of the forelimb for one whole stride, beginning at the left and ending at the right.

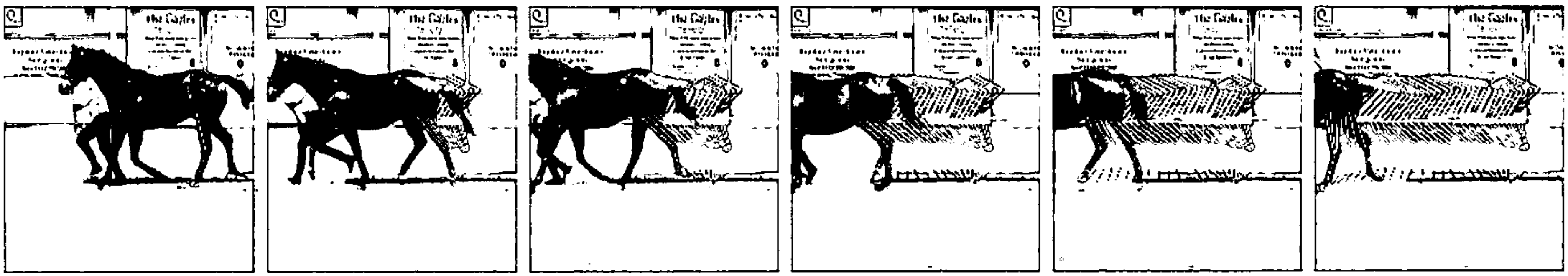

Plate 17. Digitisation of the hindlimb for one whole stride, beginning at the left and ending at the right.

Equinalysis converts the digitised figures into angle data, which can be used in Microsoft Excel to calculate a ROM figure. ROM is the difference between the joint angles when the joint is maximally extended and maximally flexed. Subjective error is a possibility when manually digitising the video footage; however the magnification feature of Equinalysis to zoom in on individual markers reduces this. SL was obtained by marking a line on the hoof at the beginning of the stride, then again at the beginning of the next stride and measuring the distance between the two lines. This SL figure was verified by digitising one complete stride and obtaining the horizontal distance tracked by the Equinalysis system.

3.3 Statistical analysis

All data was assessed for normality using an Anderson-Darling normality test (a standard test in Minitab 14). Where normality was not found, appropriate transformations (according to direction of skew) were applied (Wheater and Cook, 2001). Analysis of variance (ANOVA) was used to establish the presence of significance between SL, ROM and stretching regime. A covariate (week 0) was also added to the ANOVA to investigate the effects of the week 0 'baseline' data (see section 4.24, page 67). Where differences occurred between SL or ROM and stretching regime a post-hoc analysis using Bonferroni Dunn's test was used to establish individual differences between treatments. Ambient temperature data was examined using parametric regression (Pearsons product moment correlations).

3.4 Risk assessment and ethical approval:

A risk assessment (appendix 1, page I) was undertaken prior to collecting data to ensure the surrounding environment and equipment used was safe and suitable. Ethical approval from the Ethics Committee was also obtained (appendix 2, page II).

4.0 RESULTS: Normality test

The mean SL and ROM data was examined for normality and shown in tables 2 and 3 (below). All data was found to be normal, thus a parametric test could be used to investigate statistically significant changes in the measured parameters. A two-way analysis of variance (ANOVA) was used.

Table 2. Normality tests, mean, SD values, and normality for stride length (SL) for all weeks.

Film Week	Measurement (m)	Number of subjects (N)	Mean Stride length (m)	Standard Deviation (SD)	Normal
In hand trot - week 0,2,4,6,8,9,10,11	SL	115	2.241	0.193	✓
Ridden extended trot week 8,16	SL	30	2.603	0.223	✓

Table 3. Normality tests, mean, SD values, and normality for all joint range of motion (ROM) for all weeks.

Joint	Measurement (°)	Number of subjects (N)	Mean ROM (°)	Standard Deviation (SD)	Normal
Shoulder	ROM	114	13.596	3.355	✗
Log transformed (LT) shoulder data	Value	114			✓
Elbow	ROM	114	49.496	4.625	✓
Knee	ROM	114	78.380	6.491	✓
Fore Fetlock	ROM	114	87.415	7.166	✓
Hip	ROM	114	17.108	2.679	✓
Stifle	ROM	114	36.355	3.275	✓
Hock	ROM	114	45.772	4.328	✓
Hind Fetlock	ROM	114	93.281	9.035	✓

4.1 Stride length (SL)

Data that were collected at week 0 was classified as 'baseline data', its purpose was to gain a standardised overview of each subjects 'natural' SL prior to treatment. The baseline data also acted as a reference point to compare treatment data enabling possible differences to be detected. A two-way ANOVA was performed on the week 0 data to confirm that there were no significant differences in mean SL between the treatment groups at the beginning of the study. Table 4 illustrates that there were no significant differences between mean SL in either of the treatment groups at week 0 (P>0.05). This allows a more reliable comparison of all the treatment data at weeks 2, 4, 6, 8, 9, 10 and 11.

Table 4. ANOVA results for mean SL for all treatments at week 0.

	N	F-Value	P-Value	Significant
Stretching Treatment versus SL	3	0.620	0.555	✗

Having confirmed that all SL of subjects at week 0 were not dissimilar to each other, the treatment SL (weeks 2, 4, 6, 8) and the post treatment SL (weeks 9, 10, 11) could be compared for any statistical significant differences.

Figure 4 (page 45) demonstrates the mean SL for all three treatments at all weeks throughout the study. Weeks 9, 10 and 11 were post-stretching regime; no treatments were applied in those three weeks. The aim was to identify any differences in SL following cessation of the treatment. Mean SL was analysed against treatment type (6DSR, 3DSR, NSR) and film day for all weeks the study took place, baseline (week 0), during stretching (2, 4, 6, 8) and post stretching (9, 10, 11).

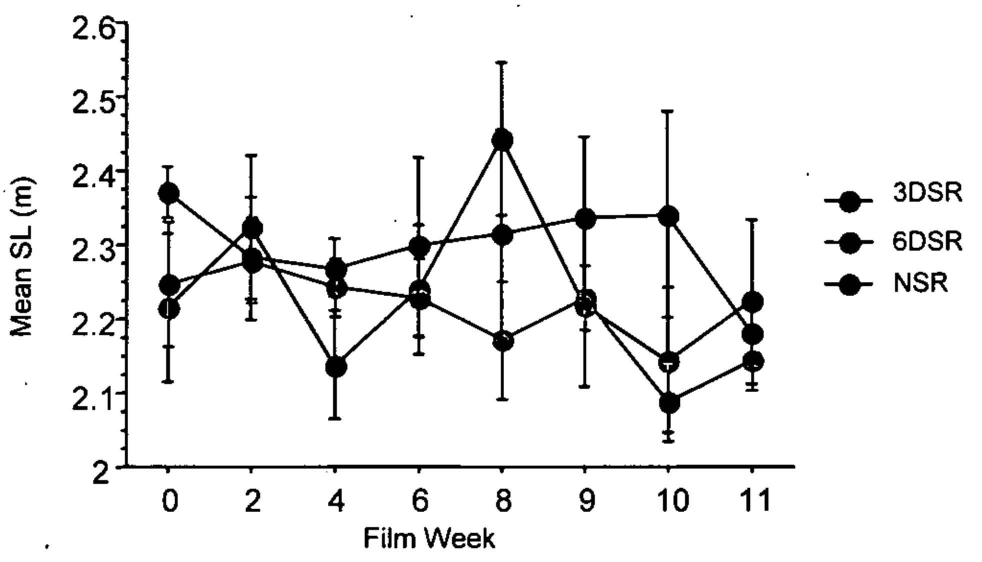

Figure 4. Mean stride lengths (± 1SE) with each treatment at all weeks of the study.

Figure 4 and table 5 demonstrate that neither the film week or the stretching had any significant effect on SL throughout the study period (P>0.05), although the 6DSR SL are generally lower than the 3DSR or NSR from week 2 onwards. There is an increase in SL with the 3DSR at week 8, then a sharp decrease in SL to week 10 followed by a small increase to week 11.

Table 5. ANOVA results for all SL and all treatments at all film weeks.

	N	F-Value	P-Value	Significant
Film week	8	0.806	0.584	✗
Stretching	3	2.043	0.135	✗
Film Week and Stretching Treatment Interaction.	15	0.646	0.819	✗

4.11 Velocity

Velocity (m/s) when trotting past the camera of each horse was calculated and mean velocity was 3.2 m/s. Velocity can influence SL (Peham *et al.,* 1998; Peham *et al.,* 2000). Both SL and stride frequency (SF) increase with increasing velocity (Leach, 1987). To confirm that velocity was kept at a constant each week thus could not have affected SL, ANOVA was carried out on the velocity data for all weeks the study took place. Table 6 demonstrates that there was no significant difference between velocities at each film week.

Table 6. ANOVA results for mean velocity (m/sec) at each film week.

	N	P-Value	Significant
Film week	8	0.843	x

4.12 Ridden SL

Figure 5 demonstrates the effects of stretching and/or film week on ridden extended trot SL. Ridden mean SL (extended trot) was also analysed against treatment type and film week (week 8 and 16).

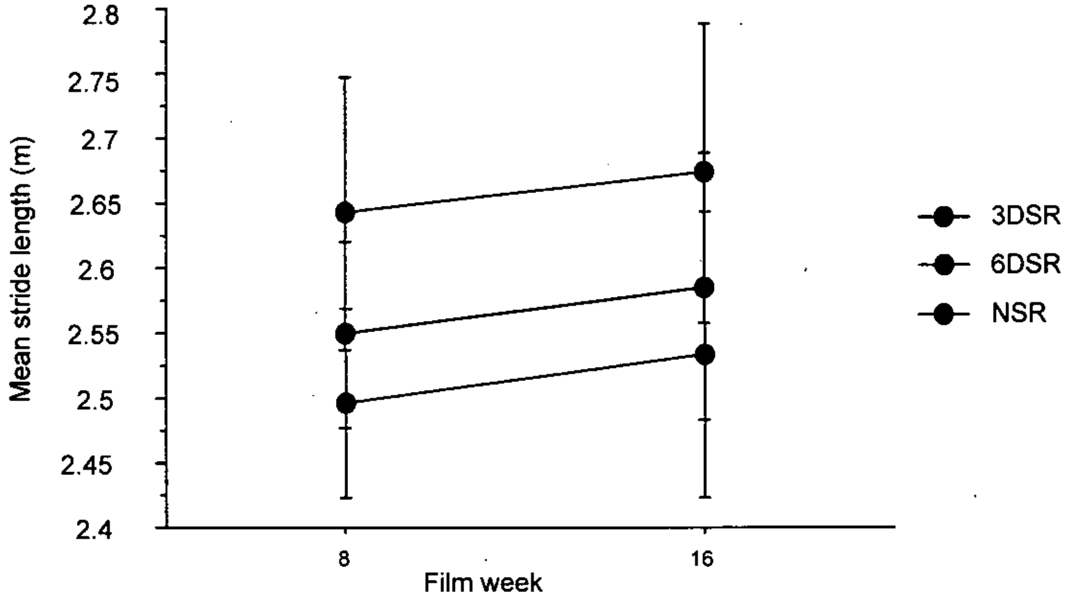

Figure 5. Mean ridden stride length (± 1SE) with each treatment at week 8 and 16.

Figure 5 and table 7 highlight no significant effects of stretching or film week on mean ridden extended trot immediately after 8 weeks of stretching or with 8 weeks of no stretching treatment, indicating that cessation of stretching did not reduce SL. Mean SL increased slightly at week 16, when stretching had not been applied to the subjects for three weeks, however this was not a significant increase. On the whole both stretching regimes (6DSR and 3DSR) did not increase SL when the subjects were ridden and pushed into a maximal extended trot.

Table 7. ANOVA results for mean ridden extended trot SL of each treatment group at week 8 and week 16.

	N	F-Value	P-Value	Significant
Film week	2	0.193	0.665	x
Stretching	3	0.942	0.404	x
Film week and Stretching Treatment Interaction.	3	0.001	0.999	x

4.13 The effect of ambient temperature on stride length

The filming of SL data took place between January and June, thus ambient temperature may be variable between these months. Ambient temperature was recorded on the days the filming took place, as temperature may have had an effect on the movement of the horse and thus SL; in humans when muscles are cold their action is inefficient and may be uncoordinated, joints may also be stiffer (Lloyd, 1994) Ambient temperature ranged from 6.4°C to 13.5°C and mean ambient temperature was 9.4°C. A regression analysis was carried out on ambient temperature and all SL data. Table 8 demonstrates that there was no significant relationship between ambient temperature (°C) and in-hand or ridden extended SL ($P>0.05$).

Table 8. Regression results for ambient temperature (°C) mean in hand and ridden extended trot SL of each treatment group at all weeks.

In-Hand SL	**F-Value**	**P-Value**	**Regression Value**	**Significant**
SL versus Ambient Temperature	0.456	0.500	0.004	✗
Ridden Extended SL				
SL versus Ambient Temperature	0.204	0.655	0.008	✗

4.2 Range of motion (ROM)

Similar to SL, ROM data that was collected at week 0 was classified as 'baseline data', it forms a natural control and its purpose was to gain a standardised overview of each subject's 'natural' joint ROM prior to treatment. A two-way ANOVA was performed on just the week 0 data to confirm that there were no significant differences in mean joint ROM between the treatment groups at the beginning of the study (figure 6).

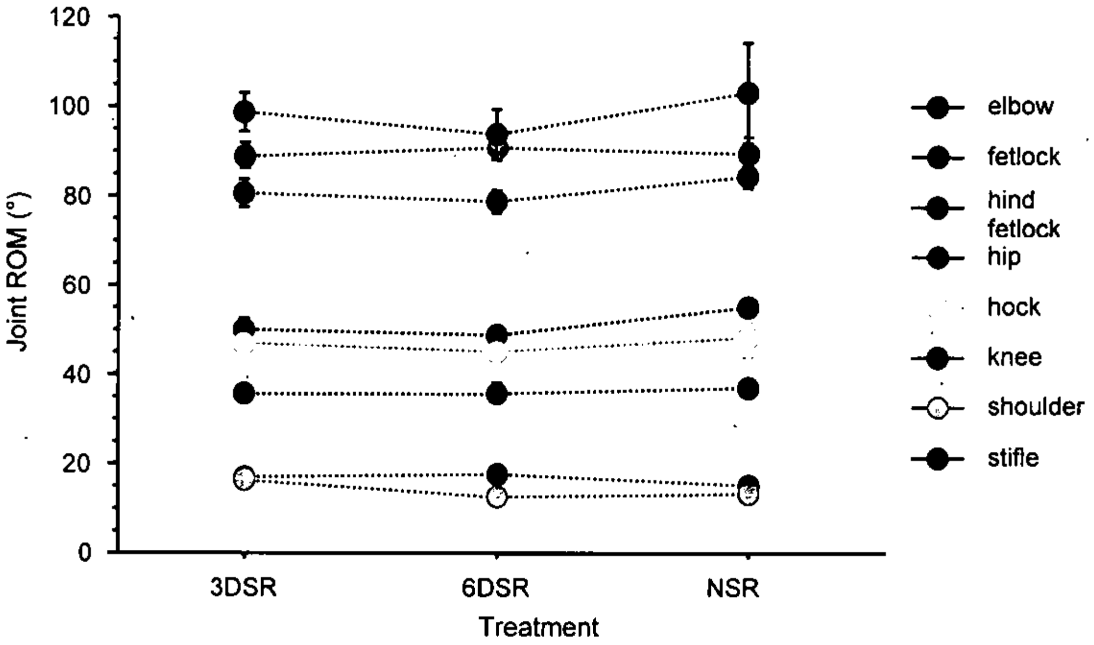

Figure 6. Mean joint range of motion for all joints of all subjects (± 1SE) with each treatment at week 0.

Figure 6 and table 9 (page 50) highlights no significant differences between joint ROM in either of the treatment groups at week 0, (P>0.05). There are highly significant differences (P<0.0001) between the joints, however this is expected as anatomical differences between the joints cause different ROM angles. ROM of subjects at week 0 were not significantly different to each other, therefore the treatment ROM at weeks 2, 4, 6 and 8 and the post treatment ROM at weeks 9, 10 and 11 could be compared for any statistical significant differences. Figure 7 to 14 (pages 50 to 63) provides an overview about all the different joints, and the effect of the stretching treatments on mean ROM throughout the study. Weeks 9, 10 and 11 were post stretching thus any differences in ROM following cessation of the treatment could be identified.

Table 9. ANOVA results for all joint ROM of all subjects at week 0.

	N	F-Value	P-Value	Significant
Stretching	3	1.842	0.232	✗
Joint	8	327.307	<0.0001	✓
Stretching Treatment and Joint Interaction	15	0.462	0.947	✗

4.21 Forelimb

The forelimb was examined in order of shoulder, elbow, knee and fetlock, followed by illustration of the hindlimb results in order of the hip, stifle, hock and hind fetlock

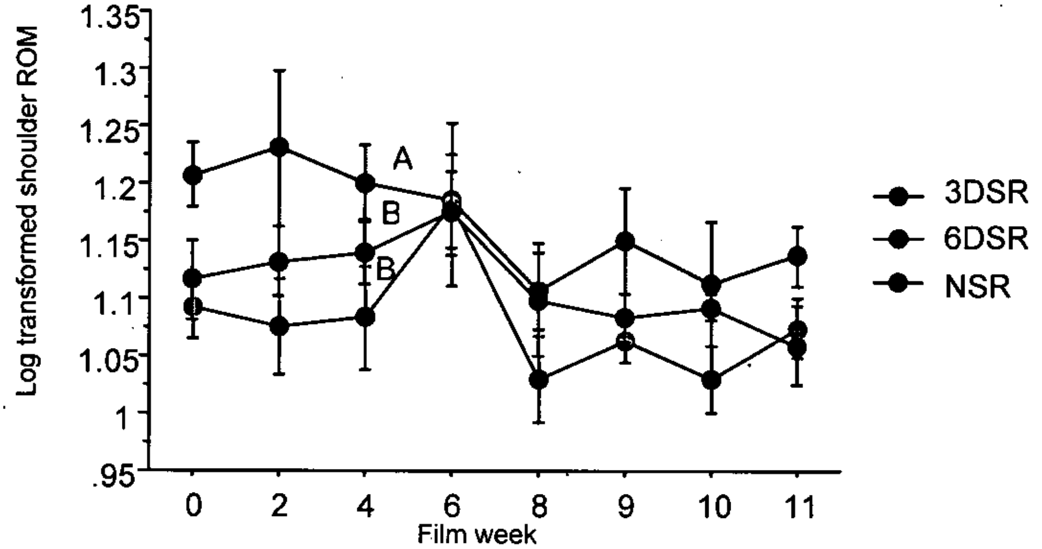

Figure 7. Log transformed shoulder ROM (± 1SE) with each treatment at all weeks of the study. Coloured letters denote differences between the treatments at the P<0.05 level.

