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The effect of dynamic mobilisation exercises on the equine multifidus muscle and thoracic profile

Gillian Tabor

THE EFFECT OF DYNAMIC MOBILISATION EXERCISES ON THE EQUINE MULTIFIDUS MUSCLE AND THORACIC PROFILE

By

GILLIAN TABOR

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ABSTRACT

THE EFFECT OF DYNAMIC MOBILISATION EXERCISES ON THE EQUINE MULTIFIDUS MUSCLE AND THORACIC PROFILE

GILLIAN TABOR

Introduction: A relationship between spinal musculature and back pathology has been established in human and equine studies. Exercises to increase Multifidus cross sectional area (CSA) have been shown to reduce the amount and reoccurrence of back pain in humans. Similarly dynamic mobilisation exercises (DME) have led to an increase Multifidus CSA in horses on box rest. The effect of DME on the Multifidus muscle of thoroughbred racehorses in training was investigated and two measurement methods, that can be used to evaluate the outcome of a treatment or exercise programme on Multifidus, were compared.

Methods: Ultrasound imaging was used to measure the CSA of the left and right Multifidus muscle at T16 spinal level on 12 Thoroughbred and the transverse external profile at T16 was recorded with a flexible curve ruler (FCR). Both measurements were repeated 3 times and the horses were randomly allocated to a control group or an experimental group which underwent DME. All horses followed the same training regime as determined by their trainer. In a different six horses the thoracolumbar posture was measured using two techniques (area and angle) and repeatability of these methods tested.

Results: DME led to a significant increase in Multifidus CSA, whilst no significant change was observed in the control group. There is no relationship between the Multifidus CSA measured by ultrasound imaging and the external profile measured with FCR, at T16. There was no significant difference in the repeated measures of either the area or angle method of measuring the thoracolumbar posture

Conclusions: DME resulted in an increase in Multifidus CSA in racehorses that were undergoing a normal training programme. Although the FCR is not a reliable measurement tool when assessing change in Multifidus, measuring posture of the thoracolumbar spine could be used to evaluate treatment effects. Further research is required to determine whether exercises to increase the CSA of Multifidus benefit horses with back pain. Effective treatment of equine back pain will improve welfare and performance.

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ABBREVIATIONS

C	Cervical
CSA	Cross Sectional Area
DME	Dynamic Mobilisation Exercises
DSP	Dorsal Spinous Process
EMG	Electromyography
FCR	Flexible Curve Ruler
ISLD	Interspinous Ligament Desmotomy
IV	Intervertebral
LD	Longissimus Dorsi
P	Photograph
PTA	Pessoa Training Aid^{TM}
OA	Osteoarthritic
ROM	Range of Movement
T	Thoracic
TrA	Transversus Abdominus
US	Ultrasound

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AUTHOR'S DECLARATION

At no time during the registration for the research degree has the author been registered by any other university award without prior agreement of the Graduate Committee

Work submitted for this research degree at the Plymouth University has not formed part of any other degree either at Plymouth University or at another establishment

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Chapter 1

Introduction and Literature Review

In humans back pain is reported to have a prevalence of 28.5% (Macfarlane *et al.,* 2011), consequently many days of work are lost with major economic significance to both employees and employers. Back pain, which may result from musculoskeletal injury in horses, can also have economic repercussions. For instance, in the racing industry, injury rates of up to 25% have been reported for horses in training (Ramzan and Palmer, 2011). Similarly Murray *et al.* (2010) reported that 40% of 11363 dressage horse owners, surveyed in the UK, responded that their horse had experienced a back problem at some time during their ridden career. If the occurrence of back pain in horses can be reduced, for instance through the use of physiotherapy, there will be a positive impact on the welfare of the horse in addition to economic benefits to the rider and the owner.

In a review of physiotherapy research, McGowan *et al.* (2007) concluded that although less research into equine physiotherapy has been conducted compared to that into human physiotherapy, an important step has been to go back to fundamental science. To do this requires not only investigation of the causes, but also the ability to objectively record the clinical findings from the assessment and the symptoms of back pain in horses. This chapter will critically examine the literature for relationship between spinal stability, human and equine back pain.

1.1 Spinal Stability

Panjabi (1992a) proposed that clinical low back pain in humans is related to abnormality in intervertebral movement which may produce a pain sensation. Panjabi (1992a) puts forward the concept that spinal stability consists of three functionally interdependent sub-systems which are the passive musculoskeletal, active musculoskeletal and neural control sub-systems (Figure 1). The passive subsystem includes vertebrae, facet articulations, intervertebral discs, spinal ligaments and joint capsules, as well as the passive mechanical properties of the muscles. The active subsystem consists of the muscles and tendons surrounding the spinal column. The neural control subsystem consists of the various force and motion transducers, located in the ligaments, tendons and muscles and the neural control centres (Panjabi, 1992a). The function of these subsystems is to provide sufficient stability of the spine when changes in position occur, and when subject to static and dynamic loads. However, deterioration of the spinal system may occur due to injury, degeneration and/or disease. Clinical instability due to alteration in one or more of these subsystems (Figure 1) can result in chronic dysfunction and pain (Panjabi 1992b; Hodges, 2003) and furthermore long term clinical instability could predispose to re-injury (Stokes *et al.*, 1997).

In human musculoskeletal studies, the focus has been on trunk and back muscles and the neuromotor control of dynamic stability (McGowan *et al.*, 2007). Neuromotor control of dynamic stability is the outcome of the function of the passive, active and neural subsystems during movement. As understanding of the human spine increases, this will aid the understanding of back pain in other species, for instance in the equine.

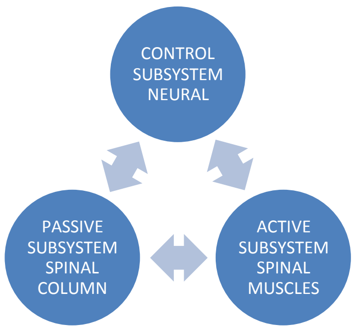


Figure 1.1 The spinal stability system adapted from Panjabi (1992a)

1.2 Human Back Pain

The abdominal and paraspinal muscles play a vital role in the stability of the human spine (Panjabi, 1992b) and functional movement of the vertebral column (Hides *et al*., 1994). Activation of the abdominal muscles used to stabilise the spine (Stokes *et al.*, 2011) and the activation of the Multifidus muscle in the lumbar region have been studied (Hides *et al.*, 1996; Stokes *et al.*, 1997; Hides *et al.*, 2008).

In a repeatability study Hides *et al.* (1992) successfully measured the cross-sectional area (CSA) of the lumbar spinal muscle Multifidus in normal young adults using real time ultrasound scanning. Hides *et al.* (1994 and 2008) found that wasting of the Multifidus in the spine occurs in the presence of spinal dysfunction back pain and also documented asymmetry of Multifidus CSA in patients with acute and subacute, unilateral, low back symptoms. Multifidus wasting in patients, demonstrated by asymmetry of CSA at the level of where the pain is evident on examination, was found to be significant. This asymmetry was greater than the difference in Multifidus CSA in the left and right sides in the subjects without back pain, at all lumbar levels. These findings support the proposed relationship between back pain and muscle wasting in the human spine (Hides *et al., 2008)*, which have provided a basis for further studies to evaluate the effects of treatments for back pain.

Exercises to increase the CSA of Multifidus have been shown to be of benefit in humans and to reduce the reoccurrence of back pain (Hides *et al.*, 1996; Stokes *et al.*, 1997). Hides *et al.* (1996) allocated 41 patients with acute, first-episode unilateral low back pain with localised Multifidus asymmetry into a control or an exercise group. The exercise group undertook a four week programme of exercises, intended to re-educate Multifidus in its stabilising role, involving facilitating an active, isometric Multifidus and deep abdominal muscle contraction. It was found that Multifidus recovery did not occur automatically once the pain had resolved in the control group but muscle recovery was found in patients who received the exercise therapy. This original study was limited to a population of patients with acute low back pain but a follow up study (Hides *et al.*, 2001) showed that after three years patients in the control group were 12.4 times more likely to have further episodes of pain than those in the exercise group. This finding is very important in supporting the argument for rehabilitative physiotherapy exercise, as it is clear that simply stopping treatment once the pain is reduced is not enough to restore the patient's muscle function to the pre-injury state.

The programme of therapeutic exercises developed by Hides *et al.* (1996) focused on establishing the neuromotor control of Multifidus activation in conjunction with Tranversus Abdominus (TrA) muscles which are muscles within the trunk of the body, also known as the 'core'. This approach using dynamic stability exercises of the core muscles relates to Panjabi's (1992a) theory, being two parts to the spinal stability systems; active musculoskeletal and neural control subsystems. The therapeutic exercises used by Hides *et al.* (1996) have subsequently been termed as core stability exercises, which have been defined loosely as 'the restoration or augmentation of the ability of the neuromuscular system to control and protect the spine from injury or re-injury' (Hodges, 2003).

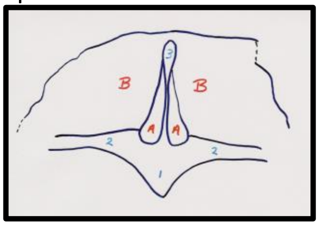
1.3 Equine Back Pain

Back pain and diseases of the spine are considered significant problems in both equine sports and veterinary medicine (Peham *et al.*, 2001). Denoix (1998) stated that in horses, back pain is a major cause of poor performance and gait abnormalities although the definitive diagnosis of the cause of the pain remains a real challenge. More recently Stubbs *et al.* (2010) also concluded that the relationship between pain, pathology and spinal function has not been clearly established in horses. Many of the difficulties associated with the clinical diagnosis of equine back problems would be solved if a system of quantifying the degree of pain in animals and a method of locating the precise site of pain could be established (Jeffcott, 1999). Although studies using movement analysis, kinematics and electromyography to evaluate normal function have been the basis of equine orthopaedic research (Jeffcott, 1980; Jeffcott *et al.*, 1982; Denoix, 1998; Gellman, 1998), to date it has not been possible to quantify the loss of performance frequently associated with these problems. There are reports of major pathology of the bone and joints found within the spine on clinical investigation but little symptomatic effects displayed and vice versa where only minor changes are recorded in the spine yet significant signs of pain and substantial changes in behaviour of the horse exhibited (Erichsen *et al.*, 2004 and Zimmerman *et al.*, 2012).