The shoulder ROM was the first joint to be analysed. Figure 7 and table 10 (page 51) show significant effects of the film week (P<0.05) on the shoulder ROM data. Stretching also had a highly significant effect (P<0.0001), however the interaction between the two evidently is not significant (P>0.05). A Bonferroni/Dunn post-hoc test was carried out (significance level 5%) to identify individual differences between film week and between the three treatments. There were no significant differences between the different film weeks; there were however significant differences between the stretching treatments. 3DSR is producing a larger shoulder ROM compared to the 6DSR. An increase in mean ROM at week 6 has appeared on figure 7, similar to that of the increase in SL at week 8 on figure 4 (page 45, the in hand SL data), however it is yet to be discovered if the two are linked.

Table 10. ANOVA results for the log transformed shoulder ROM data of all subjects at all weeks.

	N	F-Value	P-Value	Significant
Film week	8	2.561	0.018	✓
Stretching	3	10.375	<0.0001	✓
Film Week and Stretching Treatment Interaction.	15	0.452	0.952	✗

Table 11. Bonferroni/Dunn Post-hoc for log transformed shoulder data and stretching treatment (Significance level 5%).

	P-Value	Significant
3DSR – 6DSR	<0.0001	✓
3DSR - NSR	0.011	✓
6DSR - NSR	0.952	✗

Table 11 demonstrates significant differences between 3DSR and 6DSR stretching treatment and 3DSR and NSR treatment, but not 6DSR and NSR. It appears that a pattern is emerging, with the 3DSR shoulder ROM results being consistently higher than the shoulder ROM in the NSR and 6DSR.

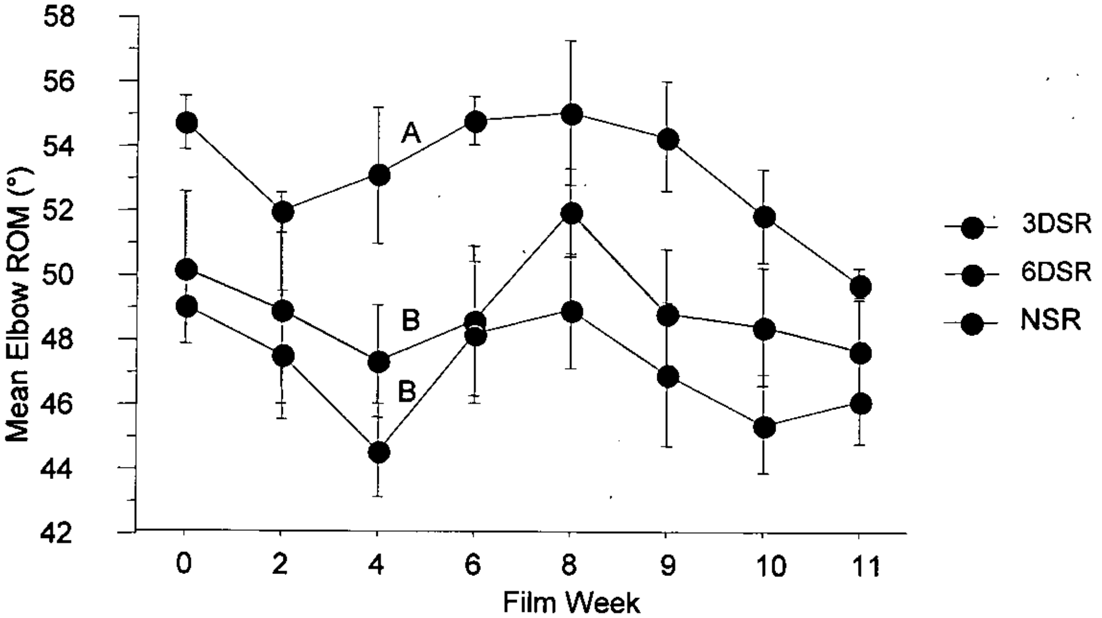

Figure 8. Mean elbow range of motion (± 1SE) with each treatment at all weeks of the study. Coloured letters denote differences between the treatments at the P<0.05 level.

The elbow was the next joint analysed. There is a pronounced difference between elbow ROM in the NSR group compared to the elbow ROM in both the stretching groups. Similar to the shoulder, the 6DSR is producing a consistently lower ROM than the 3DSR and NSR, after week 0 (all three treatments were not significantly different at week 0, figure 6 page 49) this means that the 6DSR is not effective as the 3DSR at increasing or maintaining mean elbow ROM. Film week and film week/stretching treatment interaction did not have a significant effect ($P>0.05$) on mean elbow ROM, however stretching did have a highly significant effect ($P<0.0001$). All three lines follow a somewhat similar pattern, mean elbow ROM decreases to week 4 then gradually increases to week 8, and then tailing off from week 9 to 11 when stretching treatment stopped. There is also noticeable increase in mean elbow ROM in all treatments at week 8, similar to the rise in shoulder ROM in at week 6. A Bonferroni/Dunn Post-hoc test was carried out to identify where the significances lie between the stretching regimes.

Table 12. ANOVA results for the mean elbow ROM data for all subjects at all weeks.

	N	F-Value	P-Value	Significant
Film week	8	1.803	0.963	✗
Stretching	3	19.715	<0.0001	✓
Film Week and Stretching Treatment Interaction.	15	0.252	0.997	✗

Table 13. Bonferroni/Dunn Post-hoc for mean elbow ROM and stretching treatment (Significance level 5%).

	P-Value	Significant
3DSR – 6DSR	0.064	✗
3DSR - NSR	<0.0001	✓
6DSR - NSR	<0.0001	✓

The significance lies with the 3DSR and NSR and 6DSR and NSR as demonstrated by coloured letters. The 3DSR may be demonstrating higher mean ROM values, but the difference between 3DSR and 6DSR mean elbow ROM is not significantly different.

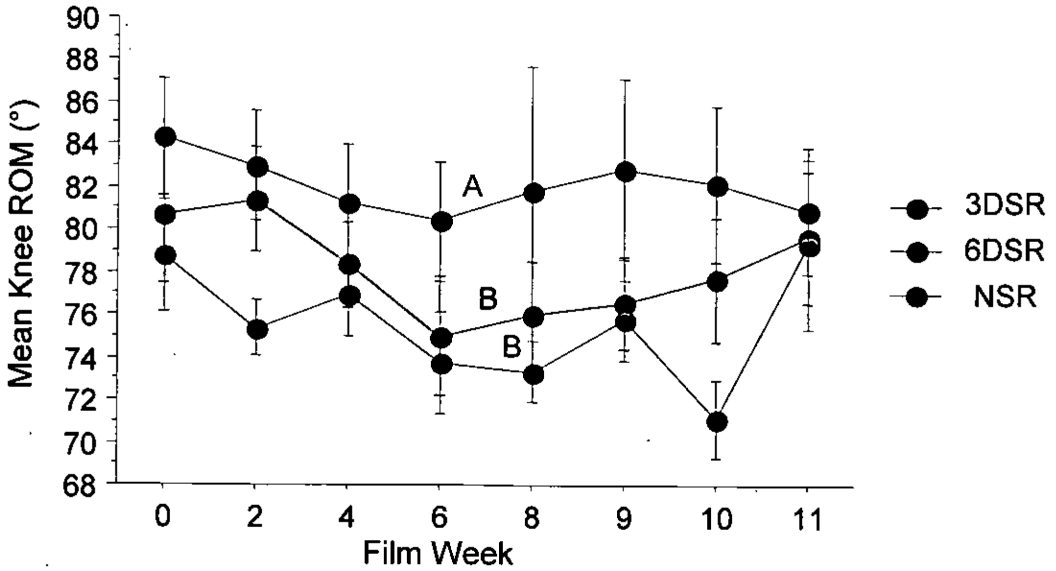

Figure 9. Mean knee range of motion (± 1SE) with each treatment at all weeks of the study. Coloured letters denote differences between the treatments at the P<0.05 level.

Figure 9 demonstrates 3DSR and 6DSR is causing mean knee ROM to decline during the stretching treatment weeks; the 6DSR is producing a lower mean knee ROM than the NSR and 3DSR, indicating that 6DSR is possibly producing more negative effects on the joints or on equine motion. There is a sharp increase in the 6DSR mean knee ROM from week 10 to 11, which is unexpected as stretching had been stopped for 2 weeks, on the other hand, it may be increasing due to the cessation of stretching treatment. Highly significant differences have been illustrated between the stretching groups (P<0.0005). The film week and interaction between film week and stretching treatment did not have a significant effect on knee ROM (P>0.05). A Bonferroni/Dunn post-hoc test was carried out to illustrate where the significant differences lie between the stretching treatments (table 15 page 55).

Table 14. ANOVA results for the mean knee ROM data for all subjects at all weeks.

	N	F-Value	P-Value	Significant
Film week	8	1.016	0.425	✗
Stretching	3	9.295	<0.0001	✓
Film Week and Stretching Treatment Interaction.	15	0.326	0.989	✗

Table 15. Bonferroni/Dunn Post-hoc for mean knee ROM and stretching treatment (Significance level 5%).

	P-Value	Significant
3DSR – 6DSR	0.086	✗
3DSR - NSR	0.008	✓
6DSR - NSR	<0.0001	✓

Slightly different from the shoulder, but similar to the elbow results; 3DSR and 6DSR knee ROM were not significantly different from one another, however the 3DSR and NSR and 6DSR and NSR knee ROM were highly significant ($P<0.005$ and $P<0.0001$ respectively).

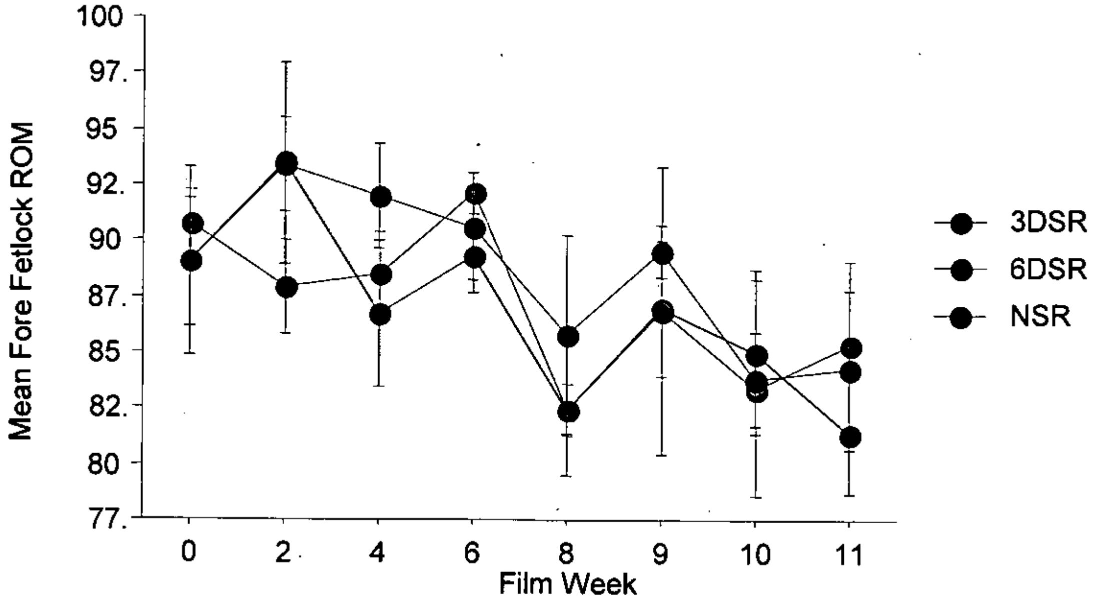

Figure 10. Mean fore fetlock range of motion (± 1SE) with each treatment at all weeks of the study.

Figure 10 illustrates the fore fetlock ROM from the 6DSR is not consistently lower than fore fetlock ROM from the other two treatments. There are many increases and decreases in mean fore fetlock ROM from week to week and not one week stands out as being different from the others, suggesting that fetlock ROM was variable from week to week. All stretching treatments appear to be having a negative effect on the fore fetlock ROM as the results are going in a diagonal downwards sloping direction as the weeks progress. Mean fore fetlock ROM is larger at the beginning of the stretching regime and then decreases as the stretching regime comes to an end.

Table 16 (page 57) highlights that stretching treatment and the interaction of film week and stretching interaction did not have a significant effect on fore fetlock ROM ($P>0.05$). Film week on the other hand did have a significant effect ($P<0.005$), however the Bonferroni/Dunn post-hoc test did not identify where the significant differences lie ($P>0.001$).

Table 16. ANOVA results for the mean fore fetlock ROM data for all subjects at all weeks.

	N	F-Value	P-Value	Significant
Film week	8	3.071	0.006	✓
Stretching	3	0.617	0.541	✗
Film Week and Stretching Treatment Interaction.	15	0.329	0.988	✗

4.22 Hindlimb

The hindlimb may show more differences in ROM compared to the forelimb, as the hindlimb propels the horse in trot and acts as the 'engine' of the horse (Goodship and Birch, 2001). The following figures will demonstrate any significances in hindlimb ROM as a result of stretching treatment.

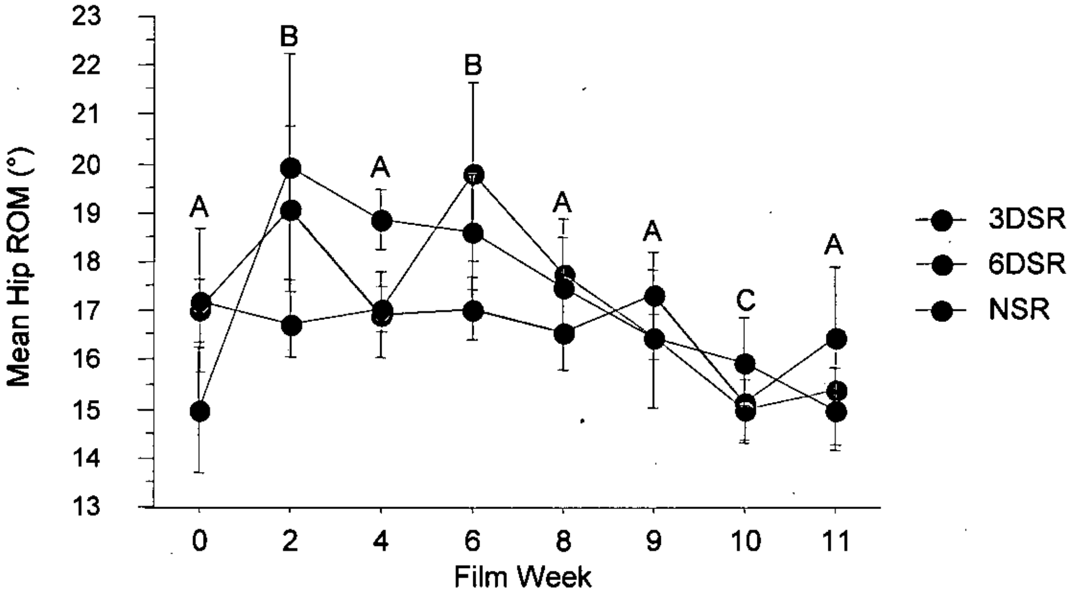

Figure 11. Mean hip range of motion (± 1SE) with each treatment at all weeks of the study. letters denote differences between the film weeks at the P<0.05 level.

Figure 11 shows a similar irregular outline to that of figure 10 (fore fetlock, page 56), there does not seem to be an emerging pattern or trend. Similar to the fore fetlock, film week does have a significant effect (P<0.005) on mean hip ROM, however stretching and the interaction between the two does not (P>0.05). The stretching treatments have not produced any significant differences between hip ROM's in any of the groups. The Bonferroni/Dunn test identified that the significance between the film weeks lies between weeks 2 and 10 and 6 and 10 (P=0.0010 and P=0.0015 respectively.

Table 17. ANOVA results for the mean hip ROM data for all subjects at all weeks.

	N	F-Value	P-Value	Significant
Film week	8	3.175	0.004	✓
Stretching	3	0.098	0.906	✗
Film Week and Stretching Treatment Interaction	15	0.875	0.587	✗

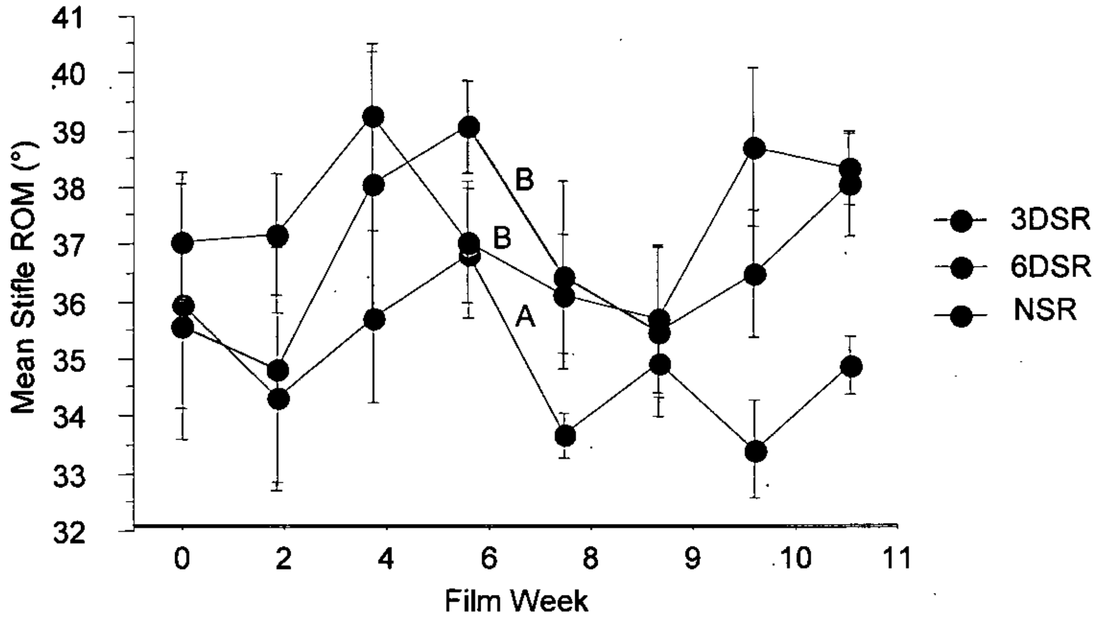

Figure 12. Mean stifle range of motion (± 1SE) with each treatment at all weeks of the study. Coloured letters denote differences between the treatments at a P<0.05 level.

The stifle ROM over all weeks is displayed in figure 12. The stifle ROM in the 6DSR are lower than NSR and 3DSR, however, again showing many increases and decreases in mean stifle ROM from week to week. All three treatments produce increases in mean stifle ROM from week 2 to week 6 and then decrease from week 6 to week 9, finally rising again to week 11. The effects of stretching treatment may have only begun to take effect from week two, after a period of adjustment to the new treatment. The increase in ROM after stretching had stopped requires further investigation. Stretching treatment had a significant effect ($P<0.005$) on the stifle results; film week and film week/stretching treatment interaction however, did not have a significant effect ($P>0.05$). A Bonferroni/Dunn post-hoc test was applied to identify where the stretching treatment significances lie (table 19, page 61).

Table 18. ANOVA results for the mean stifle ROM data for all subjects at all weeks.

	N	F-Value	P-Value	Significant
Film week	8	1.355	0.234	✗
Stretching	3	5.834	0.004	✓
Film Week and Stretching Treatment Interaction.	15	0.526	0.918	✗

Table 19. Bonferroni/Dunn Post-hoc for mean stifle ROM and stretching treatment (Significance level 5%).

	P-Value	Significant
3DSR – 6DSR	0.010	✓
3DSR - NSR	0.400	✗
6DSR - NSR	0.002	✓

The Bonferroni/Dunn post-hoc has drawn attention to the significant differences between 3DSR and 6DSR and 6DSR and NSR. So far, the shoulder is the only other joint to show significant differences between the 3DSR and 6DSR.

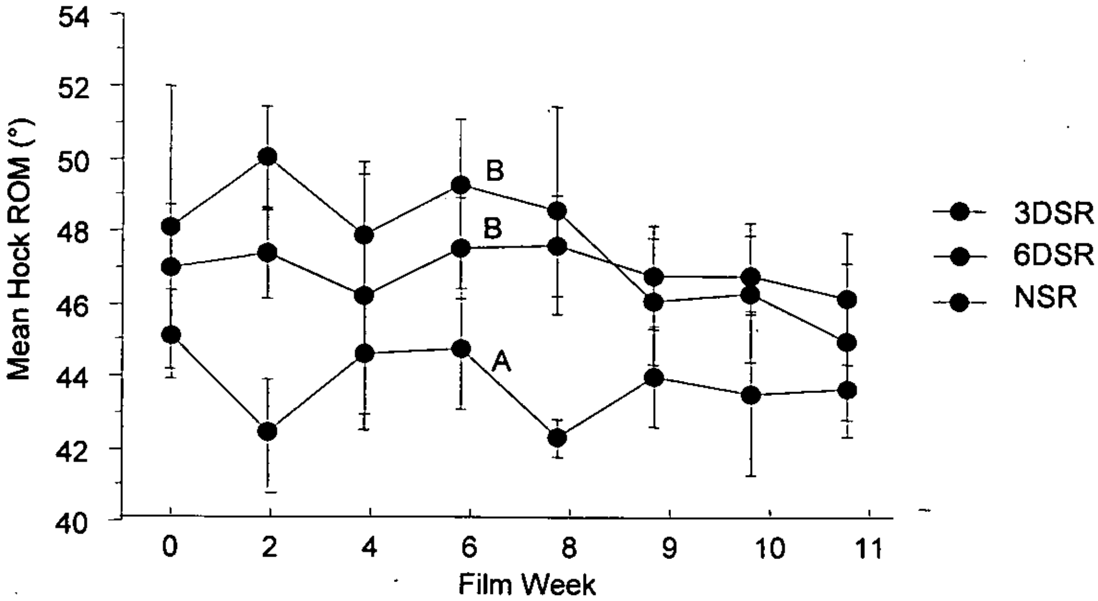

Figure 13. Mean hock range of motion (± 1SE) with each treatment at all weeks of the study. Coloured letters identify where the differences between the treatments at the P<0.05 level.

The hock ROM results are demonstrated in figure 13. The 6DSR is again following the pattern of producing the lowest mean hock ROM, compared to the NSR group, which is demonstrating the highest. It is possible that 3DSR and 6DSR treatments are only having an effect on some of the joints being investigated. The line plot follows a somewhat similar form to that of the elbow and knee (figures 8 and 9, page 52 and 54 respectively). There are not as many changes in hock ROM from week to week compared to the stifle ROM (figure 12, page 60), hip ROM (figure 11, page 58) and fore fetlock ROM (figure 10, page 56), which change frequently week to week. There may possibly be a limit to which ROM of each joint can increase and decrease, which could be why some joints don't show as many changes week to week. There are no significant effects of the film week and film week/stretching treatment interaction ($P>0.05$) on mean hock ROM. There is, however, a significant effect of stretching on the mean hock ROM ($P<0.001$). Table 20 (page 63) highlights were the Bonferroni/Dunn post-hoc test found significant differences between the stretching treatments.

Table 20. ANOVA results for the mean hock ROM data for all subjects at all weeks.

	N	F-Value	P-Value	Significant
Film week	8	0.471	0.853	✗
Stretching	3	9.112	<0.0001	✓
Film Week and Stretching Treatment Interaction.	15	0.365	0.981	✗

Table 21. Bonferroni/Dunn for mean hock ROM and stretching treatment (Significance level 5%).

	P-Value	Significant
3DSR – 6DSR	0.001	✓
3DSR - NSR	0.436	✗
6DSR - NSR	<0.0001	✓

The significances between the 3DSR and 6DSR and 6DSR and NSR that were demonstrated in the stifle results are also apparent with the hock results.

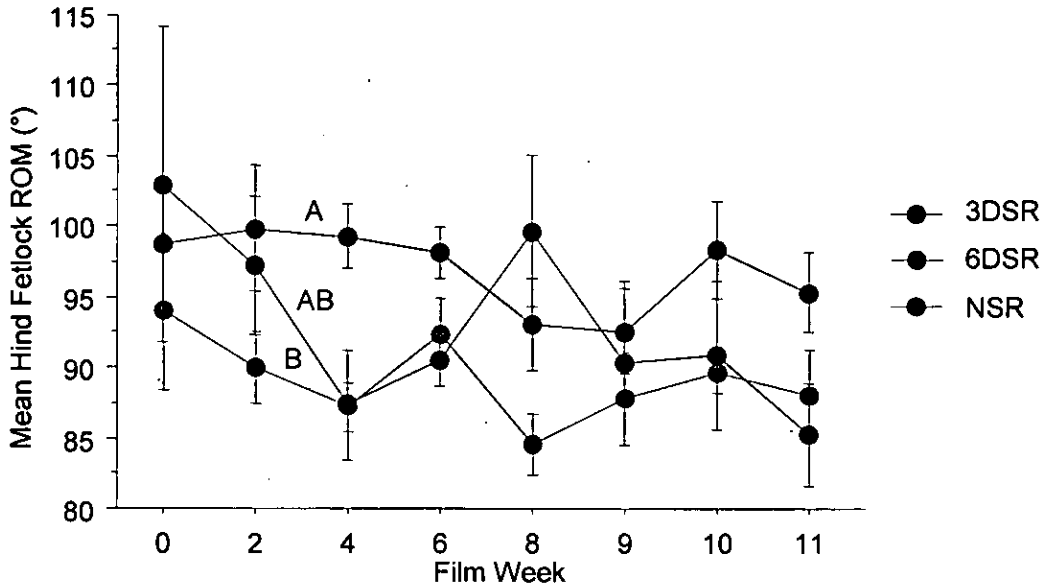

Figure 14. Mean hind fetlock range of motion (± 1SE) between each treatment at all weeks of the study. Coloured letters illustrate the differences between the stretching treatments at the P<0.05 level.

The hind fetlock ROM is the last joint to be analysed against stretching treatments and film day. The 6DSR is still causing a lower hind fetlock ROM compared to the 3DSR and NSR, this appears to have happened consistently for the majority of the results. Stretching the subjects for 6 days per week with only one rest day is not having a positive effect upon joint ROM. On the other hand, 3DSR has consistently produced higher joint ROM than the 6DSR, thus could be the more beneficial regime to apply to horses; the 3DSR has produced the largest hind fetlock ROM overall. Following suite with the hock and stifle, stretching treatments has demonstrated a significant effect (P<0.001) on mean hind fetlock ROM. Film week and film week/stretching treatment interaction did not have any significant effects (P>0.05). A Bonferroni/Dunn post-hoc test was applied to identify where the stretching treatment significances lie (table 23, page 65).

Table 22. ANOVA results for the mean hind fetlock ROM data for all subjects at all weeks.

	N	F-Value	P-Value	Significant
Film week	8	1.660	0.129	✗
Stretching	3	8.614	0.0004	✓
Film Week and Stretching Treatment Interaction.	15	0.907	0.553	✗

Table 23. Bonferroni/Dunn Post-hoc for mean hind fetlock ROM and stretching treatment (Significance level 5%).

	P-Value	Significant
3DSR – 6DSR	0.0001	✓
3DSR - NSR	0.036	✗
6DSR - NSR	0.098	✗

The hind fetlock is the first joint to identify only one difference between 6DSR and 3DSR. All the other joints have also had significant differences with the control and one other treatment. The 6DSR and 3DSR, although significantly different (P=0.0001), follow a similar pattern; both treatments cause a decline in mean hind fetlock ROM from week 6 to week 8, when the stretching treatments end, then rise from week 8 to 10 (the period when no stretching treatment had been applied). The stifle, shoulder and knee data also followed a similar incline after week 8 and will be investigated further in the discussion. The results indicate that there is definitely an effect of stretching on the ROM results, and needs to be looked at in greater depth in the discussion.

4.23 The effect of ambient temperature on range of motion

Ambient temperature could have had more of a visible effect on range of motion due to cold temperatures having detrimental effects on joints (Lloyd, 1994; Hunter and Whillans, 1951; Hunter *et al.,* 1952). The following tables will illustrate the effect ambient temperature had on joint ROM.

Table 24. Regression results for the relationship between ambient temperature and joint ROM.

Joint	F-Value	P-Value	R^2 Value	Significant
Shoulder	5.997	0.015	0.051	✓
Elbow	0.117	0.733	0.001	✗
Knee	1.395	0.240	0.012	✗
Fore Fetlock	13.091	0.0004	0.105	✓
Hip	0.967	0.327	0.009	✗
Stifle	0.013	0.908	1.179E-4	✗
Hock	0.444	0.506	0.004	✗
Hind Fetlock	1.006	0.318	0.009	✗

Table 24 highlights that ambient temperature only had a significant influence on shoulder ($P<0.05$) and fore fetlock ROM ($P<0.001$). Given that some joints were influenced by ambient temperature, but the majority were not, it cannot be said with any degree of confidence that there was a meaningful relationship between ambient temperature and the various limb angles measured.

4.24 Baseline Heterogeneity

All week 0 data was analysed for any significant differences between the groups before the treatment data was analysed. Table 4 (page 44), figure 6 (page 49) and table 9 (page 50) demonstrate that at week 0, the three treatment groups (6DSR, 3DSR and NSR) were not significantly different from one another. To verify that week 0 had no effect on the SL or ROM results overall an ANOVA with a covariate of week 0 was also analysed. Table 25 (below) highlights the outcome of the ANOVA with a covariate of week 0.

Table 25. ANOVA with covariate of week 0 for SL and all joint ROM.

Factor	Covariate	F-Value	P-Value	Significant
	Week 0	6.00	0.037	✓
SL	Stretching	3.32	0.083	✗
	Week 0	9.22	0.014	✓
Shoulder ROM	Stretching	3.20	0.088	✗
	Week 0	0.13	0.732	✗
Elbow ROM	Stretching	1.56	0.263	✗
	Week 0	2.05	0.189	✗
Knee ROM	Stretching	0.32	0.734	✗
	Week 0	0.23	0.641	✗
Fore Fetlock ROM	Stretching	0.18	0.837	✗
	Week 0	2.45	0.152	✗
Hip ROM	Stretching	0.96	0.418	✗
	Week 0	0.31	0.592	✗
Stifle ROM	Stretching	1.48	0.279	✗
	Week 0	9.75	0.012	✓
Hock ROM	Stretching	3.27	0.086	✗
	Week 0	0.80	0.395	✗
Hind Fetlock ROM	Stretching	3.43	0.078	✗

Table 25 demonstrates that ANOVA with the addition of week 0 as a covariate had no significant effect on the ROM results in the elbow, knee, fore fetlock, hip, stifle or hind fetlock. On the other hand week 0 is having an effect on SL, shoulder ROM and hock ROM, however despite that there is still no effect of stretching. To summarise this, week 0 is producing a small effect on three of the nine factors, however it is insufficient to produce some overall differences.

4.3 Results summary

To summarise, the results have demonstrated some interesting findings, especially regarding the 6DSR and 3DSR. In general the 6DSR produced smaller ROM values than the 3DSR and NSR and there were significant differences in joint ROM between the different treatments. There have also been noteworthy increases in ROM on the interaction line plots with 3DSR which need further consideration. ANOVA with a covariate of week 0 identified some significant effects of week 0 on SL and ROM of the shoulder and elbow, however there are still no overall effects of the stretching treatment. Ambient temperature had a significant influence on shoulder and fore fetlock ROM, however in-hand and ridden SL plus the other six joints did not, thus no significant conclusions can be drawn. Velocity of the subjects was kept at a constant, with no significant differences at each film week, therefore did not have an effect on the SL results. The null hypothesis was that the two differing stretch regimes (6DSR and 3DSR) would have no significant effect on SL and ROM compared to the control (NSR). The stretching treatments did not have any significant effects on SL, however the null hypothesis cannot be fully accepted yet because there are some effects on joint ROM, which need to be considered further.

5.0 DISCUSSION

The topic of stretching and its effect on equine movement has received little scientific attention and thus lacks published evidence. The majority of literature regarding stretching in horses appears in rehabilitation and therapy texts (Bromiley, 1993; Denoix and Pallioux, 2004), Buchner and Schildboeck (2006) and McGowan *et al.,* (2007) suggest that there are few equine studies investigating effects of stretching. The studies that are published (Giovagnoli *et al.,* 2004, are however not performance or motion related. The purpose of this study was to examine the effects of two eight-week stretching regimes on stride length (SL) and range of motion (ROM) in the equine trot. Ambient temperature was recorded throughout data collection to quantify any temperature effects on SL and ROM results. The null hypothesis was that the two differing stretching regimes (6DSR and 3DSR) would not have a significant effect on SL and ROM in the equine trot compared to the NSR (control). The SL results support the null hypothesis, neither 6DSR nor 3DSR had a significant effect on in hand SL or ridden extended trot SL compared to the NSR ($P>0.05$). Ambient temperature also did not influence in hand SL or ridden extended trot SL ($P>0.05$).

The joint ROM results are slightly more complex; the null hypothesis cannot be directly accepted as some significant effects were found. Joint ROM was analysed with the effect of stretching treatment and film week. Significant effects of stretching treatment and film week on joint ROM were found, however the interaction between film week and stretching treatments in all joints were not significant ($P>0.05$). The 6DSR produced smaller ROM values in most joints compared to 3DSR and NSR, which demonstrated significantly different p-values. The 3DSR treatment appeared to be more effective in increasing joint ROM in some joints compared to the 6DSR. Ambient temperature had a significant influence on the shoulder ($P<0.05$) and fore fetlock ($P<0.001$) ROM, however did not have a significant influence on the other six joints ($P>0.05$). The majority of the joints did not show a significant response to ambient temperature therefore it cannot be said with any degree of confidence that there was a meaningful relationship between temperatures and the various limb ROM's measured. Overall there was not a big temperature change from week to week, temperature ranged from 6.4°C to 13.5°C (mean 9.4°C) and thus was not believed to be a factor that affected SL or ROM. The repeatability study concluded that Equinalysis is a repeatable and effective two dimensional (2D) motion analysis system and found minimal human error when one person digitised each frame ten times.

5.1 Validation of Equinalysis

Validation of a motion analysis system is essential to biomechanical studies; measurement validity reflects the extent to which an instrument measures what it is intended to measure (Klein and DeHaven, 1995). Videographic analysis combined with a commercial software package is the most popular technique for studying equine kinematics (Clayton and Schamhardt, 2001), however the user must check the accuracy of digitisation before accepting the data for further analysis (Clayton and Schamhardt, 2001). The validation study carried out alongside to the stretching study indicated that Equinalysis is reliable and accurate in terms of the angles it calculates, and there was no significant difference (P>0.05) between the actual pendulum angle (13.99°) and the angle Equinalysis calculated (13.98°). There was also no significant difference between the pivot angle when one researcher digitised the video footage of the pendulum for ten repetitions. This information was vital for the stretching regime study to hold scientific rigour and produce valid, useful results. It must be emphasised that although successful, this is a preliminary validation procedure. Further validation work is needed to investigate the reliability of multiple researchers, and the use of Equinalysis in other applications, for example lameness quantification, looking at multiple angles and the automatic tracking feature. It would be useful to develop the validation and carry out further investigations; for example, the degree of variation between results if different anatomical markers were used, and the accuracy of digitising the centre of the marker.

Limitations of 2D motion analysis (Equinalysis in this case), are subjective human error and lighting difficulties, which restrict location of the anatomical markers on video playback. Problems can arise when a marker is temporarily obscured by another marker or part of the horse (Clayton and Schamhardt, 2001) and thus errors in the preliminary raw data will create problems throughout subsequent analysis. Human error has been ruled out (with caution, due to it being a preliminary repeatability study) following the validation study, which found no significant differences (P>0.05) between the pivot angle of the pendulum when digitised 10 times by one researcher. Light conditions can sometimes be a constraint to the software. Contrasting coloured (black and white) anatomical markers were used against each horse's colour of coat to highlight the position of the marker, however if the light in the arena was low, this occasionally blurred the anatomical marker on the video footage. This would affect the accuracy of locating the exact centre of the marker, thus deviating several numbers of pixels when digitising the marker. In other studies contrasting paint has also been used to draw a 'bull's-eye' target around a marker to improve its contrast (Clayton and Schamhardt, 2001). In this study, and others using (2D) motion analysis, circular markers 2-3cm in diameter are used; larger markers can give better accuracy when the resolution is poor (Schamhardt *et al.,* 1993). Larger markers, however, would have a greater number of pixels and potentially a sizeable standard error if deviating away from the centre of the marker when digitising. A further study looking at digitising the right, left and centre of the anatomical markers would provide useful information regarding pixel numbers on each individual marker and how deviations from the centre would affect angle data. Measuring light quality and its effects on marker clarity would also be valuable to kinematic studies.