Equine back pain can also be caused by problems distinct from the equine spine, i.e. pain referred from another non-spine source. Many horses showing back pain also have co-existent hind limb lameness, the most common being bilateral arthritis of the distal tarsal joints or bone spavin (Marks, 1999). A clinical sign of this secondary back pain is unilateral or bilateral atrophy of the epaxial muscles.

Back pain, which may be caused by a poorly fitting saddle for instance, has been discussed as another cause of asymmetry in epaxial muscle mass. The epaxial group of muscles are those that have an origin and insertion above, dorsal to, the spine in the quadruped animal. Incorrect fitting of a saddle can cause white hairs, sores, local inflammation and muscle atrophy in the withers (Gellman, 1998). This view is supported by Harman (1999) who recognises external or physical signs as temporary swellings after removing the saddle, scars, and hard spots in the muscle, in addition to the atrophy of the muscles on either side of the withers. In a survey of 443 cases referred for a second opinion to Jeffcott (1980) with thoracolumbar disorders, 38.8 per cent of the cases had evidence of epaxial soft tissue injury. Although previously back pain has only been linked to atrophy of the epaxial muscles anecdotally (Gellman, 1998; Harman, 1999), more recently this relationship has been substantiated following dissection of the equine spine (Stubbs *et al.*, 2010).

In a clinical situation, physiotherapists often assess change in the muscling of the thoracolumbar epaxial muscles by eye (Sutton, 2001). A more objective method available is to use a flexible curve ruler (FCR). This piece of equipment is a rubber covered length of malleable metal that can be shaped and will retain the shape it is moulded to until re-straightened. This method of documenting the external thoracolumbar shape and symmetry has been tested in a pilot study by Greve and Dyson (2013). The repeatability of the method was established using coefficients of variation and was then used in a study to categorise thoracolumbar shape. These data were then used to investigate the relationship between hindlimb lameness and sideway slip of the saddle when the horse is ridden. Although recording overall shape effectively, the use of this method alone does not allow the accurate measurement of individual muscle size. The epaxial group of spinal muscles comprising the Longissimus Dorsi (LD), Iliocostalis and Multifidus (Plate 1.1) are all located directly under the region of the equine spine where the measurements by Greve and Dyson (2013) were taken.

Transverse section of a Thoracic spinal level 	Schematic drawing of a Thoracic spinal level 	Plate 1.1: Anatomical Diagram of Transverse section of the equine thoracic spine KEY: A – Multifidus B – Longissimus 1 – Vertebral body 2 – Transverse Process

With training one or all of these muscles may change size due to hypertrophy or they may atrophy due to pathology but as the measurement is taken of the complete group of muscles no conclusions could be drawn as to which had undergone change. A further source of error is the variable amount of subcutaneous fat that may be present in the areas overlying and between the epaxial muscles. Body condition scoring is a reliable method of recording subcutaneous fat (Carroll and Huntington, 1988; Dugdale *et al.*, 2012) but this relates to the whole body and not just the back region in the horse. There is clearly a need for a more accurate imaging technique that can be used *in vivo*, such as ultrasonography (Hides *et al.*, 1992). The largest back muscle in the epaxial group is the LD. Whilst the whole CSA of this muscle cannot be measured with ultrasound due to its size, Abe *et al.* (2012) obtained reliable and repeatable measurements of the LD muscle thickness using an ultrasound imaging method. The justification for this choice of measurement was that there is a high possibility of significant correlations between the LD muscle thickness and sprint running and/or jumping performance in horses. Currently there is no evidence available for the application of this method as an objective measurement tool. Abe *et al.* (2012) suggest that further studies will need to be completed to determine if the difference in LD muscle thickness is genetically determined or influenced by training, or a combination of both but no comment was made regarding this and the other epaxial muscles. Until this link is made, the technique used by Abe *et al.* (2012), although repeatable, is not a valuable tool.

From the extrapolation of evidence from the human literature, which underpins the role of Multifidus in spinal stability and pathology, Multifidus is an important muscle to study in the horse. Following Hides *et al.* (1992, 1994 and 1996) ultrasound evaluation has the potential to reliably provide a direct measurement of the size of the Multifidus muscle. The results of a study by Tabor and McGowan (2002) show that the use of real-time ultrasound imaging to measure the CSA of Multifidus in the equine spine is repeatable with one operator. At this time the authors concluded that further research was needed to test first, the inter-operator reliability and second, the use of this tool to measure change of epaxial muscle cross-sectional area over a period of time to objectively quantify treatment effects. This ultrasound measurement technique has subsequently been used successfully to evaluate the change in the muscle following an exercise programme (Stubbs *et al.*, 2010 and 2011), although it has not yet been used for horses with back pain. Ultrasound imaging to measure change of muscle size following therapeutic intervention could potentially be useful for muscles other than Multifidus in the horse. However measurement of muscle CSA and hence measurement of atrophy would be possible in muscles where all the fascial borders are able to be visualised in one ultrasound scan (Tabor and McGowan, 2002).

Functional anatomy of the locomotor system, which is strongly linked to biomechanics, attempts to explain how bones, ligaments and muscles operate as a system (Pool-Goudzwaard *et al.*, 1998). Stubbs *et al.* (2006) investigated the functional anatomy of the equine thoracolumbar (TL) and lumbosacral (LS) spine of 120 cadavers. A post mortem examination revealed LS anatomical variations which may affect the stability of the LS joint, potentially leading to altered function, performance and pathology and consequences for athletic performance. Further research to determine the functional significance of these vertebral variations and their relationship to spinal stability in horses, with and without, back pain is required. Stubbs *et al.* (2006) also investigated the morphology and biomechanics of the deep stabilising epaxial muscles of 13 horses using Magnetic Resonance Imaging, anatomical dissection and biomechanical analysis and found that the equine Multifidus has a similar arrangement to, and is structurally comparable to that in humans. Since the anatomy of the stability muscles has been shown to be comparable, this is supportive of the translation of exercises that have been shown to be effective in the human, to clinical practice for the equine.

Stubbs *et al.* (2010) hypothesized that severe osseous pathological changes in the TL spine are associated with reduced Multifidus CSA on the same, ipsilateral, side at the same intervertebral level. In a study of 22 racehorses, presented for euthanasia for reasons other than back pain, ultrasonographic images were acquired, soft tissue lesions of muscle, ligament and fascia were noted and osseous pathological changes were also recorded. Osseous pathology (mild or moderate changes) was found at all spinal levels in all horses. Of this sample group of 22 horses, 20 underwent a complete clinical examination and 18 showed clinical signs of back pain prior to euthanasia, despite only 15 (68%) having a recorded history of back pain. Ultrasonographic examination showed that left/right asymmetry in the osseous pathology was significantly associated with left/right asymmetry in Multifidus CSA (Stubbs *et al.*, 2010). The association of pathology and smaller CSA area of Multifidus was on the same side, which is comparable with the findings in the human spine by Hides *et al.* (2008). It would be of interest to determine whether, in the equine, these asymmetries were clinically significant, either producing pain or having an effect on performance. A further line of study is to investigate the causal processes of the osseous pathologies. It appears that Stubbs *et al.*'s (2010) call for further work to investigate this relationship has not yet been conducted. It could be speculated that asymmetric pathology could be related to movement patterns during the race training of these horses, or perhaps to the motor laterality, or handedness, that has been shown to exist in thoroughbred horses (McGreevy and Rogers, 2005).

Diagnostic imaging tools available to veterinary surgeons include radiography and scintigraphy, although relating results from these tests to the cause of the back pain remains complex due to false positive outcomes. In an attempt to assess the clinical significance of osseous changes in the equine, a study assessing the relationship between scintigraphic and radiographic evaluations of spinous processes in the thoracolumbar (TL) spine was conducted. Erichsen *et al.* (2004) comment that while some horses perform well when they have radiographic and/or scintigraphic findings, others do not and it is not completely understood why some horses show signs of pain. A later study by Zimmerman *et al.* (2012) into 582 horses presented with perceived back pain, suggested that fore or hindlimb lameness may result in primary thoracolumbar pain or previous asymptomatic osseous spinal lesions becoming symptomatic. These findings further complicate the understanding of the relationship between radiological findings, scintigraphic findings and the clinical signs although within this group of horses radiological and scintigraphic abnormalities of the spinous processes were more severe in horses with thoracolumbar pain than in horses without.

Impingement or dorsal spinous processes that override are the most common cause of back pain according to Walmsley *et al* (2002) and this was shown further by Zimmerman *et al.* (2012) where 48% of horses with lesions on the spinous processes had experienced thoracolumbar pain. Of the remaining horses over two-thirds had osteoarthritic (OA) changes to the intervertebral (IV) articulations or spondylosis and 80% of the horses that were found to have both spinous process and IV articulation OA changes had experienced pain. With such a large sample of horses, a strong relationship between the presence of osseous changes and pain is suggested. Multifidus size or symmetry was not measured although it was noted that atrophy of the epaxial muscles in association with thoracolumbar pain commonly occurs. It would be a relevant further study to compare radiographic findings in a clinical population of horses, with Multifidus symmetry, to establish *in vivo,* the relationship observed by Stubbs *et al.* (2010) at post mortem.