Placement of the anatomical markers onto the horse can also be a constraint of such a study and the repeatability in positioning the markers must be considered (Clayton and Schamhardt, 2001). The knowledge of the researcher and accuracy in placement of the marker will have an effect on the SL and ROM results. Inevitably this has consequences for repeated measures in one horse when the markers have to be removed between sessions, unless remnants of glue or paint are left on the horse's coat to mark the spot (Clayton and Schamhardt, 2001). To increase marker placement repeatability and accuracy in this study, on the limb of the horse (elbow, knee, fetlock, stifle, hock and hind fetlock) small patches of hair (the same size as the anatomical marker) were clipped at the exact point where the marker attached to the horse. The clipped hair also made it easier for the marker to stay in position as longer hair caused the marker to move around when the horse was in motion. Skin displacement can cause errors in angle data for kinematic studies. Van Weeren (1990a) studied displacement of the skin over the underlying skeletal structures in the proximal parts of the limbs and found consistent displacement of a large magnitude; this is an important factor when interpreting results. On the other hand Back *et al.*, (1993) highlighted that if the kinematic data is predominantly used to compare the kinematics of subjects where the horse can act as its own control, trying to correct skin displacement is not entirely necessary. The subjects in this study did act as their own control, thus skin displacement was not considered to be a major limiting factor.

It was not possible to use 3D motion analysis in this study due to the amount of equipment needed, however this would be an improvement of the study in terms of accuracy and to gain a larger pool of data. Manual digitisation is tedious and time consuming, but these drawbacks are to some extent overcome by semi-automated systems (Clayton, 1991). Automatic tracking is a feature of many motion analysis software programmes. A problem when using automatic tracking is the reliability of the programme to detect all the anatomical markers at every frame. Special reflective and/or contrasting markers used alongside extensive lighting are vital to ensure correct capture of the markers (Clayton, 1991). Automatic tracking is a new feature of Equinalysis, and came onto the market after the study had finished. The feature would need validating prior to experimental use, however for studies using a large sample size with a great deal of video footage, automatic tracking would be highly beneficial.

5.2 The effect of muscle type

The reason the eight specific stretches were chosen was due to the muscles that they involved in relation to increasing SL and ROM.

The four forelimb stretches have an effect on many deep and superficial muscles; the deep muscles are the *Triceps brachii, Supraspinatus, Infraspinatus, Teres minor, Tensor fasciae antebrachii, Flexor carpi radialis, Flexor carpi ulnaris, Flexor digitorum profundus.* The superficial muscles are the

Brachialis, Extensor carpi radialis, Ulnaris lateralis, Pectoralis ascendes, Extensor digitorum communis, Extensor digitorum lateralis and the *Deltoids.*

The four hindlimb stretches also have an effect on many deep and superficial muscles; the deep muscles are the *Flexor digitorum profundus, Soleus, Gastrocnemius, Vastus lateralis, Rectus femoris, Illiacus, Semitendinosus, Gluteus profundus* and the *Gluteus accessories.* The superficial muscles are the *Extensor digitorum longus, Extensor digitorum lateralis, Biceps femoris, Gluteus superficialis and Tensor faciae latae.*

It was assumed that stretching these muscles would aid an increase in SL and ROM of the eight joints as all the muscles on the upper part of the fore and hindlimb are manipulated, plus major muscles around the shoulder, elbow, hip and stifle. The researcher had to stretch nine horses daily, plus fitting the stretching regime around each horse's exercise schedule, thus time constraints only permitted four stretches per limb to be performed. There are other stretches that could have had an effect on the subjects SL and ROM, the lack of significant increases in SL and ROM queries whether optimal stretches were chosen, or a sufficient number of stretches were applied and held for an adequate time period. On the other hand, the stretches, frequencies and hold times could have been sufficient, but the ability of SL and ROM to change may be limited.

Ronéus *et al.,* (1991) discovered muscle characteristics (Type I and Type II fibres) differ between Thoroughbreds with age and sex. Fibre types with low activity are Type I fibres (slow twitch) and those with high activity are Type II fibres (fast twitch), Type I fibres have a slower relaxation time and are more fatigue resistant than Type II fibres (Evans, 1994). Coyle *et al.,* (1992) concluded that cycling efficiency in humans is related to the percentage of Type I muscle fibres. The maximal velocity of sarcomere shortening of human Type II fibres is approximately three to five times higher than Type I fibres, therefore when contractions are performed at slow velocities Type I fibres from mammals have been observed to be more efficient than Type II fibres (Coyle *et al.,* 1992). Muscular efficiency is defined as the amount of work accomplished by the muscle fibre relative to its energy expenditure (Coyle *et al.,* 1992). In contemplation of this, it is plausible that stretching will affect horses differently depending on their percentage of muscle fibre types. If muscle fibre types vary within one breed with age and sex (Ronéus *et al.,* 1991), it is probable that they also vary between breeds. If Type I fibres are more efficient when contractions are performed slowly (Coyle *et al.,* 1992) a horse with a higher percentage of Type I fibres could benefit more from stretching than horses with a higher percentage of Type II fibres. Different breeds were used in this study; therefore stretching may have produced different effects on the different muscles types. When looking at the results as a group, significant results were not demonstrated, however individuals may have shown significant effects depending on specific muscle type.

Persson *et al.,* (1991) found that in Standardbred horses SL is positively correlated with the percentage of Type I and Type IIA fibres and negatively correlated with the percentages of fibre Type IIB. Ronéus *et al.,* (1995) found the opposite in Trotters, highlighting different muscle make-up in different breeds. From these findings, muscle fibre distribution in the horse may firstly determine the length of stride, and secondly may limit potential adaptations and increases in SL. Research into the effects of therapeutic stretching on different muscle fibres in the horse and human is limited, thus research in other muscular investigations must be extrapolated with vigilance. De Deyne (2001) identified that longer muscles (including muscle fibres and the related connective tissue) will have greater excursion ability thus increased range of motion around a joint. This finding may suggest that different joints could elicit different responses to stretching, depending on the length of muscle attached to the specific joint. This may be a reason why the joints in this study demonstrated different responses to the stretching treatment. The use of passive stretching (used in this investigation) is thought to elongate shortened tissues (De Deyne, 2001), when the load on the muscle is greater than the force developed by the muscle and the muscle is stretched, this produces a lengthening (eccentric contraction) (Faulkner *et al.,* 1993). Passive stretching therefore could potentially lengthen muscle fibres and thus increase ROM.

5.3 Hold time and frequency of stretching

Some joints in this study did show significant differences in ROM values, the 6DSR generally demonstrated lower ROM, compared to the NSR and 3DSR. Some joints showed an increase in joint ROM with the 3DSR, however this was varied throughout the eight weeks. Reasons that there were significant differences between the 6DSR and 3DSR could be due to frequency of stretching. Research on human athletes has investigated long-term stretching procedures where stretching was applied three days a week (Roberts and Wilson, 1999; LaRoche and Connolly, 2006) five days a week (Bandy and Irion, 1994; Bandy *et al.,* 1997) and seven days a week (Kubo *et al.,* 2002a). The majority of the research however comments on the effects of hold time per stretch (seconds), not the effect of the frequency of stretching per week. LaRoche and Connolly (2006) commented that stretching programs of greater duration than four weeks with increased intensity and volume of stretching could produce changes in the stiffness and work-absorption capacity of muscles. It is not clear, however it is assumed LaRoche and Connolly (2006) are indicating that stretching for more than four weeks for more than three times a day could possibly reduce muscle stiffness. A decrease in stiffness and work absorption appears to be related to increased ROM (LaRoche and Connolly, 2006). The stretching regimes used in this study were greater in duration than four weeks and had increased volume and intensity of stretching with the 6DSR, however the reduced ROM results could be indicating 6DSR subjects experienced increased muscle stiffness compared to the 3DSR and NSR.

Muscle contractions likely cause minor insignificant damage to muscle fibres daily, however less frequent damage accompanied by delayed onset of muscle soreness (DOMS) is also possible (Faulkner *et al.,* 1993). Contraction induced damage results in the degeneration and regeneration of muscle fibres (Faulkner *et al.,* 1993). Faulkner *et al.,* (1993) identified out of the three contractions; concentric (shortening), isometric (muscle length stays the same), and eccentric (lengthening), muscle injury is most likely to occur during lengthening contractions. An early investigation by Hough (1902) also agrees that lengthening (eccentric contractions) was more likely to produce delayed muscle soreness. The aim of stretching is to lengthen shortened tissues (De Deyne,

2001) in an attempt to increase flexibility and ROM, thus the regular lengthening of the muscle fibres may be causing delayed muscle soreness. Hough (1902) was the first to describe the phenomenon of DOMS, the soreness of the muscles was not reported at the time of contractions, but developed eight to ten hours later, then severity increased 48 to 60 hours afterwards. The 6DSR horses could have been experiencing DOMS from the stretching treatment, but did not have sufficient time to recover and rest from this compared to the 3DSR group. Hough (1902) and Faulkner *et al.,* (1993) commented that repeated exposure to protocols of lengthening contractions result in 'trained' muscles, which often do not demonstrate soreness. This may have happened with the 3DSR subjects as time was allowed for recovery and adaptation, so soreness was avoided but the 6DSR subjects did not have time for muscle regeneration and adaptation.

Muscle soreness from stretching contracting muscles can take up to a week to recover (Morgan and Allen, 1999). Muscle soreness may have been constantly with the 6DSR horses, which was demonstrated by the reduced SL and ROM. In humans, there are problems with quantifying structural damage to muscle fibres (Faulkner *et al.,* 1993). Faulkner *et al.,* (1993) concluded that a decrease in the maximum force developed by a muscle or muscle group, (although not a direct measurement) provides the most valid measure of the entirety of muscle damage. Muscle force has been a common measurement in relation to stretching humans (Shrier, 2004; Thacker *et al.,* 2004). Muscle force can also be measured on the conscious and moving horse (Tokuriki and Aoki, 1995); muscular contraction generates forces that stabilise and move the limbs. Muscle contraction is preceded by electrical activity, which can be detected by electromyography (EMG) (Clayton and Schamhardt, 2001). Using EMG would be a useful additional measurement for future work in order to quantify any muscle damage.

De Deyne (2001) suggests that when a substance is exposed to a passive force (stretch), it will deform according to its material properties. When the force (stretch) is removed, the tissue will return to its original length (Shrier and Gossal, 2000) in a time-dependent (relaxation) manner (De Deyne, 2001). de

Weijer *et al.,* (2003) also observed this; in humans, 15 minutes post stretch the hamstring length had decreased. The initial decrease in length could possibly be associated with the elastic component of the muscle recoiling to an equilibrium position and the return of fluids that have been squeezed out of the muscle during stretching (de Weijer *et al.,* 2003). In contemplation of this, it is questionable whether a long-term programme is necessary if the muscle length gains can potentially decline within 15 minutes post stretching. If the equine muscle lengths were decreasing immediately post stretching in this study measuring SL and ROM every other week would not have identified any increases in SL or ROM. de Weijer *et al.,* (2003) discovery of the 15 minute post stretching threshold may also indicate that SL is a component of equine locomotion that cannot be changed long term, thus why the results conclude no effects on SL.

Clinical experience demonstrates that the mobility gained with a stretch-based rehabilitation programme is maintained even when the stretch is removed, this suggests a permanent adaptive response (Steffen and Mollinger, (1995); Halbertsma *et al.,* 1996). This contradicts some researchers findings that muscles go back to their original state once the stretch has ceased (Shrier and Gossal, 2000; de Weijer *et al.,* 2003) and thus why the use of long term stretching and pre-exercise stretching is a debated topic. A biomechanical rationale may explain short-term reversible changes in muscle length, but fails to explain long-term permanent adaptations; because of the adaptable nature of live tissues a permanent increase in ROM after a stretching programme cannot be deciphered (De Deyne, 2001). One theory that could explain long-term changes is that the muscle actually becomes longer, adding sarcomeres in series allowing further movement (De Deyne, 2001), however measuring this change in the horse would most likely be an invasive procedure. To reach the muscle, the stretch is transmitted via the connective tissue to the muscle fibre. To explain whether a stretched muscle fibre ultimately leads to a longer muscle fibre with more sarcomeres in series, signal sensing, signal transduction and subsequent gene transcription must take place (De Deyne, 2001). This theory hypothesises that if stretched, a muscle responds by adding more sarcomeres (De Deyne, 2001; Simpson *et al.,* 1995). This process may or may not have been happening to the horses in the study, the lack of significantly increased SL or ROM would suggest that additions of sarcomeres did not take place. To identify this it could be assumed that signal sensing and signal transduction (used to detect sarcomere additions in human muscles (De Deyne, 2001)) would also be required on the horse's muscle.

Many authors argue that stretching for a 30 second period is sufficient to obtain increased ROM (Bandy *et al.,* 1997 and LaRoche and Connolly, 2006) and flexibility (Bandy and Irion 1994; deWeijer *et al.,* 2003 and Sharma *et al.,* 2004). The methods used in this study are a combination of Pattillo (2005) recommendations and findings from human research. In this study the horse received an initial 10-second stretch, followed by a 20-second stretch thus resulting in a 30-second hold time, 30 seconds has been found to be effective by previous researchers (Bandy *et al.,* 1997 and LaRoche and Connolly, 2006). The results however, suggest that this hold time is not sufficient to produce significant changes to the SL and ROM in the horse. This may be due to the immediate decline of muscle length post stretch (de Weijer *et al.,* 2003), that a different hold time is required or it is possible that SL cannot be altered by manual therapy. Further work is needed in the horse in relation to different hold times and also the amount of stretches applied per body part and the effects on SL and ROM.

It is plausible that different joints and muscles in the horse may require different hold times to elicit biomechanical changes. In human research studies, hold times were not different for different muscle groups, and to the researcher's knowledge using different hold times for different muscle groups in humans was not a discussion point in the research reviewed. Thacker *et al.* (2004) reported 27 studies demonstrating increased joint flexibility in the knee, hip, trunk, shoulder and ankle, of which the majority used a 15 second or 30 second passive stretch on all the muscles involved. The results in this study highlighted significant differences between the different joint ROM angles (figure 6, page 49), this is expected as anatomical design and movement restrictions differ between the joints. Back *et al.* (1997) demonstrates the different angles between joints, for example, the hind fetlock joint has considerably higher ROM than the hip joint (97.7°±7.0° and 22.5°±1.8° respectively) the results from this study agree with this. Because the anatomical design differs between joints, it could be assumed that stretching hold times may have different effects upon the joints. In consideration of this, it is possible that joints with smaller ROM may require different stretch hold times and frequency compared to joints with large ROM to elicit biomechanical changes.

The hindlimb is different from the forelimb, morphologically and has different functional responsibilities than the forelimb during locomotion (Clayton *et al.*, 2001). Clayton *et al.* (2001) expects that due to the differences between the fore and hindlimb, differences in the patterns of energy generation and absorption may occur, thus it may be necessary to apply different hold times and frequencies of stretching to the fore and hindlimb to elicit changes in SL and ROM. Clayton *et al.* (2001) also found that within the hindlimb, different joints performed different functional roles of energy generation and absorption. Within the hindlimb, the different joints may also require different hold times and stretching frequencies due to their different roles in locomotion and different abilities of absorbing and generating energy. Excluding the trend that the 6DSR generally produced smaller ROM in the joints, other trends in the results are difficult to establish. The shoulder joint (figure 7 page 50) demonstrated a small increase in ROM in all treatments until week 6, however all other joints have demonstrated either a decrease during the stretching treatments (elbow, figure 8 page 52; knee, figure 9 page 54) or sporadic and irregular increases and decreases in ROM during and post the stretching treatments (fore fetlock, figure 10 page 56; hip, figure 11 page 58; stifle figure 12 page 60 and hind fetlock, figure 14 page 64), thus concluding different joints require different hold times and frequencies requires further investigation.

5.4 Why measure conformation, stride length and range of motion?

Measuring in hand and ridden SL and ROM could be classed as 'in the field' measurements, that can be directly applied to equine performance. Investigations using equipment such as an equine treadmill provides useful information within research however, the findings often cannot be directly applied to the industry and every day routines of equine training and performance unlike 'in field' measurements. Baseline measurements are integral to biomechanical studies investigating before and after effects; the evaluation and usage of baseline measurements between conditions where an independent variable is manipulated can be crucial to the evaluation of treatment effects (Stergiou and Scott, 2005). The main principle for acquiring baseline data for each subject is to use the subject's performance in the absence of the independent variable as an objective basis for evaluating the effects of the independent variable (Stergiou and Scott, 2005).

In this study an ANOVA was carried out on all the week 0 (baseline data) to identify any possible significant differences. There were no significant differences at week 0 between the treatment groups for SL and joint ROM ($P>0.05$). To verify this ANOVA with a covariate of week 0 was also analysed to investigate if week 0 (baseline) data was having an effect on the overall outcome of SL and joint ROM data. The ANOVA with covariate of week 0 found that there was a significant effect of week 0 data on SL, shoulder and hock ROM ($P<0.05$). This could be due to the week 0 baseline data and the variation of each horse. Baseline data was obtained by trotting subjects past the camera with anatomical markers four times. This study has brought to light the variability in SL and ROM measurements from week to week irrespective of stretching and to the researchers knowledge there are no published studies investigating the variability of baseline biomechanical measurements in the horse over a period of time. There will always be variation between horses SL and joint ROM, but the degree of this variation between a number of horse or comparing the same horse on different days is relatively unknown. If baseline measurements had been established with multiple trots past the camera on multiple days (not just over one day) different baseline data may have been obtained which may not have found effects on SL or shoulder and hock ROM. If a horse was feeling stiff on the baseline measurement day, SL may have been shortened or joint ROM may have been reduced, which would in turn have an effect on the treatment data. Stergiou and Scott (2005) found that baseline measures are altered between conditions in human biomechanical studies and should be used when a repeated measures design is utilised. The knowledge of variability of baseline data for horses without any treatment being applied over a period of time would be valuable information for equine biomechanical studies.

Subjects were matched as closely as possible in terms of age, breed and conformation, however due to some variation in these factors this may have had an effect on the week 0 data, and it was the shoulder and hock ROM that have been identified as different between the groups. If all subjects were of the same breed this may have been eliminated, further research is required to investigate this. Skin displacement could also be contributing to the ANOVA with covariate outcome. Skin displacement has been reported to be of greater magnitude in the proximal part of the limb, with reported skin movements as large as 12cm, sufficient to change the shape of the entire angle-time diagrams at the proximal joints (Clayton and Schamhardt, 2001). Skin displacement on the hock joint most likely did not have an effect as distal to the stifle, skin movement is small enough to be neglected (Clayton and Schamhardt., 2001). On the other hand above the elbow, skin displacements can create a problem in joint angle reliability, which could be the reason why ANOVA with covariate of week 0 has found significant effects on shoulder ROM. Correction algorithms have been developed for correcting skin displacement in walking and trotting Dutch Warmblood horses (Van Weeren *et al.*, 1990b), thus potentially overcoming the issue of skin displacement in the proximal limb.

It is a common observation that lengthening of a muscle produces results that are not as consistent or easy to interpret as those produced from experiments in which muscles shorten (Morgan, 1990). The results from this study are proving to be challenging to interpret. The two stretching procedures carried out in this study did not have any significant effect on the mean SL of the subjects. Several topics are raised because of the SL result outcome. Firstly it is questionable whether the horse's stride length can be influenced by manual therapy, the horse's stride characteristics can be changed by various factors; the presence of a rider (Peham *et al.*, 2004), conformation (Back *et al.*, 1994) and nutritional supplements for veteran horses (Forsyth *et al.*, 2006). Therapy books (Denoix and Pallioux, 2004) and Equinology methods (Pattillo, 2005) suggest that stretching can influence SL, however to the researcher's knowledge there are no scientific investigations supporting this.

Through evolution the horse has adapted to be able to produce high speeds and intricate movements. Adaptations include elongated slender limbs with muscles closely located to the centre of mass, controlled ranges of movement in joints of the lower limb and the utilisation of the collagenous components of the muscles to reduce energy requirements in posture and locomotion (Goodship and Birch, 2001). Goodship and Birch (2001) state that systems of the equine body have a limited capacity for adaptation to achieve an optimal state when conditions are forced upon that system. The speed and intricate movements that the 21st Century horse produces has been evolving for many years and it is plausible that the locomotor system has reached its optimal capacity. If further studies continue to find similar results to this study, it must be considered that no matter how much stretching treatment is applied to the horse SL may be limited to the degree that it can change and adapt.

Assuming stretching treatment can influence SL, the second issue that is highlighted is that SL changes may not be detected from 2D video analysis of the in-hand trot. The results of the study demonstrate no significant effects of stretching on SL, there may have been effects on SL, however it may be that the detection methods were not sensitive enough to identify subtle changes. A horse would not necessarily expel more energy and engage its limbs to produce a long flowing stride if it was not encouraged to doing so. With this in mind the horses used in the study were ridden at the end of the eight-week stretching regime. If a rider applies certain aids, it is possible to physically encourage the horse to extend its limbs into an extended trot gait. Video analysis of ridden extended trot was conducted at week eight of the study (after eight weeks of stretching treatment) and at week 16 following eight weeks of no stretching treatment. No significant effect on ridden SL was found. To expand the study, ridden extended trot data could be collected throughout the study, however this idea was only developed at the end of the study, hence why it only took place at week 8 and 16.

The results indicate that the two different stretching treatments had no significant effect on SL during or post the regime ($P>0.05$), however figure 4 (page 45) demonstrates an interesting outline of the SL data. There are interesting increases and decreases in SL in the 3DSR group, with noticeably different SL from week to week. From week 0 to week 2, SL increased from 2.22m to 2.32m (mean 0.10m increase), from week 2 to week 4 shows a decline in SL from 2.32m to 2.15m (mean 0.17m decrease). Between week 4 and week 8 SL showed a big increase of nearly 0.30m, this demonstrates that SL is an erratic measurement with considerable changes from week to week. It would be assumed that an increase in SL of nearly 0.30m would be significant; it would most definitely be significant in the equine competition, however significance was not detected by ANOVA. This may be due to ANOVA not being sensitive enough to detect statistically significant changes in terms of equine competition. Harris and Harris (2005) highlight that individual variability in response means that it may be difficult to assess scientific significance if small sample sizes are used. If only one in five horses show a marked improvement, this would not be deemed statistically significant, but could be highly significant to the individual athlete (which did respond) in the field (Harris and Harris, 2005). Harris and Harris (2005) highlight that the effect a treatment has on performance may be so small as to be masked by the normal within-subject variability intrinsic within any testing program, and the sensitivity of the procedures employed, but in competition, could be the difference between winning or being placed. Winning margins in many athletic events are small compared to the duration of the event (Hinchcliff, 2004). Behm *et al.* (2004) emphasised that considering the minute differences between winning and losing in individual and team sports, the low but significant percentage changes in factors such as reaction time, movement time and balance (all affected by stretching) could result in serious consequences. SL and joint ROM could have had a small increase that could aid an equine athlete to win a race, or clear a show jump, however the small increases in SL and ROM cannot be detected by the testing methods used here.

ROM of the joints and SL are closely related, if the joints have good supple ROM, the limbs can be rotated around the joint fully, propelling the limbs to create a long flowing stride. There is a considerable amount of anecdotal evidence highlighting that racehorses often win by millimetre margins and endurance horses would cover a greater distance in a shorter time with an increase in SL, thus measuring ROM and SL is a good indicator of equine performance. ROM is also a measure of flexibility, as specific flexibility tests for horses have not been developed. Further work is needed in the area of SL and ROM to devise instruments to assess horses' flexibility objectively and quantifiably. Many studies have been able to control and accurately investigate stride characteristics using an equine treadmill (Back *et al.,* 1996b; Lewis *et al.,* 2001; Preedy and Colborne, 2001), however treadmills can alter a horses natural movement (Fredricson *et al.,* 1983; Barrey *et al.,* 1993) thus it would not be known what was affecting the SL, the treatment or compensation in the movement because of the treadmill.

Kinematic analysis of the subjects took place at 1-2 week intervals. Anecdotal evidence supports the notion, that similar to humans, horses can move and feel stiff from time to time. Experimental protocol involved filming each horses movement immediately following removal from its stable without a prior warm-up. Standing in the stable for prolonged periods can result in a build up of fluid in the legs (Reed, 2003), which could cause stiff motion. If a particular horse was not moving efficiently on the day of filming, this would have affected the results dramatically, however the following day normal fluent motion could have been resumed. It would be of benefit to have filmed the horses more often, perhaps two or three times a week to avoid such situations.

Lewczuk and Pfeffer (1998) discovered that endurance horses' SL increased over the course of a race, it was suggested that the increase in SL was due to warming-up during the race. If a warm-up had been applied to the horses prior to assessment, this may have activated the muscles and facilitated an increase in SL. The SL may have increased linearly over time as stretching was applied over the course of the regime. If a warm-up had been included however, it would be difficult to distinguish the reason for the increased SL, the warm-up, the stretching, or the combined effects of the two. Previous research (Rose *et* *al.,* 2007) incorporating warm-up with stretching failed to identify significant differences in SL and ROM, therefore this study did not utilise a warm-up.

One element of the method that could be misinterpreted as an extra variable is that the NSR subjects did not undertake a warm-up on the horse walker. The main reason for this was time and horse availability. On a busy working yard, trying to organise a timetable for 18 horses to carry out a warm-up and a treatment in a similar order every day is quite challenging. The warm-up was a necessity for the stretch regime horses, however not for the NSR horses, thus it was not carried out. Nevertheless it could be difficult to determine whether the stretching treatments were beneficial compared to the NSR, or whether it was the walking exercise that resulted in the observed differences between groups. The latter is unlikely, because there would have been horses in different groups who had walked different distances each day, it would be impossible to control a detail such as distance walked per day on a working yard. Even if the NSR horses did have a warm-up on the horse walker, the 6DSR horses, for example could sill have walked further on a particular day if they had been assigned to be used in more lessons.

5.5 Application to the industry:

Many equine locomotion studies utilise a small number of subjects, which may be insufficient to give the required power for a statistical analysis (Clayton and Schamhardt, 2001). In these cases trends in the data may identify a biologically significant effect that cannot be proven statistically, but is nevertheless important (Clayton and Schamhardt, 2001). To make research applicable, appropriate testing is required: other than filming SL and ROM, a means of testing that can be used to investigate biomechanical or physiological changes to the muscles would be valuable. Human research has developed devices such as the sit and reach test and fleximetres to analyse flexibility and degree of bending, goniometres to measure joint angles and arthrometres to measure joints (Thacker *et al.,* 2004). These tools are generally used to measure static flexibility and ROM about a joint in humans (Thacker *et al.,* 2004). It is not possible to use these devices on horses, as communication is required between researcher and subject, and the subject has to work the device, and comment on his/her resistance point. Viewing the horse in trot commonly assesses the quality of equine motion; it is the gait most extensively used in kinematic research (Clayton, 2001), however specific methods to assess flexibility and ROM in the horse are apparently unavailable.

One method that could be used in the field to assess equine flexibility and ROM around the elbow, shoulder and stifle and hip joints is to measure how far a horse's leg (fore or hind) can be lifted from the ground (vertically) and away from or towards the midline (laterally), until resistance is met. The distance would be measured from the hoof to the ground, for example, using equipment such as a laser tape measure. Care must be taken however to avoid overstretching and pushing the horse past its resistance limit; a human would be able to inform the researcher of their resistance limit, a horse would not be able to do so. It must be noted that feeling the resistance point of the horse would be a subjective decision and may vary between researchers. This idea was initially considered when performing stretches on the horses, noticing that certain horse's legs could be lifted higher after several weeks of stretching. The resistance point had altered but there was no available means of measuring this apart from the therapist's 'feel' and subjective assessment. A brief written assessment of each horse's response to the stretching and progress over the eight weeks is in appendix 5 (page X).

A possibility of measuring different muscle activity and subsequent effects of stretching could be the use of electromyography (EMG), which is currently utilised in equine (Colborne *et al.,* 2001; Robert *et al.,* 2002) and human research (De Luca, 1997; Kleissen *et al.,* 1998). In human biomechanics there are three main applications within the use of EMG; its use as an indicator for the initiation of muscle activation, its relationship to the force produced by the muscle, and its use as an index of the fatigue processes occurring within a muscle (De Luca 1997). Indicators of fatigue have also been investigated in horses (Colborne *et al.,* 2001). EMG has been previously used alongside a kinematic study in the horse (Colborne *et al.,* 2001; Robert *et al.,* 2004), correlation between EMG and kinematic data for different muscles demonstrated specific muscle involvement, predominantly in the restriction of movement of the trunk at the trot. The application of EMG combined with kinematic data has the potential to be a valuable tool in researching the effects of different warm-ups and/or stretching regimes. For example, highlighting the onset of fatigue in relation to stretching and/or warm-ups, to examine how stretching affects the activation of the muscles and whether force production in the muscles is altered post stretching. An essential component of an EMG system are electrodes for recording potentials, the electrodes function as an antenna to pick up the electrical signal (Clayton and Schamhardt, 2001). The electrodes may be placed on the skin surface, inserted percutaneously into the muscle or implanted surgically. Surface electrodes have the advantage of being non-invasive and are a reliable and reproducible technique (Jansen *et al.*, 1992), however only provide a gross estimation of muscle activity in large superficial muscles and many locomotor muscles of the horse lie deep beneath the cutaneous muscle (Clayton and Schamhardt, 2001). Further work would be required to investigate EMG application to the horse in relation to stretching, but it has the potential to discover stretching effects on a more detailed muscular level.

Individually matched samples in studies can produce unbiased comparisons by eliminating covariate effects (Nam, 1997). Matched pairs are used in a variety of studies (Hagen and Broom, 2004; Garnett *et al.*, 2005) including equine biomechanical studies (Clayton *et al.*, 2002). A matched group design was used for this investigation. The horses were matched in three groups as closely as possible in terms of age, breed and build/conformation (appendix 3 page VII illustrates matched horses), however, due to the limited horses available for use in the study, not all horses were an ideal match, breed, age and gender did vary. Muscle characteristics were studied in Thoroughbreds by Ronéus *et al.* (1991), the percentage of Type I fibres of all horses increased with age, irrespective of gender, Type II fibres decreased with age and differed between gender and age is a factor influencing enzyme activities in the muscles (Ronéus *et al.*, 1991). The ages that were investigated by Ronéus *et al.* (1991) were between one and six years, thus all horses were still relatively young, however the ages of the horses used in this study ranged between six and 17 years. Differences between their muscle compositions are a possibility and could influence the effects of the stretching. If muscle characteristics are different within one breed with age and gender (Ronéus *et al.,* 1991), it could be assumed that muscle type may vary between breeds potentially influencing the stretching effects.

In this study only one researcher applied the stretches and subsequently analysed the data. This can cause problems with bias and limit reliability of interpreting results. It would be preferable to have two different researchers (unaware to the assigned groups and purpose of the study), one stretching and one analysing. This was not possible and therefore extra care was taken to avoid bias. An advantage of using stretching, as a therapy aid to performance, is that stretching can easily be applied to a routine and fit in with the horse's training schedule. The horses were stretched at the same time each day in a particular order, to minimise external variables and create uniformity. An external variable that could not be controlled and sometimes forced alterations to the order each horse was stretched was the activity each horse performed before and/or after the stretching protocol. All horses were involved in riding lessons on a daily basis, however individual schedules varied from day to day, thus before or after stretching had been applied, the horse was either working in a lesson, or resting in the stable. It is possible that the extra activity before or after stretches, or the resting period could have had an influence on how the stretches affected each individual. Little and Williams (2006) and Behm *et al.* (2001) highlighted that extra muscle activity after stretching or a rest period prior to performance may reverse any decrease in muscular compliance and associated decrease in neural drive initiated by stretching. It is not clear the exact mechanisms of this (Little and Williams, 2006). The time delay and the extra activity before performance could both have had an effect on the reverse of decrease in muscular compliance; it might not necessarily be just one factor having an effect. The effect of the horse either being ridden or being rested in the stable after stretching is unknown, nevertheless it is thought that there would be a difference in how the muscles react.

If a subject had been ridden in a lesson prior to stretching, this could also have a different effect on the muscles than being exposed to 10 minutes on a horse walker. It is recommended that equine muscles are warmed-up prior to stretching (Denoix and Pallioux, 2004; Pattillo, 2005). In humans a warm-up 'primes' the muscle's physiological mechanisms (Burnley and Jones 2005), the synovial fluid warms and lubricates the joints. Core temperature is raised and thus muscle fibres and fascia are lengthened (Mattes 1996). It would be assumed that an hour of being ridden in a lesson compared with ten minutes on the horse walker prior to being stretched would have different effects upon the horse's muscular system and thus in turn cause stretching effects to differ. This may have happened in this study, but was not measured; EMG would be useful to measure muscle activity and its effects.

All horses involved in the study had been given veterinary approval and cleared fit to be stretched, however, despite being physically fit, temperaments and attitude to stretching between subjects differed. Some horses adjusted well to the stretching and did not resist the movements, on the other hand some horses did resist the stretches and were not as comfortable having their limbs moved into unfamiliar positions. This did improve over the weeks, however the effect of the stretches would not have had the same degree of impact on the resisting horses. Relaxation is vital for effectiveness of the stretch. Individual response differences however will always be a part of investigating humans or animals, it is the researcher's role to minimise the differences and keep uniformity in the research. Uniformity was a feature of this study by using the same researcher to apply the anatomical markers and stretches, the same person to digitise and analyse the results and by keeping the procedures of stretching and filming consistent.

Cold temperatures can have an effect on joint stiffness (Lloyd, 1994; Hunter and Whillans, 1951; Hunter *et al.,* 1952). Ambient temperature was recorded during data collection and was found to have a significant influence on the shoulder ROM ($P>0.05$) and fore fetlock ROM ($P>0.005$), however did not have any influences on the other six joints or SL. Ambient temperature did not have any influences on the majority of the joints and SL, thus it cannot be said with confidence that temperature had an overall effect on the results.

If similar stretching methods used in this study are applied to the industry, in training yards for example, more stretches per limb could be applied. Only four stretches per limb were used in this investigation due to time constraints, however there are many more stretches that would be useful to enhance a horse's training and daily care routine. The four stretches applied to the limbs were chosen to increase SL and ROM, however other stretches can be applied not just to the limbs, but also to the head, back and barrel similar to those used by Rose *et al.* (2007). In the equine industry the main focus, apart from producing elite performance horses, is to provide excellent care and welfare for the horse. In this study, stretching may have affected the wellbeing of each horse, many horses did exhibit a state of rest and relaxation, indicated by posture and behaviour, however, this is difficult to measure scientifically. Giovagnoli *et al.* (2004) found stretching decreased wither height; this was attributed to a neuro-muscular relaxation. A decrease in wither height could therefore be a potential measure of relaxation in the horse when stretching is applied. Using stretching to improve welfare could increase longevity of a horse's career by maintaining healthy supple joints and providing a recuperating and relaxing environment. Further research into stretching effects on horses could use a behaviour ethogram, or questionnaires to the horse owners to comment on daily behaviour in the stable and when being ridden. Investigating cortisol and heart rate levels pre and post stretching would also be interesting. This would provide an insight into the effects of stretching on horses and which can be directly related to the daily care of the horse.

5.6 Conclusion

This study has touched on many interesting aspects of stretching horses, which is an unsubstantiated area within the equine and veterinary industry compared to human sports medicine. Increasing a horses SL and ROM could potentially raise performance in many equine disciplines. Joint ROM has displayed some significant differences between stretching treatments, however further work is required to investigate whether SL can be altered by manual therapy. The results highlighted some exciting findings in relation to the frequency of stretching and joint ROM; 6DSR produced smaller joint ROM compared to 3DSR and NSR in some joints. Analysing ANOVA with a covariate of week 0 highlighted some significant effects of week 0 on SL, shoulder and hock ROM. This is most likely due to horse variation and the methods used to obtain the baseline data, which requires further investigation. The joints that did show smaller ROM in the 6DSR could possibly be attributed to the occurrence of delayed onset of muscle soreness (DOMS) and lack of recovery time, indicating six days of stretching is possibly too intense and three days of stretching is a more suitable stretching frequency. Muscle composition and type may have varied between the breeds of subjects, thus stretching could have influenced individuals differently. A similar investigation focusing on one breed would be interesting.

It is evident that testing procedures and statistical analysis need to be more sensitive to measure potential small but highly important changes in the equine stride. 3D motion analysis could investigate more aspects of the equine stride. Equinalysis was a practical and reliable program for investigating SL and ROM; however further validation is required, especially to the automatic tracking application, which could be a breakthrough to reduce tedious manual labour. If this study were repeated a more strategic procedure in selecting horses and way of measuring the stride characteristics should be modified, the use of EMG to look at muscle activity would also be valuable. To conclude, stretching is an exciting and developing area of equine training and performance, SL was unchanged, however 3DSR appears to be more beneficial than 6DSR for increasing joint ROM.