Analysis of the literature surrounding back pain in quadruped species other than the equine reveals a limited amount of evidence for any pathologies similar to those described in the horse. Intervertebral disc degeneration is common in dogs (Bergknut *et al.,* 2012) and reported in cats (Harris and Dhupa, 2008) and lumbosacral degenerative stenosis and treatments have also been documented (Meij *et al.,* 2010), but pathologies and specific diagnoses such as these are not evident in the literature relating to the horse. Likewise no literature exists regarding the measurement of epaxial muscle size in any other species, except for that discussed from the human and equine literature.

1.4 Equine Spinal Muscle Activity

The use of electromyography (EMG) is relevant because spinal stability is reportedly highly dependent on the contribution of the muscular system (Panjabi 1992a, 1992b). EMG has been used to measure and analyse the degree of muscular activation in investigations of equine back pain and spinal function. Research methods using EMG in horses without clinical signs of back pain has predominantly used surface EMG where electrodes are placed on the individual's skin surface overlying selected muscles. Fine needle EMG has been used to successfully discriminate between normal muscle function and function that is altered by either a nerve or muscle pathology and this can assist in the location of the pathology in horses with neuromuscular locomotor problems (Wijnberg *et al.*, 2004) However, needle EMG only samples a small volume of muscle activity in the area close to the needle (Zsoldos *et al.*, 2010), plus the invasive nature of this technique which is by law only to be performed by a veterinary surgeon and under the Animals (Scientific Procedures) Act (1986) for experimental set-ups, means that most studies have used surface EMG.

The EMG activity of the LD in the back has been studied during induced back movements of horses at stance (Peham *et al.*, 2001), in horses walking (Licka *et al.*, 2009) and trotting on a treadmill (Licka *et al.*, 2004) and when being lunged on a circle (Cottriall *et al.*, 2009). Surface EMG demonstrated that in the weight-bearing phase of the stride the main muscle activity was centred around the 12th thoracic vertebral level, muscles were bilaterally active during induced spinal extension and when in lateroflexion, only one side of the LD was activated (Peham *et al.*, 2001). In EMG studies of horses at walk and trot the activity of the long back muscle, LD, varies during the phase of the stride cycle. At walk only one maximum activity for each LD was detected during each motion cycle and in trot there are two periods of maximum activity;

the range of relative EMG amplitude at the walk is much smaller than at the trot (Licka *et al.*, 2004; Licka *et al.*, 2009). This muscular activity is concluded to be necessary for the stabilisation of the vertebral column against dynamic forces, as the muscle activity is required to counteract the propulsive force generated by the hind limb. It can therefore be argued that the function of the back muscles in the equine are similar to the human spine, where function of the stabilising system is to provide sufficient stability of the spine to match the instantaneously varying stability demands due to changes in spinal posture and static and dynamic loads (Panjabi, 1992b).

In horses, training aids are used to artificially alter the way the horse moves and are said to be able to strengthen the back muscles. Claims to their benefits are made by the manufacturers of training aids, for instance the Pessoa Training Aid™ (PTA), which is described as 'a revolutionary lunging aid for horses that strengthens the back, stretches the top line and gently encourages the horse to work correctly' (*Pessoa Training Aid* www.thesaddleryshop.co.uk). The scientific value of training aids had not been tested until Cottriall *et al.* (2009) measured the changes in the activity of the LD, when a horse was being lunged on a circle with no artificial aids, with side reins and with a Pessoa during both walk and trot. Interestingly, the data showed that the EMG activity in the LD was reduced with the training aids. The LD was more active when on the inside of a lunge circle although the authors go on to say that it remains to be seen whether such increases in LD activity are beneficial or not. Whilst the results of assessment of superficial muscles are not conclusive with relation to the function of the spine the effect of training aids on the deeper muscles such as the Multifidus and the abdominal muscles has not yet been measured. In reality only superficially located muscles can be assessed using surface EMG (Zsoldos *et al.*, 2010) therefore, due to the location of the Multifidus it is not feasible to measure its activity using this method.

The abdominal muscles are described as part of the ventral chain of muscles in the trunk of the horse by Denoix and Pallioux (1996) who suggest that the ventral chain and the muscles in the dorsal region, the dorsal chain, have to exist in equilibrium creating a functional unity in the equine spine. This is derived from the early theories of the bow and string model of the equine spine proposed by Slijper in 1946 where the equine thoracolumbar spine acts like a bow that is held in flexion by the action of the string, i.e. the ventral hypaxial muscles (Clayton, 2012). Biomechanical disorders are reported to break this unity, creating problems in the movement of the horse, for instance if the activity of the dorsal chain of muscles is predominant, the thoracolumbar spine extends (Peham *et al.*, 2001) and the amplitude of movement will be impeded (Denoix and Pallioux, 1996). Investigations into the equine abdominal muscles have been undertaken to verify the effects of the ventral muscle groups.

Zsoldos *et al.* (2010) measured the Rectus Abdominis (RA) and Oblique External Abdominal (OEA) muscles activity of horses at walk and trot on a treadmill, using surface EMG. Significant differences between the mean left and mean right muscle activities over the motion cycle at walk were seen in all six horses and in four of six horses at trot. Between walk and trot muscle activity there were significant differences for the OEA in all horses and for RA in 5/6 horses (Zsoldos *et al.*, 2010). The authors assumed that the activity pattern of OEA and RA would be correlated to the gait of the horse although it appears that the activity of OEA can also be linked to the recruitment of the muscle for expiration. Studies at canter where breathing and motion cycles are coupled, would help further to investigate the recruitment of the OEA during gait. The RA was active on both sides simultaneously which indicated that RA counteracts ventral spinal extensions during the phase of the stride when the foot is in contact with the ground. This supports the theory of muscular chains affecting movement in the thoracolumbar spine, as presented by Denoix and Pallioux (1996). In agreement with Cottriall *et al.* (2009), Zsoldos *et al.* (2010) suggested future investigations of muscle activity in a variety of body postures during motion. Unfortunately to measure changes in muscle activity over time, the value of EMG activity is limited, as it fails to provide a comparative quantitative measure of muscle activity when used on different occasions.

1.5 Equine Core Stability

Investigations using surface EMG have examined the activity of the superficial, large and multi-spinal level muscles LD, OEA and RA. A series of studies using clinical populations of humans with back pain have examined the effect of using exercises to activate the deep spinal stabiliser muscles, for example Multifidus and TrA. Given the published comparative findings between humans and equines, it is reasonable to suggest that the approaches developed to human back pain rehabilitation based on the use of core stability exercises, may also be of benefit to horses.

The PTA is frequently used to facilitate correct muscle activation and develop core muscle strength. Walker *et al.* (2013) sought to establish its effectiveness for this purpose. Although Cottriall *et al.* (2009) showed that there was no increase in LD muscle activity, the effect on spinal or limb kinematics was not measured. If this training aid is to be effective, the outcome of any alteration of muscular activity will be altered kinematics. Walker *et al.* (2013) showed that the PTA resulted in a decreased speed and stride length but maintained stride duration, which may suggest the horse is working in a better balance. There was also an increase in flexion at the lumbosacral joint but the mechanism for this remains unclear as the activation of the spinal and abdominal core muscles was not investigated. If the investigations by Walker *et al.* (2013) and Cottriall *et al.* (2009) could be repeated with combined methodologies plus EMG measurement of the abdominal muscles, then more in-depth conclusions could be drawn.

Clayton *et al.* (2010) considered the use of core stability exercises in the horse and described dynamic mobilisation exercises (DME) as movements that are produced by concentric activation of the muscles, which alter the horse’s posture, while abdominal, epaxial and pelvic muscles act isometrically or eccentrically to stabilise the trunk and limbs. Recently Stubbs *et al.* (2011) demonstrated that DME are effective in activating the deep spinal stabiliser muscle Multifidus. This study used eight horses who were clinically assessed as having no back pain and whilst stabled for 24 hours per day, these horses undertook a programme of DME. The Multifidus muscle was measured with ultrasound imaging at the onset and after three months. At all spinal levels measured, the Multifidus CSA had increased significantly and right/left asymmetries had decreased between the initial and final measurement. The authors subsequently concluded that the use of DME could potentially be beneficial in the rehabilitation of horse with back pain. However a limitation of this study was that there was no control group subject to the same period of exercise restriction that did not participate in the exercises. Without a control group other variables affecting the muscle size may have influenced the results, for example, the cessation of their usual ridden exercise programme.

1.6 Spinal movement during DME

In a study aiming to quantify back ROM, flexion and extension were induced in the thoracolumbar spine by provoking reflex dipping (extension) and arching (flexion). Licka and Peham (1998) measured movement of spherical markers on the spine in ten horses without back pain. The data were collected in the form of the vertical distance between the height of a marker on the top of 16th thoracic (T16) spinous process a standing position and then at the end of the movement into flexion or extension. The end of the movement was considered to be when T16 had reached either maximal extension or flexion. Extension of the back was induced by firm palpation of the back with both hands dorsally between T10 and T16, this movement is termed the rounding reflex. Flexion of the back resulted in simultaneous rubbing of two points, one on either side, dorsolateral to the root of the tail above the Biceps Femoris muscles. In this study the change in height of T16, relative to the starting position was a maximum of 12.8cm when flexed and -6.4cm when in extension, with one horse having a 15.6cm movement of T16 from flexion to extension (Licka and Peham, 1998). The measurement technique means the data cannot be compared to the more recent study

Clayton *et al.* (2010) which recorded change in joint angulations. Licka and Peham (1998) used induced reflex movements to achieve an alteration in the ROM which potentially could move the joints outside the comfortable range in the horse in comparison to a more normal neuromotor control pattern using muscular activity to move the joints when performing DME (Clayton *et al.*, 2010). Although induced reflex movements can be used to flex and extend the spine the effects may be detrimental to the horse, especially if lack of active control of the movement and excessive ROM may cause pain or damage if pathology exists.