Back, W., Barneveld, A., van Weeren, P.R. and van den Bogert, A.J. (1993). Kinematic gait analysis in equine carpal lameness. *Acta Anatomica.* **146** (2-3) 86 – 89.

Back, W., Barneveld, A., Bruin, G., Schamhardt, H.C. and Hartman, W. (1994). Kinematic detection of superior gait quality in young trotting warmbloods. *The Veterinary Quarterly, Supplement.* **17,** 3 – 6.

Back, W., Schamhardt, H.C., Savelberg, H.H., van den Bogert, A.J., Bruin, G., Hartman, W. and Barneveld, A. (1995). How the horse moves: 1. Significance of graphical representations of equine forelimb kinematics. *Equine Veterinary Journal.* **27** (1) 31 – 38.

Back, W., Schamhardt, H.C. and Barneveld, A. (1996a). Are kinematics of the walk related to the locomotion of a Warmblood horse at the trot? *The Veterinary Quarterly.* **18** (2) S79 – S84.

Back, W., Schamhardt, H.C. and Barneveld, A. (1996b). The influence of conformation on fore and hind limb kinematics of the trotting Dutch Warmblood horse. *Pferdeheilkunde.* **12** (4) 647 – 650.

Back, W., Schamhardt, H.C. and Barneveld, A. (1997). Kinematic comparison of the leading and trailing limb at the canter. *Equine Veterinary Journal Supplement.* **23,** 80 – 83.

Back, W. and Clayton, H. M. – eds. (2001). *Equine Locomotion.* London; W.B Saunders.

Baechle, T.R. and Earle, R.W. – eds. (2000). *Essentials of Strength Training and Conditioning.* 2nd ed. Leeds; Human Kinetics.

Bandy, W.D. and Irion, J.M. (1994). The effect of time on static stretch on the flexibility of the hamstring muscles. *Physical Therapy.* **74,** 845 – 850.

Bandy, W.D., Irion, J.M. and Briggler, M. (1997). The effect of time and frequency of static stretching on flexibility of the hamstring muscles. *Physical Therapy.* **77** (10) 1090 – 1096.

Barrey, E. (1999). Methods, Applications and Limitations of Gait Analysis in Horses. *The Veterinary Journal.* **157,** 7 – 22.

Barrey, E., Galloux, P., Valette, J.P., Auvinet, B. and Wolter, R. (1993). Stride characteristics of overground versus treadmill locomotion in the saddle horse. *Acta Anatomica.* **146** (2-3) 90 – 94.

Beam, J., DeLany, J., Haynes, W., Lardner, R., Liebenson, C., Martin, S., Rowland, P., Schleip, R., Sharkey, J., Vaugh, B., Herbert, R and Gabriel, M. (2003). 'The Stretching Debate'. *Journal of Bodywork and Movement Therapies.* **7** (2) 80 – 96.

Behm, D.G., Button, D.C. and Butt, J.C. (2001). Factors Affecting Force Loss With Prolonged Stretching. *Canadian Journal of Applied Physiology.* **26,** 261 – 272.

Behm, D.G., Bambury, A., Cahill, F. and Power, K. (2004). Effect of Acute Static Stretching on Force, Balance, Reaction Time, and Movement Time. *Medicine & Science In Sports & Exercise.* **36** (8) 1397 – 1402.

Belloy, E. and Bathe, A.P. (1996). The importance of standardising the evaluation of conformation in the horse. *Equine Veterinary Journal.* **28** (6) 429 – 430.

Bennett, A.F. (1985). Temperature and muscle. *The Journal of Experimental Biology.* **115,** 333 – 344.

Bergmann, P. and Irschick, D.J. (2006). Effects of temperature on maximum acceleration, deceleration and power output during vertical running in geckos. *The Journal of Experimental Biology.* **209,** 1404 – 1412.

Best, T.M. (1995). Muscle-tendon injuries in young athletes. *Clinics In Sports Medicine.* **14** (3) 669 – 686.

Bromiley, M. (1993). *Equine Injury, Therapy and Rehabilitation,* 2nd ed.. Oxford; Blackwell Publishing.

Buchner, H.H.F. and Schildboeck, U. (2006). Physiotherapy applied to the horse: a review. *Equine Veterinary Journal.* **38** (6) 574 – 580.

Burnley, M. and Jones, A. (2005). Effects of 'warm-up' exercise on energy provision and exercise performance in horses and humans: a comparative review. *Equine and Comparative Exercise Physiology.* **2** (3), 135 - 147.

Chandler, T.J., Kibler, W., Uhl, T.L., Wooten, B. and Kiser. A. (1990). Flexibility comparisons of junior elite tennis players to other athletes. *American Journal of Sports Medicine.* **18,** 134 – 136.

Chateau, H., Degueurce, C. and Denoix, J.M. (2005). Three-dimensional kinematics of the equine distal forelimb: effects of a sharp turn at the walk. *Equine Veterinary Journal.* **37** (1) 12 – 18.

Clayton, H.M. (1990). The effect of an acute hoof wall angulation on the stride kinematics of trotting horses. *Equine Veterinary Journal Supplement.* **9,** 86 – 90.

Clayton, H.M. (1991). Advances in motion analysis. The *Veterinary Clinics of North America. Equine Practice.* **7** (2) 365 – 382.

Clayton, H.M. (1994). Comparison of the stride kinematics of the collected, working , medium and extended trot in horses. *Equine Veterinary Journal.* **26** (3) 230 – 234.

Clayton, H.M. (2001). Performance in Equestrian Sports. **In: Back, W. and Clayton, H. M. – eds.** *Equine Locomotion.* London; W.B Saunders.

Clayton, H.M. (2006). Gait analysis shows off its moves. *British Equine Veterinary Association. Congress Times September 13th*. 8 – 9.

Clayton, H.M., Hodson, E., Lanovaz, J.L. and Colborne, G.R. (2001). The hindlimb in walking horses: 2. Net joint moments and joint powers. *Equine Veterinary Journal.* **33** (1) 44 – 48.

Clayton, H.M., Almedia, P.E., Prades, M., Brown, J., Tessier, C. and Lanovaz, J.L. (2002). Double-Blind Study of the Effect of an Oral Supplement Intended to Support Joint Health in Horses with Tarsal Degenerative Joint Disease. *AAEP Proceedings.* **48,** 314 – 317.

Clayton, H.M. and Schamhardt, H.C. (2001). Measurement Techniques for Gait Analysis. **In: Back, W. and Clayton, H. M. – eds.** *Equine Locomotion.* London; W.B Saunders.

Clayton, H.M., Sha, D., Stick, J.A. and Mullineaux, D.R. (2004). Three-dimensional carpal kinematics of trotting horses. *Equine Veterinary Journal.* **36** (8) 671 – 676.

Colborne, G.R. (2004). Gait analysis; technology looking for a place to happen? *The Veterinary Journal.* **168,** 112 – 113.

Coyle, E.F., Sidossis, L.S., Horowitz, J.F. and Beltz, J.D. (1992). Cycling efficiency is related to the percentage of Type I muscle fibres. *Medical Science in Sports Exercise.* **24** (7) 782 – 788.

De Deyne, P.G. (2001). Applications of Passive Stretch and its Implications for Muscle Fibres. *Physical Therapy.* **18** (2) 819- 827.

De Luca, C.J. (1997). The use of surface electromyography in biomechanics. *Journal of Applied Biomechanics.* **13** (2) 135 – 163.

De Luzio, K.J., Wyss, U.R. and Costigan, P.A. (1993). A procedure to validate three-dimensional motion assessment systems. *Journal of Biomechanics.* **26** (6) 753 – 759.

Denoix, J.M. and Pailloux, J.P. (2004). *Physical therapy and Massage for the Horse, 2nd ed.* London, Manson Publishing.

de Weijer, V.C., Gorniak, G.C. and Shamus, E. (2003). The Effect of Static Stretch and Warm-up Exercise on Hamstring Length Over the course of 24 Hours. *Journal of Orthopaedic & Sports Physical Therapy.* **33** (12) 727 – 733.

Deuel, N.R. and Park, J. (1990). The gait patterns of Olympic dressage horses. *International Journal of Sports Biomechanics.* **6,** 198 – 226.

Doll, H. and Carney, S. (2007). Statistical approaches to uncertainty; P values and confidence intervals unpacked. *Equine Veterinary Journal.* **39** (3) 275 – 276.

Dyson, S. (2000). Lameness and Poor Performance in the Sports Horse: Dressage, Show Jumping and Horse Trails (Eventing). *AAEP Proceedings.* **22,** 308 – 315.

Evans, D.L. (1994). The Cardiovascular System: Anatomy, Physiology and Adaptations to Exercise and Training. **In: Hodgson, D.R. and Rose, R.J.** *The Athletic Horse.* Philadelphia; WB Saunders.

Faulkner, J. A., Brooks, S. V. and Oplteck, J. A. (1993). Injury to Skeletal Muscle Fibres During Contractions: Conditions of Occurrence and Prevention. *Physical Therapy.* **73** (12) 911 – 921.

Forsyth, R.K., Brigden, C.V. and Northrop, A.J. (2006). Double blind investigation of the effects of combined Glucosamine Hydrochloride (GHCL) and Chondroitin Sulphate (CS) on stride characteristics of veteran horses. *Equine Veterinary Journal Supplement. The Seventh International Conference of Equine Exercise Physiology.* **36,** 622 – 625.

Fowles, J.R., Sale, D.G. and MacDougall, J.D. (2000). Reduced strength after passive stretch of the human plantarflexors. *Journal of Applied Physiology.* **89,** 1179 – 1188.

Fredricson, I., Drevemo, S., Dalin, G., Hjertén, G., Björne, K., Rynde, R. and Franzen, G. (1983). Treadmill for equine locomotion analysis. *Equine Veterinary Journal.* **15** (2) 111 – 115.

Gajdosik, R.L., Vander Linden, D.W., McNair, P.J., Williams, A.K. and Riggin, T.J. (2005). Effects of an eight-week stretching program on the passive-elastic properties and function of the calf muscle of older women. *Clinical Biomechanics.* **20,** 973 – 983.

Garnett, B.T., Delahay, R.J. and Roper, T.J. (2005). Ranging behaviour of European badgers *(Meles meles)* in relation to bovine tuberculosis (*Mycobacterium bovis)* infection. *Applied Animal Behaviour Science.* **94,** 331 – 340.

Giovagnoli. G., Plebani, G. and Daubon. J.C. (2004). *Withers height variations after muscle stretching. In Proceedings: Conference on Equine Sports Medicine and Science:* 2004. Oslo, Norway. 172 – 176.

Goodship, A. E. and Birch, H. L. (2001). Exercise Effects on the Skeletal Tissues. **In: Back, W. and Clayton, H. M. – eds.** *Equine Locomotion.* London; W.B Saunders.

Gremion, G. (2005). Is stretching for sports performance still useful? A review of the literature. *Review Medicale Suisse.* **1** (28) 1830 – 1834.

Guissard, N., Duchateau, J. and Hainaut, K. (2001). Mechanism of decreased motoneuron excitation during passive muscle stretching. *Experimental Brain Research.* **137,** 163 – 169.

Hagen, K. and Broom, D.M. (2004). Emotional reactions to learning in cattle. *Applied Animal Behaviour Science.* **85,** 203 – 213.

Halbertsma, J.P., van Bolhuis, A.I. and Goeken, L.N. (1996). Sport stretching: effect on passive muscle stiffness of short hamstrings. *Archives of Physical Medical Rehabilitation.* **77,** 688 – 692.

Harris, P.A. and Harris, R.C. (2005). Ergogenic potential of nutritional strategies and substances in the horse. *Livestock Production Science.* **92,** 147 – 165.

Herbert, R.D. and Gabriel, M. (2002). Effects of stretching before and after exercising in muscle soreness and risk of injury: systematic review. *The British Medical Journal.* **325,** 468 – 472.

Hinchcliff, K.W. (2004). Drug effects on performance. **In: Hinchcliff, K.W., Kaneps, A.J. and Geor, R.J. –** **eds.** *Equine Sports Medicine and Surgery.* London: Saunders.

Holmström, M and Drevemo, S. (1997). Effects of trot quality and collection on the angular velocity in the hindlimbs of riding horses. *Equine Veterinary Journal Supplement.* **23,** 62 – 65.

Holmström, M., Magnusson, L-E. and Philipsson, J. (1990). Variation in comformation of Swedish Warmblood horses and conformational characteristics of elite sport horses. *Equine Veterinary Journal.* **22** (3) 186 – 193.

Holmström, M., Fredricson, I. And Drevemo, S. (1994). Biokinematic differences between riding horses judged as good and poor at the trot. *Equine Veterinary Journal, Supplement.* **17,** 51 – 56.

Holmström, M. (2001). The Effects of Conformation. **In: Back, W. and Clayton, H. M. –** **eds.** *Equine Locomotion.* London; W.B Saunders.

Hough, T. (1902). Ergogenic studies in muscular soreness. *American Journal of Physiology.* **7,** 76 – 92.

Hourdebaigt. J.P. (1997). *Equine Massage. A Practical Guide.* Gloucestershire, Ringpress Books Ltd.

Hunter, J. and Whillans, M.G. (1951). A study of the effect of cold on joint temperature and mobility. *Canadian Journal of Medical Sciences.* **29,** 255 – 262.

Hunter, J., Kerr, E.H. and Whillans, M.G. (1952). The relationship between joint stiffness upon exposure to cold and the characteristics of synovial fluid. *Canadian Journal of Medical Sciences.* **30** (5) 367 – 377.

Jansen, M.O., Raaij, J.A.G.M., van den Bogert, A.J., Schamhardt, H.C. and Hartman, W. (1992). Quantitative analysis of computer-averaged electromyographic profiles of intrinsic limb muscles in ponies at the walk. *American Journal of Veterinary Research.* **53,** 2343 – 2349.

Kasashima, Y., Smith, R.K.W., Birch, H.L., Takahashi, T., Kusano, K. and Goodship, A.E. (2002). Exercise-induced tendon hypertrophy; cross-sectional area changes during growth are influenced by exercise. *Equine Exercise Physiology 6. Equine Veterinary Journal Supplement.* **34,** 264 – 268.

Khumsap, S., Lanovaz, J.L. and Clayton, H.M. (2004). Verification of skin-based markers for 3-dimesional kinematic analysis of the equine tarsal joint. *Equine Veterinary Journal.* **36** (8) 655 – 658.

Klein, P.J. and DeHaven, J.J. (1995). Accuracy of Three-Dimensional Linear and Angular Estimates Obtained With The Ariel Performance Analysis System. *Archives of Physical Medical Rehabilitation.* **76,** 183 – 189.

Kleine, D. (1990). Anxiety and sport performance; A meta-analysis. *Anxiety, Stress and Coping.* **2** (2) 113 – 131.

Kleissen, R.F.M., Buurke, J.H., Harlaar, J. and Zilvold, G. (1998). Electromyography in the biomechanical analysis of human movement and its clinical application. *Gait and Posture.* **8** 143 – 158.

Knudson, D. (1998). Stretching: From Science to Practice. *The Journal of Physical Education, Recreation and Dance.* **69** (3) 38 – 42.

Kubo, K., Kanehisa, H., Kawakami, Y. and Fukunaga, T. (2001). Influence of static stretching on viscoelastic properties of human tendon structures in vivo [Sic]. *Journal of Applied Physiology.* **90,** 520 – 527.

Kubo, K., Kanehisa, H. and Fukunaga, T. (2002a). Effects of resistance and stretching training programmes on viscoelastic properties of human tendon structures *in vivo. Journal of Physiology.* **538.1,** 219 – 226.

Kubo, K., Kanehisa, H. and Fukunaga, T. (2002b). Effect of stretching training on the viscoelastic properties of human tendon structures in vivo [Sic]. *Journal of Applied Physiology.* **92,** 595 – 601.

Lam, K.H., Parkin, T.D.H., Riggs, C.M. and Morgan, K.L. (2007). Descriptive analysis of retirement of Thoroughbred racehorses due to tendon injuries at the Hong Kong Jockey Club (1992-2004). *Equine Veterinary Journal.* **39** (2) 143 – 148.

Lardner, R. (2001). Stretching and flexibility: its importance in rehabilitation. *Journal of Bodywork and Movement Therapies.* **5** (4) 254 – 263.

LaRoche, D.P. and Connolly, D.A.J. (2006). Effects of Stretching on Passive Muscle Tension and Response to Eccentric Exercise. *The American Journal of Sports Medicine.* **34** (6) 1000 – 1007.

Leach, D. (1987). Locomotion of the Athletic Horse. **In**: **Gillespie, J.R. and Robinson, N.E.** – **eds.** *Equine Exercise Physiology.* California: ICEEP Publications.

Leleu, C., Gloria, E., Renault, G. and Barrey, E. (2002). Analysis of trotter gait on the track by accelerometry and image analysis. *Equine Veterinary Journal, Supplement.* **34,** 344 – 348.

Lewczuk, D. and Pfeffer, M. (1998) Investigation into the horses' stride length during endurance race competition using video image analysis. **In:** *Conference on Equine Sports Medicine and Science.* The Netherlands: Wageningen Pers. 249 – 250.

Lewis, G.S., Preedy, D.F. and Colborne, G.R. (2001). Effect of Variations in Morphological Data on Calculated Mechanical Energy Cost in Equine Gait. *The Veterinary Journal.* **164,** 71 – 73.

Little, T. and Williams, A.G. (2006). Effects of Differential Stretching Protocols During Warm-Ups on High-Speed Motor Capacities in Professional Soccer Players. *Journal of Strength and Conditioning Research.* **20** (1) 203 – 207.

Lloyd, E.L. (1994). ABC of Sports Medicine: Temperature and Performance I: Cold. *British Medical Journal.* **309,** 531 – 534.

Lovett, B. (2006). An investigation into the reliability of Quintic Biomechanics Software, when used to measure Transverse Plane Tibial Rotation through the use of a Tibial Pointer. Unpublished undergraduate dissertation. The University of Wales, Cardiff.

Magnusson, S.P. (1998). Passive properties of human skeletal muscle during stretch maneuvers. *Scandinavian Journal of Medicine & Science in Sports.* **8** (2) 65 – 77.

Mattes, A.L. (1996). Active isolated stretching. *Journal of Bodywork and Movement Therapies.* **1** (1), 28 – 33.

Mawdsley, A., Kelly, E.P., Smith, F.H. and Brophy, P.O. (1996). Linear assessment of the Thoroughbred horse: an approach to conformation evaluation. *Equine Veterinary Journal.* **28** (6) 461 – 467.

McGowan, C.M., Stubbs, N.C. and Jull, G.A. (2007). Equine physiotherapy: a comparative review of the science underlying the profession. *Equine Veterinary Journal.* **39** (1) 90 – 94.