Examination of the cervical ROM during the three different flexion DME has been carried out by Clayton *et al*. (2010), demonstrating significant change in intervertebral angulation in the specific DME exercises of chin-to chest, chin-between-carpus and chin-between fetlocks when compared to the neutral position. Clayton *et al.* (2010) recorded the largest angular change at the first cervical vertebrae, C1 the poll (47^0 extension) and at C6 (91^0 flexion) during the chin-between-fetlock movement, with small movements in the intervertebral joints between. This is in contrast to neutral position where C1 is the most flexed and C6 most extended. During DME chin-between-fetlocks the majority of the movement occurs at the cranial and caudal cervical regions. Lowering the head and neck increases tension on the nuchal ligament which in turn tensions the supraspinous ligament in the thoracolumbar region (Denoix, 1999). During DME there is a change in the joint angles in the thoracic spine as a consequence and the region of most movement corresponded to the DME performed (Clayton *et al.*, 2010). Chin-to-chest flexion increased flexion in T6 to T8 and chin-between-fetlocks increased flexion in joints between T10 to T16. Using the exercises as a therapeutic exercise to affect ROM should take these data into account.

1.7 Pilates and the Equine

A large amount of information is communicated to the general horse owning population regarding methods to strengthen a horse's back by the lay press. In reality the majority of this ‘instructional guidance’ is based on the translation of exercises frequently used in human sports and fitness training, such as the popular ‘Pilates’ method of core stability training. This is based on the development of an exercise programme by Joseph Pilates (1880-1967) who was born in Germany and suffered multiple bouts of sickness during childhood. During the First World War, when living in England, Pilates was placed in internment due to his nationality. It was here that he was reported to have designed a series of exercises to help himself and others in the camp to become fit and healthy (Robinson and Thomson, 1999:14). Post war, his method progressed and after Pilates moved to the United States he set up a studio for dancers. Since his death the technique has found a much wider audience (Herdman, 2003:6). Many of his original clients went on to teach the methods but adapted the exercises as a result of their own experiences with him, which has led to the diverse range of Pilates-type exercise classes. Robinson and Thomson (1999:2) describe Pilates as a method to change the way in which the body is used by redressing imbalances and altering movement patterns, which apparently brings the body back into balance. The Pilates method has been modified from a pure approach, to improve posture and strength in dancers, as originally designed by Joseph Pilates, to being used to enhance the fitness of healthy people and also for rehabilitation of people with back pain. Many lay books have been published that exalt the virtues of the Pilates method but, until recently, no studies had been published providing evidence for this technique.

A review by Cruz-Ferreira *et al.* (2011) presented strong evidence to support the use of the Pilates method of exercise at the end of training to improve flexibility and dynamic balance and moderate evidence to enhance muscular endurance in healthy people. However in their comparison of the Pilates method with either no exercise or lumbar stabilization, for pain and functionality in patients with chronic low back pain, Pereira *et al.* (2011) concluded that when compared with control and lumbar stabilization exercise groups the Pilates method did not improve functionality or reduce pain in patients who have back pain. It would appear then that the Pilates method should be carefully considered before being applied for patients with back pain. Both authors recommend that further investigation in required and a suggestion would be to apply a standardised form of the Pilates method of exercise to different population groups and to achieve comparable objective measurable outcomes.

The original teaching by Pilates, which is now taught by contemporary instructors, was based on eight key principles which are relaxation, concentration, alignment, breathing, centring, co-ordination, flowing movement and stamina (Robinson and Thomson, 1999; Herdman, 2003). Whilst these principles may be appropriate and relevant for the human body when following the exercises, these may not readily translate for application of the method to the equine. Alignment, flowing movement, stamina and even relaxation may be achieved with a horse performing movements akin to Pilates type exercises, however these exercises would not be performed without the external direction of a handler and therefore the concept of concentration i.e. conscious focus on what the subject is trying to achieve (Gavin, 2002) would not be relevant. Timing the exercises with the breath in/out could be achievable with a skilled handler but is unlikely to be consistent or repeatable. Centring is described as actively engaging the pelvic floor muscles whilst at the same time hollowing the lower abdominals to engage the TrA. In the horse, the pelvic floor musculature has a different role to that in the biped upright human, therefore specific activity of this muscle group in the horse would not be a desirable rehabilitation goal. Although EMG data for the superficial abdominal muscles External Oblique and Rectus Abdominus have been reported on (Zsoldos *et al.*, 2010), to date no studies on horses have measured the activity of the TrA during either active or reflexive movement.

Based on the key principles determined by Joseph Pilates, it would seem that the Pilates method is not entirely appropriate for use with the equine. Despite this, the popularity and awareness of the method has led to a proliferation of books, websites and courses for horse owners. One such book entitled ‘Pilates and Stretching, An Exercise Index for Horse Owners’ (Higgins, 2009) describes exercises but there is no mention of the reasons for the selected exercises other than anecdotal reporting of the benefits.

1.8 Equine Posture

The applicability and positive impact on health of the application of exercises that include focus on spinal alignment, posture alteration, patterns of muscle activation and balance in humans could be relevant to horse training. In order to make the case for this there would have to be an objectively measurable effect on the horse's posture following such an exercises programme. Although discussed within the lay press, no studies are available that use this term and either measure or investigate for a change of posture. Conformation of the horse has largely been based on subjective observations according to Anderson and McIlwraith (2004), in their study into the role of conformation in musculoskeletal problems in the racing Thoroughbred. This study focuses on the more generic conformation which is related to the structure and arrangement of the physical parts of the horse (Dictionary.com, 2013). However, conformation is considered to be fixed, whereas posture, which concerns the positioning of the limbs or the carriage of the body (Dictionary.com, 2013), is alterable. For example the addition of weight to the thoracolumbar spine induces extension, or 'hollowing' of the spine (de Cocq *et al.*, 2004) and this could be deemed a postural change. Thoracolumbar extension is clinically significant in the presence of pathology such as close, impinging and overriding dorsal spinous processes in the thoracolumbar spine. This particular pathology, which is also known as kissing spines, has been reported to be present in high numbers of horses referred with back pain to the veterinary surgeon (Erichsen *et al.*, 2004 and Zimmerman *et al.*, 2012).

1.9 Measuring equine posture and its response to treatment

Being able to collect, record and evaluate data is crucial for physiotherapists working within the veterinary medicine field. Although anecdotal reports of positive outcomes following treatment of horses are widespread, methods of objectively collecting measurements are poorly reported in the literature. To date, the use of ultrasound imaging to measure muscle CSA has been validated (Tabor and McGowan, 2002; Stubbs *et al.*, 2006) and shown to be useful to quantitatively demonstrate treatment effects (Stubbs *et al.,* 2010). Although Abe *et al.* (2012) used ultrasound imaging to record LD depth, this has not be used pre- and post-treatment. Unfortunately, however reliable, ultrasound imaging equipment is expensive and requires substantial to be used as an objective measurement tool.

In canine rehabilitation, thigh circumference is used to measure muscle bulk of the extensors and flexors of the stifle, post cruciate ligament repair (Monk *et al*., 2006). This method using a flexible tape measure is widely used and a valid measure of response to rehabilitation following surgery. However this cannot be used in the spinal regions of canines, or any other species, as change in size of the complete transverse section the trunk could be a result of change in abdominal contents or even abdominal muscle contraction.

Pressure algometry (PA) can be used to quantitatively measure the soft tissues response to deformation from a small handheld device. The unit records the force applied before the user notes behavioural response which indicates the mechanical nociceptive threshold (MNT) has been reached. Haussler and Erb (2006), Varcoe-Cocks *et al* (2006) and Heus *et al.* (2010) have all sought to objectify the palpation of soft tissues with PA and it been shown to a repeatable method for assessing the presence of musculoskeletal pain in horses (Haussler and Erb, 2006). Horses with suspected sacroiliac dysfunction presented with lower MNT in the pelvic region (Varcoe-Cocks *et al.,* 2006) and therefore may be able to be used to record palpation findings within the course of physiotherapy assessment and following treatment. Spasm or tenderness on palpation of gluteal muscles, presented with pelvic asymmetry, has been suggested as a warning of potential presence of (impending) pelvic or hindlimb fracture in racing thoroughbreds (Hesse and Verheyen, 2010). Being able to quantify the level of response to palpation would support the skill of the experience physiotherapist in their role in the prevention of career-ending injuries such as these. However PA cannot measure the CSA of muscle, posture or the function of the region, only the response to pressure. Therefore this may not be considered suitable for measuring the postural effect and therefore the functional result of treatment.

An inexpensive and easy to use tool for physiotherapists to measure muscle and posture changes during a treatment programme, in the clinical setting, is needed. One method to assist measurement is to use photographs to record the effect of treatment on posture. Digital cameras are readily available, as are cameras on smart phones. Developing a method of measuring the posture of the horse pre- and post-treatment using photography and analysing either on-site or after the session, using simple software would be ideal.

1.10 Conclusion

To manage back pain in horses a greater understanding of the function of the spinal stabiliser muscles in pain-free horses is needed. This requires investigation into the effects of dynamic mobilisation exercises on horses that are following a normal work pattern, to investigate whether these types of exercises have any benefit over general activity levels. The effect of dynamic mobilisation exercises on the other muscles of the core, for example the abdominals, also requires further study. Investigation into activity of these muscles during normal movement patterns, and when undertaking specific dynamic mobilisation exercise programmes, would be useful for understanding the significance in these muscles during normal function and as a rehabilitative technique. Once such data have been established for horses without back pain, a further topic of investigation would be the effect of dynamic mobilisation exercises on horses with back pain. Results of this type of investigation will provide an evidence base for physiotherapists who prescribe exercises as part of the treatment for horses with back pain. Using the correct choice of treatment techniques will therefore aid the welfare of horses by reducing back pain.