McMillian, D.J., Moore, J.H., Hatler, B.S. and Taylor, D.C. (2006). Dynamic vs. Static-Stretching Warm-up: The Effect on Power and Agility and Performance. *Journal of Strength and conditioning Research.* **20** (3) 492 – 499.

Meagher, J. (1985). *Beating Muscle Injuries for Horses, 1st ed.* United States of America, Hamilton Horse Associates.

Meershoek, L.S., Roepstorff, H.C., Schamhardt, H.C., Johnston, C. and Bobbert, M.F. (2001). Joint moments in the distal forelimbs of jumping horses during landing. *Equine Veterinary Journal.* **33** (4) 410 – 415.

Morgan, D.L. (1990). New insights into the behaviour of muscle during active lengthening. *Biophysical Journal.* **57,** 209 – 221.

Morgan, D.L. and Allen, D.G. (1999). Early events in stretch-induced muscle damage. *Journal of Applied Physiology.* **87** (6) 2007 – 2015.

Nam, J.M. (1997). Establishing Equivalence of Two Treatments and Sample Size Requirements in Matched-Pairs Design. (1997). *Biometrics.* **53,** 1422 – 1430.

Patterson-Kane, J.C., Firth, E.X., Goodship, A.E. and Parry, D.A.D. (1997). Age-related differences in collagen crimp patterns of the superficial digital flexor tendon core region of untrained horses. *Australian Veterinary Journal.* **75,** 39 – 44.

Pattillo, D. (2005). *Equine Sports Massage, Foundation Certification Course.* Unpublished course notes. California, Equinology Inc.

Peham, C., Licka, T., Mayr, A., Scheidl, M. and Girtler, D. (1998). Speed dependency of motion pattern consistency. *Journal of Biomechanics.* **31,** 769 – 772.

Peham, C., Licka, T., Mayr, A. and Scheidl, M. (2000). Individual Speed Dependancy of Forelimb Lameness in Trotting Horses. *The Veterinary Journal.* **160,** 135 – 138.

Peham, C., Licka, T., Schobesberger, H. and Meschan, E. (2004). Influence of the rider on the variability of the equine gait. *Human Movement Science.* **23,** 663 – 671.

Persson, S.G.B., Essen-Gustavsson, B. and Lindholm, A. (1991). Energy profile and locomotor pattern if trotting on an inclined treadmill. In: Equine Exercise Physiology, 3rd ed. Davies, CA:ICEEP Publications. 231 – 238.

Power, K., Behm, D., Cahill, F., Carroll, M. and Young, W. (2004). An Acute Bout of Static Stretching: Effects on Force and Jumping Performance. *Medicine & Science In Sports & Exercise.* **36** (8) 1389 – 1396.

Preedy, D.F. and Colborne, G.R. (2001). A method to determine mechanical energy conservation and efficiency in equine gait; a preliminary study. *Equine Veterinary Journal Supplement.* **33,** 94 – 98.

Raglin, J.S. (1992). Anxiety and sports performance. *Exercise Sport Science Review.* **20,** 243 – 274.

Reaburn, P. (2006). Passive stretching before sprinting may impede performance. *Sports Coach.* **28** (3), 36.

Reed, H. (2003). *Stage Two, Riding & Stable Management.* Hampshire, Nova Publications.

Robert, C., Valette, J.P., Pourcelot, P., Audigié. F. and Denoix, J.M. (2002). Effects if trotting speed on muscle activity and kinematics in saddlehorses. *Equine Exercise Physiology 6. Equine Veterinary Journal Supplement.* **34,** 295 – 301.

Roberts, J.M. and Wilson, K. (1999). Effect of stretching duration on active and passive range of motion in the lower extremity. *British Journal of Sports Medicine.* **33,** 259 – 263.

Ronéus, M., Lindholm, A. and Asheim, A. (1991). Muscle characteristics in standardbreds of different ages and sexes. *Equine Veterinary Journal.* **23** (3) 207 – 210.

Ronéus, M., Essen-Gustavsson, B., Johnson, C, et al. (1995). Lactate response to maximal exercise on the track; relation to muscle characteristics and kinematic variables. *Equine Veterinary Journal Supplement.* **26** (18) 191 – 194.

Rose, N.S., Northrop, A.J. and Martin, J. H. (2007). The effect of warm-up and stretching on stride length and range of motion in the horse. *In Proceedings: British Society of Animal Science*: April, 2007, Southport: BSAS.

Rossdale, P.D. and Butterfield, R.M. (2006). Preface: Conformation: a step along the pathway to objective assessment. *Equine Veterinary Journal.* **38** (7) 588 – 590.

Schamhardt, H.C., Bogert, A.J. van den and Hartman, W. (1993). Measurement techniques in animal locomotion analysis. *Acta Anatomica.* **146,** 123 – 129.

Sha, D.H., Mullineaux, D.R. and Clayton, H.M. (2004). Three-dimensional analysis of patterns of skin displacement over the equine radius. *Equine Veterinary Journal.* **36** (8), 665 – 670.

Shannon, K., Butler, A. and Fallano, J. (2005). Procedure: Muscle Flexibility and Stretching. Brigham and Womens Hospital, Department of Rehabilitation Services. . Accessed 2/05/07 via: http://www.brighamandwomens.org/RehabilitationServices/Physical%20Therapy%20Standards%20of%20Care%20and%20Protocols/Stretching%20and%20Flexibility.pdf

Sharma, J., White, C. and Senjyu, H. (2004). A Description of Single Case Design – As an Example to Evaluate the Effect of Warm-up and Stretching on Hamstring Flexibility in a Clinical Setting. *Journal of Physical Therapy Science,* **16,** 21 – 26.

Shellock, F.G. and Prentice, W.E. (1985). Warming-up and stretching for improved physical performance and prevention of sports-related injuries. *Sports Medicine Auckland N.Z.)* **2** (4) 267 – 278.

Shrier, I. (2004). Does Stretching Improve Performance? A Systematic and Critical Review of the Literature. *Clinical Journal of Sports Medicine.* **14** (5) 267 – 273.

Simpson, A.H., Williams, P.E. and Kyberd, P. et al. (1995). The response of muscle to leg lengthening. *Journal of Bone Joint Surgery.* **77,** 630 – 636.

Steffen, T.M. and Mollinger, L.A. (1995). Low-load, prolonged stretch in the treatment of knee-flexion contractures in nursing home residents. *Physiacl Therapy.* **75,** 886 – 897.

Stergiou, N. and Scott, M.M. (2005). Baseline measures are altered in biomechanical studies. *Journal of Biomechanics.* **38,** 175 – 178.

Thacker, S.B., Gilchrist, J., Stroup, D.F. and Dexter Kimsey Jr, C. (2004). The Impact of Stretching on Sports Injury Risk: A Systematic Review of the Literature. *Medicine & Science in Sports & Exercise.* **36** (3) 371 – 378.

Tokuriki, M. and Aoki, O. (1995). Electromyographic activity of the hindlimb muscles during the walk, trot and canter. *Equine Veterinary Journal Supplement.* **18,** 152 – 155.

Van Weeren, P.R. and Crevier-Denoix, N. (2006). Science Overview: Equine conformation: clues to performance and soundness? *Equine Veterinary Journal.* **38** (7) 591 – 596.

Van Weeren, P.R., van den Dogert, A.J. and Barneveld, A. (1990a). Quantification of skin displacement in the proximal parts of the limbs of the walking horse. *Equine Veterinary Journal, Supplement.* **9**, 110 – 118.

Van Weeren, P.R., van den Dogert, A.J. and Barneveld, A. (1990b). A quantitative analysis of sin displacement in the trotting horse. *Equine Veterinary Journal, Supplement.* **9**, 101 – 109.

Weldon, S.M. and Hill, R.H. (2003). The efficacy of stretching for prevention of exercise-related injury: a systematic review of the literature. *Manual Therapy.* **8** (3) 141 – 150.

Wheater, P.C. and Cook, P.A. (2005). *Using Statistics to Understand the Environment.* Oxon, Routledge.

Williams, R.B., Harkins, L.S., Hammond, C.J. and Wood, J.L.N. (2001). Racehorse injuries, clinical problems and fatalities recorded on British racecourses from flat racing and National Hunt racing during 1996, 1997 and 1998. *Equine Veterinary Journal.* **33** (5) 478 – 486.

Witvrouw, E., Mahieu, N., Danneels, L. and McNair P. (2004). Stretching and Injury Prevention. An Obscure Relationship. *Sports Medicine.* **34** (7) 443 – 449.

Zakas, A. (2005). The effect of stretching duration on the lower –extremity flexibility of adolescent soccer players. *Journal of Bodywork and Movement Therapies,* **9,** 220 – 225.

Zakas, A., Doganis, G., Papakonstandinou, V., Sentelidis, T. and Vamvakoudis, E. (2006). Acute effects of static stretching duration on isokinetic peak torque production of soccer players. *Journal of Bodywork and Movement Therapies.* **10,** 89 – 95.

Zebarth, B. J. and Sheard, R.W. (1985). Impact and shear resistance of turf grass racing surfaces for Thoroughbreds. *American Journal of Veterinary Research.* **46** (4) 778 – 784.

Appendices

RISK ASSESSMENT TITLE The effect of stretching regimes on equine performance	PROGRAMME AREA Equine	ASSESSMENT UNDERTAKEN Signed: Date:	ASSESSMENT REVIEW Date:

STEP ONE	STEP TWO	STEP THREE
Being kicked, bitten or trodden on when stretching the horse.	The researcher is at risk from this.	The researcher is qualified in equine stretching (Equine Body Worker level 1) and is trained up to BHS stage 2 (riding and stable management). The researcher will be wearing protective clothing.
Being kicked, bitten or trodden on when leading the horse to/from the horse walker and in front of the video camera (which will be on a tripod).	The researcher and co-worker are at risk	Both the researcher and co-worker have experience with horses and are aware of equine behaviour and body language. Both researcher and co-worker will be wearing a hard hat to current safety standards, gloves and protective footwear and clothing.
The horse could become strong when being led in front of the video camera.	The researcher and co-worker are at risk.	The horse will be led in an enclosed arena. The horse will be wearing a bridle so the researcher and co-worker will have more control over the horse.
The horse may be frightened by the video camera and jump, possibly injuring the researcher or co-worker.	The researcher and co-worker are at risk.	The camera will be set up on a tripod before the horse enters the arena. The horse will be led past the camera quietly and reassuringly to habituate the horse to the presence of the camera.
Being kicked when placing the anatomical markers onto the horse. The horse may be sensitive.	The researcher and co-worker are at risk.	The horse will be desensitised by stroking and reassurance. The anatomical markers will first be placed in a low risk area, e.g. the neck rather then the leg to see how the horse responds. Great care will be taken when applying the markers making sure the researcher is aware of her body position in relation to the horse. The researcher and co-worker have undergone Myerscough College yard safety training.

REFERENCE NO.

FACULTY OF SCIENCE

APPLICATION TO ANIMAL PROJECTS COMMITTEE FOR APPROVAL OF RESEARCH PROJECT

This form should be completed for all <u>**NEW**</u> applications for University research support and submitted to the Chair of the Animal Projects Committee.

Does project require a Home Office Licence? **NO** Project Licence no:_________

Is there a licence holder? YES/NO Who holds it___**N.A**_______ Personal Licence no: _________

Date: **08.05.07**

Title of Project:

The effect of stretching regimes on equine movement

Name of researcher and co-workers:

Natasha Rose - Researcher	**Charlotte Brigden - Supervisor**
Katherine Fidler – Co-worker	**Alison Northrop - Supervisor**
Rose Thornton – Co-worker	

1. Aims and objectives of project: (Layperson's terms)

The study aims to quantify the effects of two differing 8 week stretching regimes on SL and ROM on a group of riding school horses at Myerscough College.

Research Objectives:

- **To obtain baseline measurements of each subject's stride length (SL) and range of motion (ROM).**
- **To obtain measurements of SL and ROM every two weeks during the study.**
- **To obtain ambient temperature recordings on the days the study is carried out and when SL and ROM ate being measured.**
- **To compare the measured parameters pre, during and post stretching regimes.**
- **To provide beneficial information where there is a current lack of research.**

2. In layperson's terms explain precisely what will happen to them (e.g. killed for Langendorf; tissues collected from abattoir and analysed for zymogen etc):

Primarily all subjects (n=18) will be assessed for static and dynamic conformation. The subjects will have anatomical markers attached to specific points of the body to outline the shoulder, knee, fetlock, hip, stifle and hock joints and will be filmed trotting past the camera four times to gain a true average. The data gained at this point will be used as baseline data for individual stride length (SL) and range of motion (ROM).

Subjects will be divided equally into three groups (A,B and C) and will be matched as closely as possible in terms of breed, age and conformation. Group A will be stretched daily for six days over a week eight week period. Group B will be stretched daily for three days over an eight week period. Group C will not be stretched at all for eight weeks and will act as a control group; however the subjects in group C will have the same time spent with them as human contact, daily for six days for the eight week period. Human contact will consist of being in the stable with the horse, picking up the legs, cleaning out the hooves, stroking and/or brushing the horse. The stretching regimes for groups A and B will be exactly the same in terms of hold time, repetition and type. Prior to carrying out the stretches or human contact, each subject will go through a ten minute warm-up on the horse walker.

The person applying the stretches will be a qualified Equine Body Worker (level 1), and fully insured under Myerscough College's insurance.
Relaxation technique will be applied to all four legs prior to the stretches being applied, this entails picking up the leg and circling with slow relaxed movements.
The stretches to be carried out on the forelimb are; modified girth stretch, full girth stretch, leg flexor lift, modified half pass, full half pass, and triceps release.
The stretches to be carried out on the hindlimb are; hamstring stretch, farrier stretch, modified farrier stretch, stifle and hip flexor stretch, thigh adductor stretch and lateral quad stretch.
Each stretch will be applied twice, held initially for ten seconds (to familiarise the horse to the sensation) then the second stretch for 20 seconds.

A pilot study prior to the beginning of the eight week regimes will be carried out on a separate small group of subjects (n=2) to determine whether the hold times, repetitions and type of stretches are deemed practical and useful.

During the eight week regime, each subjects SL and ROM will be assessed at week two, four, six and eight and subsequently one, two and three weeks post stretch regime. Upon analysis of the one week post regime, it may be decided to take further measurements of SL and ROM. These further measurements could be filming the horses being ridden in extended trot at week 8 of the study, and then repeating 8 weeks later to see if the stride length has changed.
Measuring SL and ROM will be the same procedure as taking the dynamic baseline measurements; each subject will have anatomical markers attached to the body to highlight the shoulder, knee, fetlock, hip, stifle and hock joints and will be led in trot past a digital camera six times in the indoor arena. All subjects will be familiarised to the procedure of attaching anatomical markers, the same person will attach the makers each time to increase reliability. Video clips of each subject from the digital video camera will be downloaded onto a laptop/computer and SL and ROM will be analysed using Equinalysis. Baseline SL and ROM will be compared to during and post stretch regime SL and ROM for statistical differences.

3a. How many, and which species of animals are intended to be used in the first year?

Three horses are intended for use for the small stretching pilot study.
It is intended to use 18 horses that are owned by Myerscough College for the motion analysis validation study and the eight week stretching regimes, the horses will be as similar as possible in terms of age, breed and conformation.

3b. Where more than one species is used, how many of each are to be used

N.A

4. What is the balance between the cost to the animals involved and the likely benefits to be gained by the research?

There is minimal cost to the horses; the researcher employing the stretches has been through training by Equinenergy ™ to ensure the stretches are carried out correctly. The positions the horse will be put in are likely positions the horse will have experienced before, e.g. when the farrier lifts a leg to shoe the horse etc. The warm up procedure only requires the horse walking around the covered horse walker for ten minutes, all horses are familiar with this type of exercise and all horses are fit enough to perform this, so not to put the horse under any unnecessary physical stress.
Horses will be removed from the trial if they show any signs of stress or become lame.

There is very limited research in horses regarding stretching effects on the stride length and range of motion, therefore the likely benefits are that a more effective

and training programme can be derived from the data gained from this study. If stretching increases stride length and range of motion, this could influence owners and trainers to incorporate stretching into the horse's daily routine type as an increase in stride length and range of motion would be highly valuable to all disciplines. It has been found in humans that an increase in range of motion directly increases flexibility which in turn aids correct posture, reduces injury risk and helps muscular relaxation (Lardner 2001) therefore potentially benefiting the horse.

5. Are there ways in which the procedures could be refined to reduce the cost to animals without affecting the scientific validity of the project?

Prior to the eight week regimes commencing, a pilot study will be performed with a small group of horses to asses whether the hold times, number of repetitions and type of stretches are deemed practical and useful.

6. Indicate what scope exists for reduction in the number of animals used and refinement in technique as the project progresses.

There is no real scope to reduce the number of horses used. The person performing the stretches is fully trained and qualified so they will be applied correctly, thus should not be any cost to the horse. The more horses used the more valid the data gained will become. Refinement in technique could be related to the placing of the markers for analysis of stride length and range of motion. It would be beneficial if the person analysing the SL and ROM was blind to which horse had been in which group to increase the reliability of the results and avoid bias.

7. State any additional reasons that support this proposed use of animals to obtain the specific objectives. Is the number of animals you propose to use appropriate? – i.e. large enough to produce a satisfactory valid result and not greater, in accordance with the principles of Reduction, Refinement and Replacement.

An additional reason to support the proposed use of the horses is that if the and a daily stretching regime does increase range of motion and stride length, from a welfare perspective this will make the horse more comfortable, by increasing flexibility, reducing the chance of injury, improving posture and aiding in muscular relaxation and from a performance perspective, potentially raise the level of performance and competition.

There is minimal cost to the horses used in the investigation and number of horses used is large enough to obtain valid results, there is no room for reduction, if more

horses were available, the greater number of horses used would further increase the validity of the results.

To refine the investigation, it would be beneficial if a different person, blind to the treatment groups would analyse the SL and ROM

Table 26. Horse profiles. Colours of names indicate the matched groups.