CHAPTER 2

Aims and Objectives

This study aims to objectively measure the effects of a specific type of core stability exercise regime, dynamic mobilisation exercises, on horses. This study aims to investigate the effect of dynamic mobilisation exercises on the CSA of the Multifidus muscle in backs of horses that are undergoing a normal exercise programme. This approach aligns with that taken by Zsoldos *et al.* (2010) who reported the relevance of investigating training strategies to achieve better core stability e.g. for young racehorses at risk of developing athletic performance related thoracolumbar pathologies.

Ultrasound evaluation of muscle in this region can offer direct measurement of the size of the Multifidus muscle (Tabor and McGowan, 2002) but despite Stubbs *et al.* (2011) concluding that it is not a difficult technique, it is unlikely that physiotherapists will routinely have access to the equipment necessary to measure the Multifidus muscles with ultrasound imaging. The FCR is readily available and could potentially offer a simple solution to producing objective measurement of change in muscle size over time. Currently no study has compared the external profile, as measured by FCR, with the CSA of Multifidus muscle via ultrasound imaging. Therefore this study will also evaluate the relationship between the dorsal Thoracic transverse profile and the Multifidus muscle CSA looking at the correlation between the measurement methods and also after a programme of core stability exercises.

Posture of the equine back has been under researched despite frequent subjective analysis of the thoracolumbar position and its apparent relevance to pain and pathology. To date no methods to objectively measure this posture have been developed and documented. As part of this study an aim is to develop a method of objectively recording posture. Once this has been achieved measuring change of posture in response to pain or in response to treatment for instance will be of significant value to physiotherapists.

Objectives:

1. To investigate the effect of dynamic mobilisation exercises on the cross sectional area of the Multifidus muscle in thoroughbred horses undergoing a normal exercise training programme.

2. To evaluate the relationship between the dorsal thoracic transverse profile and the Multifidus muscle CSA after a programme of dynamic mobilisation exercises.

3. To develop a simple method of objectively measuring equine thoracolumbar posture.

Hypothesis

Ha1: A programme of dynamic mobilisation exercises will result in a change in the Multifidus cross sectional area in horses undergoing a normal exercise training programme.

Ha2: There is a relationship between the dorsal thoracic transverse profile and the Multifidus muscle CSA after a programme of dynamic mobilisation exercises.

Ha3: A simple measure can objectively measure equine thoracolumbar posture

Chapter 3

Study One: The Effect of DME on Multifidus in Racehorses

To investigate the effect of dynamic mobilisation exercises (DME) on the cross sectional area (CSA) of the Multifidus muscle in thoroughbred horses, undergoing a normal exercise training programme, and to evaluate the relationship between the dorsal Thoracic transverse profile CSA and the Multifidus muscle CSA, the following research process was carried out.

3.1 Materials and methods

3.11 Subject selection

The subjects used in this study were selected from a group of thoroughbred horses that were stabled at a racing yard belonging to the racehorse trainer Mr B. R. Millman of The Paddocks, Kentisbeare, Devon, U.K. The horses at this yard were in training for flat racing in the 2012 season, which started nationally on the 31st March 2012. The sampling frame of 62 horses located at this yard were of mixed age, ranging from 2 to 9 years and mixed sex (fillies, mares, geldings and colts). A series of selection criteria were applied to obtain the sample. The initial selection excluded horses that were either two years old or younger. These were excluded due to an anticipated large growth rate that occurs within this age group (Anderson and McIlwraith, 2004). This change in body mass and proportions would have the potential to confound the result from the planned data collection.

Stubbs *et al.* (2010) demonstrated osseous and muscular changes *ex vivo* by using ultrasound imaging in racehorses, therefore horses within the sampling frame with known injuries or pathologies were identified. Any horses with a previous history of injury, lameness or spinal pathology (indicated by back pain) were excluded in order to limit the variability that could be a result of the previous pathology.

After the exclusion criteria had been applied a sample of n=35 horses remained. All of these 35 horses were returning to a programme of training at a point in the annual racing season following a lay off phase of at least four weeks. For the duration of the trial all horses were stabled, apart from the time period they were undertaking exercise which was carried out in the morning. The horses did not spend any time in a field. All subjects were considered by the racehorse trainer as unfit and were intended to follow a training programme enabling them to be sufficiently fit to enter their first race in April 2012.

Twelve horses were required for this study. This sample size was chosen due to the maximum availability of, and the financial constraints associated with, the chosen veterinary procedure for measurement and allies with similar studies undertaken in equine research (de Cocq *et al.*, 2004; Cottriall *et al.*, 2009; Clayton *et al.,* 2010; Stubbs *et al.,* 2011; Abe *et al.,* 2012; Clayton *et al.,* 2012). The sample population were randomly selected from the remaining 35 horses in the sampling frame. Each horse was allocated a number and using a random number generator in Microsoft Excel 2010 producing numbers 1 to 35, the first twelve numbers were generated were recorded and the corresponding horses were allocated/chosen for the study. The 12 horses (age: 4.5 ± 1.8 years; height: 160.5 ± 6.2 cm; weight: 507.8 ± 40.4 kg) were divided into two groups using the random number generator a second time. Horses numbered 1 to 6 were placed in the control group and horses numbered 7 to 12 were placed in the experimental group. The horses were independent with no genetic links in their immediate parentage.

Group one, the experimental group, contained one colt, four geldings and one filly and group two, the control group, contained five geldings and one filly. It was felt that these were sufficiently similar and that no further strategic sampling (e.g. to balance for age or sex) was necessary.

3.12 Experimental Protocol

On day one (17th January 2012) of the study a series of measurements was taken of each horse by the researcher, a Veterinary Surgeon and assistant. The data were collected from each horse in an enclosed area measuring 4m by 3.6m (a stable on the racing yard). The stable had a level concrete floor and half height stable door (1.25m high x 1.3m wide). There was no bedding on the floor. The horses were individually led from their stable to the measurement area by the assistant. The assistant followed the protocol set by the yard trainer for leading horses from their stables. All horses wore a webbing headcollar and a chifney bit in their mouth. A single lead rope was clipped to the base of the bit and this was used to control the horse.

Each subject was housed individually in similar sized and constructed stables but with a bedding of wood shavings mixed with shredded paper. All subjects were accustomed to the experimental stable environment for routine husbandry and veterinary procedures such as examination by the Veterinary Surgeon or visits by the farrier. During the period of the study (17^{th} January to 10^{th} April 2012) each horse when not undertaking exercise were housed individually in stables at least 3.6m by 3.6m. The horses were fed according to the trainer's management, were provided with concentrates and forage, and had free access to water.

<u>Post measurement protocols</u>

After the measurements were completed horses in the experimental group undertook a programme of dynamic mobilisation exercises (DME) whilst the horses in the control group did not repeat the DME but were handled to a similar extent by the yard staff. All the horses followed a programme of exercise determined by the trainer. The amount and intensity of exercise was progressed over the length of the study. The exact daily activity undertaken for each subject horse was recorded to allow evaluation of the level of exercise in relation to the results of the measurements for each group.

3.13 Measurement of the Epaxial Muscles

Two measurements of the epaxial muscles were taken from each horse. The cross sectional area (CSA) of the dorsal thoracic profile was determined with a flexible curve ruler (FCR) and the CSA of Multifidus was measured using ultrasonography. Each horse was brought into the empty measurement stable for assessment and was held by the assistant for the duration of the measurements. The horses were handled by the assistant, who was asked to stand the horse with its weight evenly balanced over its front and hind legs with the feet from the right and left sides, aligned as if on parallel lines, and this position was maintained throughout the period of time when measurements were taken. This position is known to horse handlers as being 'stood square'. All measurements were taken from the horses during their afternoon rest period when they had been stood in their stables for at least 2 hours. The measurement period was approximately 20 minutes long.

Flexible Curve Rule

The dorsal thoracic profile was measured at the level of the 16th (T16) thoracic vertebrae, identified by palpation of the ribs. This was done by counting forwards from the most caudal 18^{th} rib to locate the 16^{th} rib and this rib was followed dorsally to the Dorsal Spinous Process. The midpoint of a FCR was placed on the dorsal midline and then it was shaped to follow around the dorsum, perpendicular to the dorsal midline (Plate 3.1), following the body contours and the resultant shape was manually drawn onto A3 paper (Plate 3.2). This method of measuring thoracolumbar shape was tested in a repeatability study by Greve and Dyson (2013) and minimal detectable differences were demonstrated between sequential measurements. A single investigator (the author, G.T.) performed all the measurements.

To be able to measure CSA of the dorsal thoracic profile, rather than just record the shape, the area needed to have a complete boundary. When the resultant shape was drawn onto A3 paper the lower/dorsal limit was added to the shape. This limit was either side of the ruler at the point at which the lateral border of the epaxial muscles can be palpated over the ribs, as the ribs project laterally from the midline. The anatomical shape *in vivo* is a convex curve following the dorsal aspect of the ribcage but as this was not able to be reliably estimated, a straight line was used for all horses as the ventral boundary to the area. A line was drawn from the highest dorsal midpoint to the lower line to separate the left and right sides and a scale was drawn on the paper in the form of a 10cm line (Plate 3.3). This was to allow accurate measurement of the area under the curve in cm^2. Each A3 paper was scanned and saved in pdf format so that the file could be viewed on a computer. Then computer software programme ImageJ™ was used to trace the around the shape and calculate the area under the curve and therefore the CSA of Multifidus could be derived and recorded. The method was repeated three times for each horse to allow analysis of repeatability.