Treatment	Horse	Height (hh)	Age	Breed	Sex	Comments
A	Annie	15.3	13	WB x	M	Sound, lame for 2nd extended trot- curb, filming was not repeated
A	Dudley	15.1	7	Cob	G	Sound
A	Jake 2	14.3	6	Welsh x	G	Mild case of azoturia 27/2/07, recovered in 5 days, now sound
A	Toddy	16.1	17	IDxTB	G	Sound
A	Sky	16.1	7	Appaloosa	M	Sound
A	Joe	16	6	CobxTB	G	Sound
B	Blue	16	11	3/4 TB x shire	M	Melanoma on bum, can get dry skin on belly
B	Buddy	15.1	10	TB	G	Off side hamstring pulled over year ago, physio, no further problems
B	Champ	14.2	16	Cob	G	Sound
B	Jack cob	14.2	8	Welsh cob S.D	G	Sound
B	Fergus	16.1	17	IDxTB	G	Sound
B	Georgina	15.1	14	IDxTB	M	Lymphangitis 12/2/07, sound after 2 weeks
C	Colourful	15	15	Cob x TB	M	Sound
C	Curly	15	10	Welsh S.D	G	Sound
C	Tiny	18.1	9	TB x Clydesdale	G	Sound
C	Reefer	17	16	Sports horse	G	Lame in week 1, no baseline data. Lame extended trot wk 2-lymphangitis, filmed again 15/6/07. Now sound
C	Snowflake	15.2	13	Appaloosa	M	Abdominal surgery in the past. Now sound
C	Bootz	15.1	10	Welsh x	G	Sound
Mean		15.2	11.3			

Table 27. Group A (6DSR) horse conformation. Two scores were recorded by two different researchers and an average was calculated.

Traits	6DSR	Annie		6DSR	Joe		6DSR	Toddy		6DSR	Jake 2		6DSR	Sky		6DSR	Dudley	
	Score 1	Score 2	Average	Score 1	Score 2	Average	Score 1	Score 2	Average	Score 1	Score 2	Average	Score 1	Score 2	Average	Score 1	Score 2	Average
2. Head shape	4	3	3.5	6	5	5.5	5	5	5	3	3	3	4	3	3.5	6	6	6
5. Neck shape	5	5	5	5	5	5	5	5	5	4	5	4.5	4	4	4	5	5	5
7. Croup shape	3	4	3.5	5	6	5.5	4	4	4	5	6	5.5	5	4	4.5	6	5	5.5
9. Withers	3	4	3.5	4	4	4	5	4	4.5	3	3	3	4	5	4.5	3	3	3
10. Back shape	4	4	4	3	4	3.5	3	3	3	1	3	2	4	4	4	3	3	3
12. FL shoulder to ground	3	4	3.5	3	3	3	4	3	3.5	4	3	3.5	4	4	4	3	4	3.5
13. FL knees 1	4	4	4	4	4	4	4	4	4	4	4	4	3	4	3.5	4	4	4
13a. FL knees 2	4	4	4	4	4	4	4	4	4	4	4	4	3	4	3.5	4	4	4
14. FL hoof pastern axis	5	3	4	4	4	4	3	3	3	4	5	4.5	4	4	4	5	4	4.5
15. FL foot slope	4	5	4.5	4	4	4	5	5	5	4	3	3.5	4	3	3.5	2	3	2.5
16. FL upstandingness	4	3	3.5	4	5	4.5	3	4	3.5	5	4	4.5	5	4	4.5	4	5	4.5
17. FL cannon angle	4	4	4	4	5	4.5	4	4	4	4	4	4	4	4	4	5	5	5
18. FL knees	4	4	4	3	5	4	3	4	3.5	3	4	3.5	4	4	4	4	3	3.5
19. FL pastern angle	3	5	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3
20. HL hip to ground	4	4	4	4	3	3.5	4	3	3.5	4	3	3.5	4	4	4	4	4	4
21. HL hock set	5	5	5	4	3	3.5	3	3	3	3	4	3.5	4	5	4.5	3	3	3
22. HL hoof pastern axis	5	5	5	6	6	6	4	4	4	5	5	5	5	4	4.5	5	5	5
23. HL foot slope	3	3	3	3	2	2.5	4	4	4	2	4	3	4	3	3.5	2	3	2.5
24. HL upstandingness	5	4	4.5	4	4	4	5	4	4.5	6	4	5	5	5	5	4	4	4
25. HL hock set 2	5	5	5	5	5	5	5	4	4.5	5	5	5	5	5	5	5	5	5
26. HL pastern angle	2	3	2.5	3	3	3	3	4	3.5	4	3	3.5	3	3	3	3	3	3

Table 28. Group B (3DSR) horse conformation. Two scores were recorded by two different researchers and an average was calculated.

Traits	3DSR Fergus			3DSR Blue			3DSR Champ			3DSR Georgina			3DSR Buddy			3DSR Jackcob		
	Score 1	Score 2	Average	Score 1	Score 2	Average	Score 1	Score 2	Average	Score 1	Score 2	Average	Score 1	Score 2	Average	Score 1	Score 2	Average
2. Head shape	5	4	4.5	4	4	4	5	6	5.5	5	4	4.5	2	2	2	3	4	3.5
5. Neck shape	6	4	5	4	4	4	5	5	5	5	5	5	4	3	3.5	5	5	5
7. Croup shape	3	5	4	3	4	3.5	4	4	4	2	2	2	3	3	3	4	4	4
9. Withers	6	5	5.5	3	4	3.5	4	3	3.5	3	3	3	4	4	4	2	3	2.5
10. Back shape	4	3	3.5	3	3	3	3	3	3	2	3	2.5	4	4	4	4	5	4.5
12. FL shoulder to ground	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	5	3	4
13. FL knees 1	4	4	4	4	4	4	4	4	4	3	4	3.5	3	4	3.5	5	4	4.5
13a. FL knees 2	3	4	3.5	4	4	4	4	4	4	4	4	4	4	3	3.5	5	3	4
14. FL hoof pastern axis	4	4	4	3	3	3	4	4	4	4	3	3.5	4	4	4	7	7	7
15. FL foot slope	4	4	4	4	5	4.5	4	4	4	4	5	4.5	4	5	4.5	2	1	1.5
16. FL upstandingness	3	4	3.5	5	4	4.5	4	4	4	4	4	4	4	3	3.5	5	5	5
17. FL cannon angle	4	4	4	4	4	4	3	4	3.5	4	4	4	4	5	4.5	4	4	4
18. FL knees	4	4	4	4	3	3.5	3	3	3	3	4	3.5	3	4	3.5	3	4	3.4
19. FL pastern angle	4	4	4	4	4	4	5	5	5	4	4	4	3	3	3	4	4	4
20. HL hip to ground	3	4	3.5	4	4	4	4	4	4	4	3	3.5	4	4	4	5	4	4.5
21. HL hock set	5	4	4.5	5	4	4.5	5	5	5	4	3	3.5	4	4	4	4	5	4.5
22. HL hoof pastern axis	5	4	4.5	6	4	5	4	4	4	5	6	5.5	5	4	4.5	6	7	6.5
23. HL foot slope	3	4	3.5	2	4	3	3	3	3	3	2	2.5	3	3	3	1	1	1
24. HL upstandingness	6	5	5.5	3	4	3.5	4	4	4	5	5	5	6	5	5.5	4	4	4
25. HL hock set 2	5	5	5	4	5	4.5	4	4	4	3	5	4	5	5	5	5	5	5
26. HL pastern angle	3	3	3	4	3	3.5	4	4	4	3	3	3	3	4	3.5	3	3	3

Table 29. Group C (NSR) horse conformation. Two scores were recorded by two different researchers and an average was calculated.

Traits	NSR Curley			NSR Reefer			NSR Snowflake			NSR Bootz			NSR Colourful			NSR Tiny		
	Score 1	Score 2	Average	Score 1	Score 2	Average	Score 1	Score 2	Average	Score 1	Score 2	Average	Score 1	Score 2	Average	Score 1	Score 2	Average
2. Head shape	3	3	3	5	5	5	3	3	3	3	3	3	5	4	4.5	6	6	6
5. Neck shape	6	6	6	3	3	3	4	5	4.5	5	6	5.5	5	5	5	6	6	6
7. Croup shape	3	4	3.5	3	2	2.5	4	4	4	2	4	3	2	3	2.5	4	4	4
9. Withers	2	3	2.5	5	5	5	3	3	3	3	3	3	5	3	4	4	5	4.5
10. Back shape	2	4	3	3	3	3	3	4	3.5	3	4	3.5	3	4	3.5	4	3	3.5
12. FL shoulder to ground	4	3	3.5	4	3	3.5	3	3	3	4	4	4	5	3	4	3	4	3.5
13. FL knees 1	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3.5	3	4	3.5
13a. FL knees 2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
14. FL hoof pastern axis	6	4	5	3	5	4	5	3	4	7	7	7	4	4	4	4	4	4
15. FL foot slope	2	3	2.5	5	6	5.5	6	5	5.5	1	1	1	4	4	4	4	4	4
16. FL upstandingness	4	4	4	3	3	3	3	3	3	4	4	4	3	3	3	4	3	3.5
17. FL cannon angle	4	4	4	4	5	4.5	5	4	4.5	4	4	4	4	5	4.5	4	4	4
18. FL knees	4	4	4	3	3	3	6	3	4.5	3	4	3.5	3	4	3.5	4	4	4
19. FL pastern angle	4	4	4	4	3	3.5	5	4	4.5	4	4	4	4	3	3.5	4	4	4
20. HL hip to ground	4	3	3.5	3	3	3	3	4	3.5	5	3	4	4	4	4	5	4	4.5
21. HL hock set	3	4	3.5	4	5	4.5	3	4	3.5	4	3	3.5	4	3	3.5	4	3	3.5
22. HL hoof pastern axis	6	4	5	5	5	5	3	4	3.5	5	6	5.5	5	4	4.5	4	5	4.5
23. HL foot slope	1	2	1.5	4	4	4	4	4	4	3	2	2.5	5	4	4.5	4	4	4
24. HL upstandingness	4	5	4.5	5	5	5	5	5	5	3	3	3	5	3	4	6	5	5.5
25. HL hock set 2	4	5	4.5	5	5	5	5	4	4.5	5	5	5	6	5	5.5	3	5	4
26. HL pastern angle	4	3	3.5	3	3	3	3	4	3.5	3	3	3	3	3	3	4	3	3.5

Equine Body Worker Stretching Regime Horse Reports

Week 0- 2.

Group A (6 day per week stretching):

Toddy – week 1 and 2 noticeably stiff in the hindlegs, often looks lame when first walks out of the stable, this is normal, but very stiff.

Joe – seeks attention and often plays with clothing and hair! Is easily distracted when trying to stretch legs, good ROM, relaxes well into stretches.

Dudley – very difficult to stretch, needs to be held in a bridle when stretching. Snatches legs back and has tried kicking! Average ROM in the limbs.

Jake 2 – week one he snatched legs back and did not relax into the stretches. Week 2- showed small improvement, he has good ROM in all limbs, especially the hindlimbs.

Sky – very supple and took to the stretches well, relaxes well although sometimes pull back hindlimb suddenly.

Annie – week 1 she took well to the stretches, good ROM in fore and hindlimbs. The ROM is there, she just needs to relax more in the hindlimbs.

Group B (3 day per week stretching):

Fergus – Average ROM in fore and hindlimbs. He often rests his weight on his forehand when holding a leg

Champ- good ROM in all limbs, beginning to relax more in the stretches.

Georgina – week 1, she was reluctant to stretch and did not relax, week 2 she developed lymphangitis and had one week off.

Blue – Good ROM, cooperates well with the stretches, not much improvement seen over 2 weeks.

Jack cob – Good ROM in all four limbs, a definite improvement over 2 weeks, hindlimbs can easily touch the back of the forelimbs and stretch out fully.

Buddy – Very good ROM in all four limbs relaxes well into stretches and often stretches himself when I pick up the leg.

Group C (control horses no stretching) all being groomed 6 days a week for 5-10 minutes.

Reefer - no problems, enjoys the attention.

Curly – no problems, enjoys the attention.

Tiny – loves the attention, very gentle giant!

Bootz – can be grumpy when rugging up and grooming, scowls and can nip sometimes.

Colourful – no problems, enjoys the attention, can scowl when rugging up.

Snowflake – can be grumpy when grooming and rugging up, often hard to catch in stable and can nip sometimes.

Week 2-4.

Group A (6 day per week stretching):

Toddy – Stiffness is progressively improving in week 3 and 4. ROM in the forelegs and especially the hindlegs is definitely increasing.

Joe – Good ROM, although not increasing over the weeks, seems to stay the same.

Dudley – Still very difficult to stretch, considering taking him out of the study as he has snatched legs back and has tried kicking! Average ROM in the limbs, no real signs of increasing ROM over the 4 weeks.

Jake 2 –Week 2-4 has had much improvement, excellent ROM in all limbs, especially the hindlimbs, the hind foot can touch the back of the forelimb with ease.

Sky –Forelimbs have excellent ROM, which has noticeably improved over the 4 weeks.

Annie – Week 3-4 she has been snatching her back legs back suddenly and has kicked out a few times. The ROM is there, she just needs to relax more in the hindlimbs.

Group B (3 day per week stretching):

Fergus – Average ROM in fore and hindlimbs, small improvement over the 4 weeks, often reluctant to pick up his legs.

Champ- good ROM in all limbs, beginning to relax more in the stretches small improvement in ROM over the 4 weeks.

Georgina – Week 3 she was back into the stretching regime with lots of walks throughout the day, her right hind leg is still swollen, no lameness has occurred and she is beginning to relax more into the stretches. Average ROM.

Blue – Good ROM, a small improvement in hind leg ROM has been noted in week 4.

Jack cob – Excellent ROM in all four limbs, a definite improvement over the 4 weeks, hindlimbs can easily touch the back of the forelimbs and stretch out fully.

Buddy – Excellent ROM in all four limbs relaxes well into stretches and often stretches himself when I pick up the leg. Falls asleep a lot while being stretched, seems to enjoy it.

Group C (control horses no stretching) all being groomed 6 days a week for 5-10 minutes.

Reefer - not a problem, enjoys the attention.

Curly – not a problem, enjoys the attention.

Tiny – loves the attention, very gentle giant!

Bootz – can be grumpy when rugging up and grooming, scowls and can nip sometimes.

Colourful – not a problem, enjoys the attention, can scowl when rugging up.

Snowflake – can be grumpy when grooming and rugging up, often hard to catch in stable and can nip sometimes.

Week 4-6.

Group A (6 day per week stretching):

Toddy – He had a dip in stiffness at the end of week 5 -6 (cold weather possibly) ROM in the forelegs and hindlegs has definitely improved and I think possibly reached a plateau. He has been snatching hindlegs, but has had a skin condition with scabs.

Joe – seeks attention still. Is easily distracted when trying to stretch legs, good ROM, although not increasing over the weeks, seems to stay the same. Week 6 has been snatching hindlegs a little.

Dudley – Dropped out of the study, considered dangerous to stretch on a daily basis!

Jake 2 –excellent ROM in all limbs, especially the hindlimbs, the hind foot can touch the back of the forelimb with ease, has had a definite increase in ROM over the 6 weeks.

Sky – Week 6, she no longer pulls back her hindlegs.

Annie – Week 5-6 she is relaxing more, but occasionally pulls her hindlimbs back still.

Group B (3 day per week stretching):

Fergus – Average ROM in fore and hindlimbs, small improvement over the 4 weeks, often reluctant to pick up his legs. Week 5-6 the same as previous

Champ- good ROM in all limbs, beginning to relax more in the stretches. Definite small improvement in ROM at week6.

Georgina – Reluctant to stretch the swollen leg, but perseverance often encourages her to relax, possibly nervous about treatment? The Vet reassured me that the stretching would aid her recovery. All other limbs have good ROM

Blue – Good ROM, a small improvement in hind leg ROM has been noted in week 4. Much the same in week 6.

Jack cob – Excellent ROM in all four limbs, a definite improvement over the 4 weeks, hindlimbs can easily touch the back of the forelimbs and stretch out fully. Same in week 6

Buddy – Excellent ROM in all four limbs relaxes well into stretches and often stretches himself when I pick up the leg. Falls asleep a lot while being stretched, seems to enjoy it. Maximum ROM has been gained, I think it is at a plateau.

Group C (control horses no stretching) all being groomed 6 days a week for 5-10 minutes.

Reefer - not a problem, enjoys the attention.

Curly – not a problem, enjoys the attention.

Tiny – loves the attention, very gentle giant! – had a wobble at filming week 6. (adam jumping)

Bootz – can be grumpy when rugging up and grooming, scowls and can nip sometimes.

Colourful – not a problem, enjoys the attention, can scowl when rugging up.

Snowflake – gone.

End Report – week 8.

Group A (6 day per week stretching):

Toddy – His stiffness has definitely improved over the 8 weeks of stretching. His fore and hind leg point of resistance (when lifting legs from the ground) has increased quite dramatically

Joe – seeks attention still. Is easily distracted when trying to stretch legs, good ROM, although not increasing over the weeks, seems to stay the same. Week 6 has been snatching hindlegs a little.

Dudley –dropped

Jake 2 –excellent ROM in all limbs, especially the hindlimbs, the hind foot can touch the back of the forelimb with ease, has had a definite increase in ROM over the 6 weeks.

Sky – very supple and took to the stretches well, relaxes well although sometimes pull back hindlimb suddenly. Forelimbs have excellent ROM, which has noticeably improved. Week 6, she no longer pulls back her hindlegs.

Annie –Week 3-4 she has been snatching her back legs back suddenly and has kicked out a few times. The ROM is there, she just needs to relax more in the hindlimbs. Week 5-6 she is relaxing more, but occasionally pulls her hindlimbs back still.

Group B (3 day per week stretching):

Fergus – Average ROM in fore and hindlimbs, small improvement over the 4 weeks, often reluctant to pick up his legs. Week 5-6 the same as previous

Champp- good ROM in all limbs, beginning to relax more in the stretches. Definite small improvement in ROM at week6.

Georgina – her hind leg is still slightly swollen, much better then week3-4. reluctant to stretch the swollen leg, but perseverance often encourages her to relax, possibly nervous about treatment? All other limbs have good ROM

Blue – Good ROM, a small improvement in hind leg ROM has been noted in week 4. Much the same in week 6.

Jack cob – Excellent ROM in all four limbs, a definite improvement over the 4 weeks, hindlimbs can easily touch the back of the forelimbs and stretch out fully. Same in week 6

Buddy – Excellent ROM in all four limbs relaxes well into stretches and often stretches himself when I pick up the leg. Falls asleep a lot while being stretched, seems to enjoy it. Maximum ROM has been gained, I think it is at a plateau.

Group C (control horses no stretching) all being groomed 6 days a week for 5-10 minutes.

Reefer - not a problem, enjoys the attention.

Curly – not a problem, enjoys the attention.

Tiny – loves the attention, very gentle giant! – had a wobble at filming week 6. (adam jumping)

Bootz – can be grumpy when rugging up and grooming, scowls and can nip sometimes.

Colourful – not a problem, enjoys the attention, can scowl when rugging up.

Snowflake – gone.