Plate 3.1: Flexible curve ruler placed over the 16th Thoracic Dorsal Spinous Process and shaped to follow the dorsal profile.

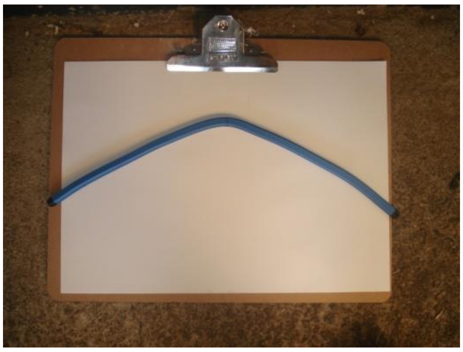


Plate 3.2: Flexible curve ruler placed on a firm surface in preparation for tracing shape from the lower edge onto A3 paper

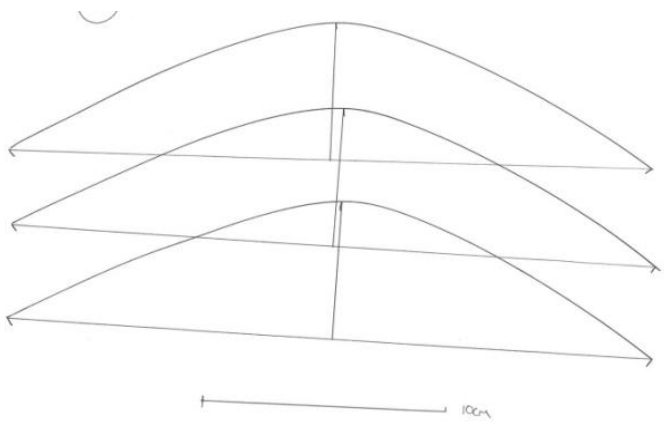


Plate 3.3: Resultant profile of one subject repeated three times, traced onto A3 paper with ventral border, midpoint line and scale (10cm line).

Ultrasonographic measurement of the Multifidus muscle

Ultrasonic images of the left and right Multifidus muscle were acquired at the 16th Thoracic level using a real-time ultrasound imaging machine (Make: My Lab Five VET) operated by Veterinary Surgeon, Chris Johannson (MRCVS). The horses were stood as for the FCR measurements and the 16th dorsal spinous process was identified by palpation of the ribs. The skin and coat were prepared by wetting the area with ethanol liquid. A curvilinear probe was used with 5 – 7.5 MHz frequency dependent on the depth of penetration required. This was determined by the Veterinary Surgeon based on the clarity of the image obtained and the ability to visualise the full length of the transverse process in each horse. Using the methodology described by Stubbs *et al*. (2011) the transducer probe was orientated transversely adjacent to the dorsal midline and followed the skin curvature of the epaxial muscles, so that an angle of approximately 45° was achieved. The margins of the Multifidus muscle were located using the bony dorsal spinous process medially, the rib/transverse process ventrally and the lateral fascial border between Multifidus and Longissimus Dorsi (LD) muscles. This produced a transverse section view of Multifidus with medial being on the left of the screen, viewing cranial to caudal. Once the image of Multifidus was obtained it was frozen on the screen of the ultrasound machine. Electronic callipers, a function of the software within the ultrasound imaging machine, were used to draw a line around the border of the muscle viewed as shown in Plate 3.4. The CSA (in cm^2) of the muscle traced was calculated using the ultrasound software programme and displayed on the screen. This figure was recorded and the muscle edge was traced three times with the electronic callipers on each image obtained. The process was repeated for the left and the right Multifidus muscle at T16. The veterinary surgeon was blinded as to which group each horse was allocated.

Plate 3.4:
Image of Multifidus at T16 with the border marked using the electronic callipers function

Weight

The horse's weight was recorded at weekly intervals by the trainer. These data were collected by measurement on an equine weigh bridge (Horse Requisites: Newmarket Horse Weigher Mark 3) which was installed on the yard. Weighing each horse on a weekly basis was repeated as part of the normal routine of horse management at the racing yard and the information from this relating to each horse used in the study was collected.

Exercise training programme

All the horses followed a programme of exercise determined by the trainer. This programme included using the mechanical horse walker or being ridden at walk, trot or canter. When on the mechanical horse walker the horses did not wear any tack and were moved by the panels of the machine in a walk and on alternate days in either a clockwise or an anticlockwise circle, with a 20 metre diameter. When exercised at walk and trot the horses wore a saddle and bridle and were ridden by one of the stable staff. The horses followed a 10m wide track around an oval shape, with a distance of 300m on a 15cm deep woodchip surface. When cantered the horses were taken onto the 5 furlong (One furlong = 201.168 metres) gallops, also with a woodchip surface. The time spent engaging with these activities and the amount and intensity of exercise was set by the trainer and increased progressively over the duration of the study. The exact daily activity was recorded to allow evaluation of the level of exercise in relation to the results of the measurements for each group.

3.14 Dynamic Mobilisation Exercises (DME)

After the initial Multifidus and dorsal thoracic profile measurements were completed, horses in the experimental group undertook a programme of DME, as per the protocol used by Stubbs *et al.* (2010). This consisted of three cervical flexion exercises, one cervical extension exercise and three lateral bending exercises to the left and right (Plate 3.5). The exercises were repeated 10 times, once a day, five days per week following Stubbs *et al.* (2012). The DME were movements in which the horse actively follows the bait (either carrot or a small portion of commercially available feed, Spillers HDF™ Lay-Off cubes) to achieve the desired position. The positions were used following the guidance within Stubbs and Clayton (2008): ‘chin-to-chest in which the chin was moved as close to the manubrium (most cranial point on the sternum); chin-between-carpi in which the chin was moved as far as possible with the dorsum of the nose level with the carpi (knees); chin-between-fore fetlocks in which the chin was taken as far ventrally and caudally as possible between the forelegs at fetlock level; neck extended in which the chin reached as far forward as possible; chin-to-girth in which the horse stretched laterally until the chin reached the level of the girth; chin-to-flank in which the horse stretched laterally with the chin moving towards the tuber coxae (lateral aspect of the pelvis); and chin-to-tarsus in which the horse reached laterally towards the tarsus on the hindleg, reaching as far caudally and ventrally as possible’. The horse was encouraged to hold each position for 5 seconds and was then rewarded with the bait.

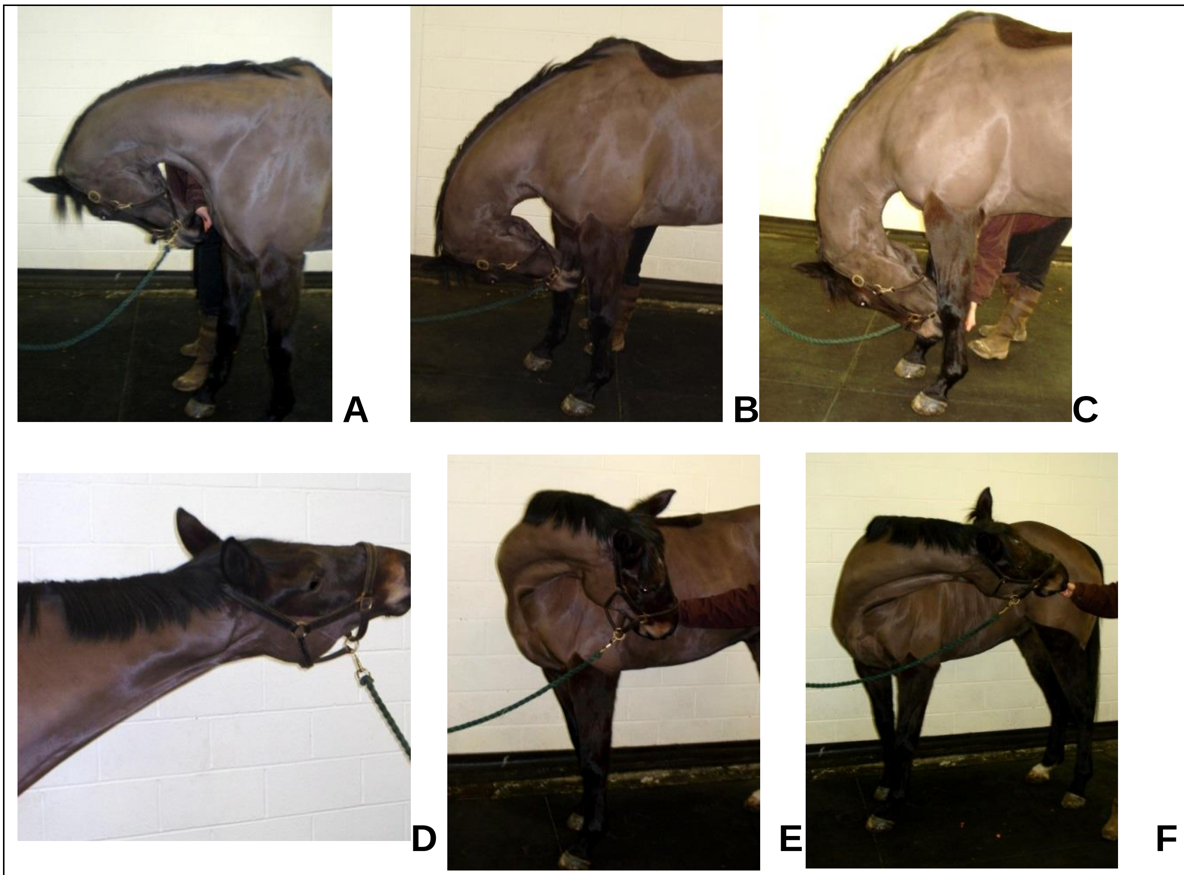


Plate 3.5: Dynamic Mobilisation Exercises:
A – Chin-to-chest;
B – chin-between-carpi;
C – chin-between-fore fetlocks;
D – extension;
E – chin-to-girth;
F – chin-to-flank;
G – chin-to-tarsus.

3.15 Frequency of Data Collection

The FCR area measurements and ultrasound image of the CSA of Multifidus were collected at the start of week one (17th January 2012), the end of week six (28th February 2012) and the end of week twelve (10th April 2012). Re-measurement at six weeks was specifically chosen as a set interval to assess for change in Multifidus CSA. Previous studies used a 12 week interval (Stubbs *et al.,* 2012) but it would be beneficial to examine if there is CSA change in a shorter time frame. This would have application if the exercises are to be used in the therapy industry. The horses' weights were recorded from the measurements collected at the yard at these times. The exercise training programme undertaken by each horse was recorded on a daily basis.

3.16 Ethics Approval and Risk Assessment

Ethics approval for this study was obtained from Plymouth University, School of Biomedical & Biological Sciences. A health and safety risk assessment was also completed and both documents are in Appendix One.

3.17 Statistical Analysis

The raw data collected were collated in Microsoft Excel 2010 and descriptive statistics applied initially to explore the results. For further analysis data were transferred to Minitab v 16. All data were tested for normality using Andersen-Darling test of normality prior to further inferential quantitative statistical analysis. Pearson Product-Moment Correlation test was used to test the association between the measurements of Multifidus CSA by ultrasonography and dorsal thoracic profile CSA. Paired t-test (two tailed) was used to test for differences between Multifidus CSA in the experimental and control groups, and general linear module AnoVa tests were used to examine the data in relation to the group and the time factor. Significance values were set at alpha = 0.05 for all statistical tests.

3.2 Results

3.21 Multifidus CSA

All twelve horses included at the start completed the trial. There were no training injuries reported in any of the subjects, in either the experimental or control group, by the trainer and no unplanned changes to each horse's day-to-day management or exercise programme.

Measurements were taken on day 0, day 42 and day 84. Measurement dates coincided with the start of week 1 of the trial, week 6 and week 12. The day within the weeks 6 and 12 for data collection was dictated by the availability of the Veterinary Surgeon and Ultrasound scanner. The DME were started on day 1 and continued in the DME group for the 12 week period. Horses in the control group were not subject to intervention by the researcher except for the measurement of Multifidus and measurement of dorsal thoracic profile with the FCR on three occasions.

The CSA of the Multifidus muscle collected at week 0, 6 and 12 were tested with the normality test Anderson-Darling and found to be normally distributed (AD = 0.656, n=72, $p>0.05$). The CSA of the dorsal thoracic profile collected at week 0, 6 and 12 were tested with the normality test Anderson-Darling and the data were parametric (AD = 1.99, n=72, $p<0.05$).

Results from re-measurement at six weeks

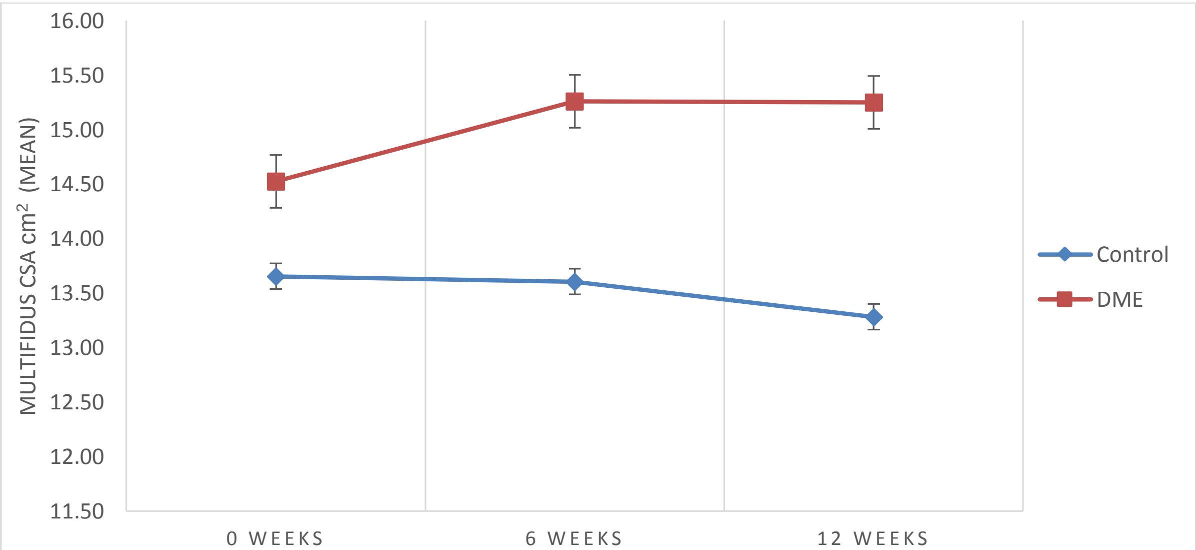
The experimental group, who had undergone DME, had a significant increase in Multifidus CSA (time 0 weeks: mean 14.52±1.64 cm^2 vs. mean 15.26±1.05 cm^2 after 6 weeks; $t_{10}=0.04$; $p<0.05$) in both the left and right sides; whilst no significant change was observed in the control group (time 0 weeks: mean 13.65±0.82 cm^2 vs. mean 13.61±0.78 cm^2 after 6 weeks; $t_{12}=0.88$; $p>0.05$).

Results from re-measurement at twelve weeks

A significant difference between the experimental group and the control group was present at the final measurement ($F_{2, 69}$=41.11; $p<0.05$). One experimental horse was excluded from the analysis at week 6, following an anomalous 20% CSA reduction which was reversed at 12 weeks. The error was regarded to be due to the horse's behaviour at the time of the measurement via US. The horse did not stand still for the required period and the Vet was unhappy to repeat the measurement at that time.

There was no significant change in CSA for the control group between six to twelve weeks (time 6 weeks: mean 13.61±0.78 cm^2 vs. mean 13.28±0.52 cm^2 after 12 weeks). There was no significant difference between Multifidus CSA at 6 to 12 weeks (time 6 weeks: mean 15.26±1.05 cm^2 vs. mean 15.42±0.78 cm^2 after 12 weeks).

The change in Multifidus CSA for the experimental group at six and twelve weeks is shown in Figure 3.1 along with the CSA of the control group.



The lines on the graph show the mean Multifidus cross sectional area (CSA) at measurement times 0, 6 and 12 weeks with standard error represented. The higher red line (square makers) display the average data for the experimental group in which the horses (n=6) undertook a programme of Dynamic Mobilisation Exercises (DME). The lower, blue line (diamond markers) shows the CSA measurements for the control group of horses (n=6)

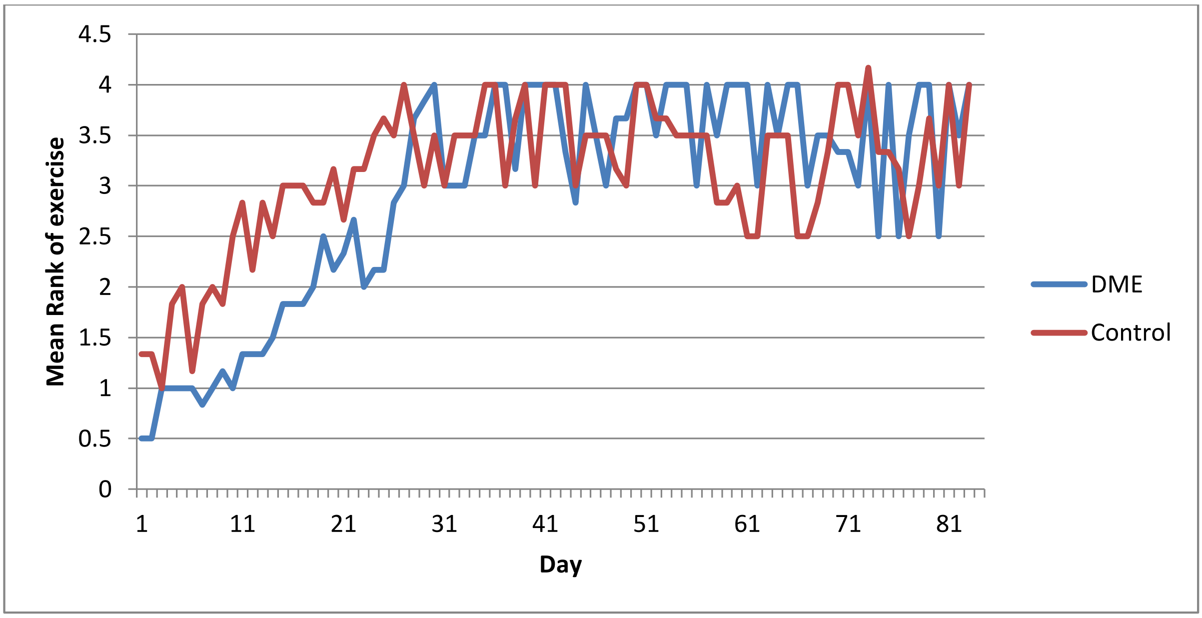
Figure 3.1: Mean Multifidus CSA (cm^2) at 16th Thoracic Vertebrae level in the experimental and control groups at 0, 6 and 12 weeks.

3.22 Exercise level

The level of exercise was ranked in order of intensity on a self-derived scale and given a number to relate to that level of exercise (Table 3.1) and the mean exercise intensity for each group per day was derived and recorded (Figure 3.2). There was no significant difference between the intensity of exercise for the experimental and control groups during the 12 week duration of the DME programme (t_{162}=-1.13; $p>0.05$). Three horses were considered by the trainer to have gained enough fitness to race by week 12 and all three of these horses were in the experimental group.

Exercise	**Rank**
Rest	0
Walker or ridden Walk and &Trot	1
Single Canter	2
Two Canters	3
Three Canters	4
Race	5

Table 3.1. Ranking of daily exercise level of Thoroughbred racehorses in the experimental and control groups.



The lines on the graph show the mean daily exercises (derived from rank of exercise level) in horses that undertook a 12 week programme of Dynamic Mobilisation Exercises (DME) in the experimental group (n = 6) and the control group (n=6) from Jan 4th 2012 for 14 weeks.

Figure 3.2: Mean rank of exercise level per day for the experimental and control group

Symmetry of Multifidus

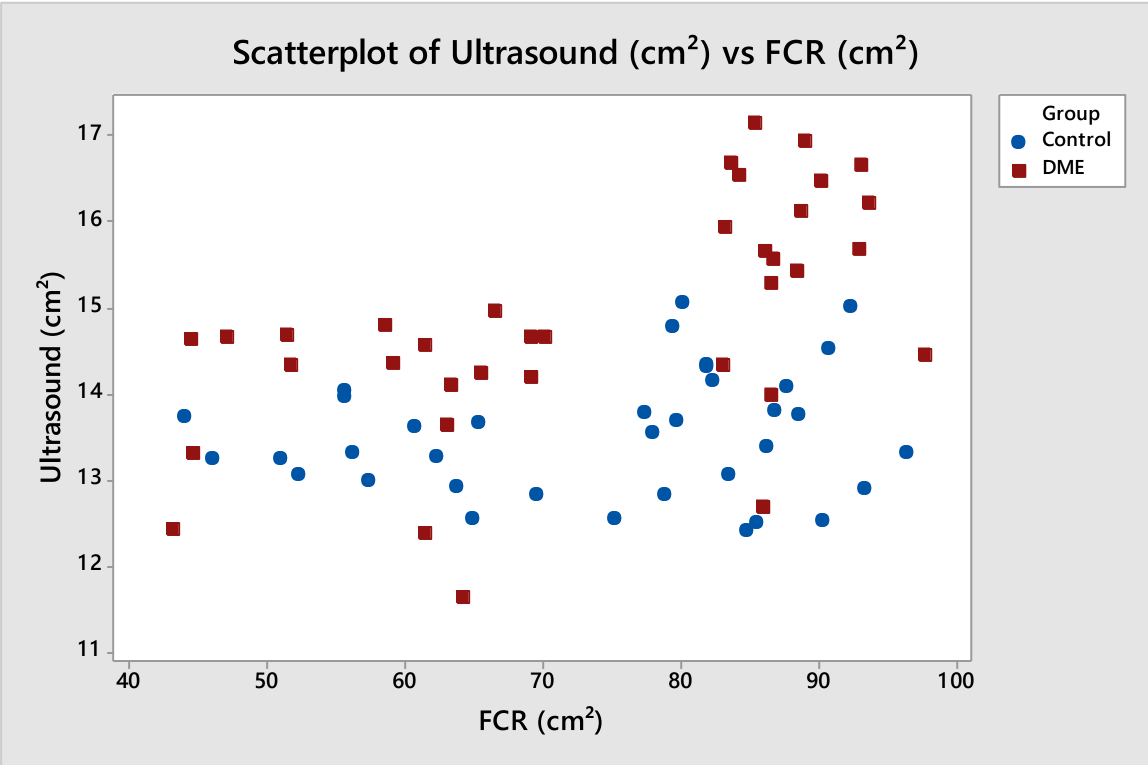
There was no significant difference between the CSA of left and right Multifidus (t_{35}=-0.72; p>0.05) when measurement at week 0, 6 and 12 were combined for the experimental and control groups.

Weight

All twelve horses experienced a weight reduction during the 12 week period. The mean percentage reduction in weight in the experimental group was 3.38±1.85% compared with the control group 3.78±1.94% (t_8=0.14; p<0.05).

3.23 The Relationship between Dorsal Thoracic Profile CSA and Multifidus Muscle CSA.

Pearson Product Moment Correlation was conducted on the mean of the left and the right Multifidus CSA measured by US and dorsal thoracic profile CSA at T16 as measured by FCR (r_{22}=0.344; p>0.05). The coefficient of variation of the area measured by FCR ranged from 0.38-4.71%. The Pearson Product Moment Correlation demonstrated no significant relationship between the Multifidus CSA measured by ultrasound imaging and the external profile CSA when measured with a FCR at T16 (see Figure 3.3).



Scatter plot illustrating the relationship between the mean right and left measurement of Multifidus by ultrasound imaging (US) (blue round markers) and the measurement of the thoracic dorsal profile by Flexible curve ruler (FCR) (red square markers) in each horse (n=12) in both the experimental and control groups at week 0, 6 and 12.

Figure 3.3: Scatter plot of mean right and left CSA measured by US and FCR

3.3 Study One Discussion

The results of this study show that there was a significant increase in Multifidus cross sectional area (CSA), after six weeks of performing Dynamic Mobilisation Exercises (DME) in the experimental group, whilst there was no significant change was observed in the control group. Therefore the increase in Multifidus CSA appears to be in response to the DME and not to the exercise training programme undertaken by both groups. This result corresponds with findings in a convenience sample of elite cricketers (human) with low back pain, who showed an improvement in Multifidus CSA after a 13 week specific exercise programme compared to a control group who did not receive rehabilitation (Hides *et al.*, 2008b). The increase in CSA in the equine is also comparable to the findings of Stubbs *et al.* (2011), although in their study the horses were on box rest for the duration of the three month experimental exercise period and there were no control subjects.

The DME continued in the experimental group for twelve weeks and the horses in both groups followed a similar racing exercise training programme during this time. However there was no further increase in Multifidus CSA in the experimental group when measured at twelve weeks compared with the measurements taken at six weeks. These results could be due to the maximal change in CSA of Multifidus occurring during the first six weeks and there was no potential to further hypertrophy from this point. Alternatively the demand for Multifidus activity was not increased via the DME to sufficiently stimulate further increase in CSA. This suggests the maximum change in muscle activation during the DME occurs within the first six weeks of a programme of DME

A reduction in body weight during the 12 week period was observed in both the experimental group and the control group. This was a goal set for the horses, by the trainer, during the training programme as during the rest period before the start of training the horses had increased weight. The ideal weight for each horse when it reaches peak fitness is set based on the weight the horse's best performance in the previous season. For unraced horses this ideal weight is unknown but is described at approximately level 2 of 5 body condition score (Carroll and Huntington, 1988; Millman, 2012). As there was no significant difference between the groups, the reduction in the weight of the horses was not considered to have influenced the change in CSA of Multifidus.

A limitation of this study is that further measurements of the Multifidus CSA were not possible after the end of the DME period. Ideally further measurements at eighteen weeks, i.e. after the cessation of the DME exercises at twelve weeks, would have revealed whether the increased Multifidus CSA had been maintained during this period. The horses in both the control and experimental groups would have continued their training and all would have raced during this period. Repeat measurements were not possible after twelve weeks due to availability of the horses and cost of the ultrasound imaging. One subject had been sold, and two were removed from training due to injuries unrelated to this study, one from the experimental and one from the control group.

With six horses in each group of the DME part of the study the sample size was small and a larger sample could have produced results with a greater external validity. However, the sample size was limited by the availability of horses and the financial constraints regarding access to the veterinary surgeon and the ultrasound imaging equipment. The sample size used in this study is however comparable with Stubbs *et al.*, (2011) and unlike the Stubbs *et al.* (2010) study, also included a control group. To extrapolate the results to the general horse population repetition of the DME programme on a group of mix breed horses and those undertaking exercise based on difference disciplines, for instance dressage and show jumping, would be warranted. This would then allow identification of the breed/size that responds to the DME greatest, or indeed demonstrate that the outcome for any type of horse is similar.

For human patients following specific Multifidus training programmes, the exercises were only repeated twice a week for four weeks (Hides *et al*. 2001), compared with the five times a week for horses in both this study and Stubbs *et al.* (2011). This warrants further enquiry into the minimum repetitions needed to gain observable benefits in the equine spine. A shorter timescale and less frequent intervention may aid compliance with the programme and relate to possible economic factors regarding time spent repeating the exercises with the horse.

There are the obvious differences of spinal orientation and Multifidus alignment between a biped human and quadruped equine but the muscle fibre arrangement and function appears to be comparable (Stubbs *et al.*, 2006). However the results from this study support the theory that changes in Multifidus following specific exercises programmes are consistent between human and equine species. Objective measurements of these changes have been recorded by ultrasound imaging in equines but in humans reporting of effects such as pain reduction and functional improvements are also included in the measurements taken. It would have been interesting to record functional outcome in terms of results from racing from the racehorses in the experimental group and compared that to the control group. However, this was not chosen to be done as part of this study due to the variables that would have confounded the results. One such variable is that the interval that the horses' race during a season is not consistent due to the scheduling of the race calendar and the owners' choice and another is the demand in each race due to the race horse handicapping system.

3.31 Measurement of Multifidus using Ultrasound Imaging

The US technique used to measure Multifidus CSA has been shown to be repeatable and a valid measure (McGowan *et al.*, 1997; Tabor and McGowan, 2002; Stubbs *et al.*, 2011) but the equipment used is very expensive. For this study a portable device (Make: My Lab Five VET) was used and this costs approximately £15,000 plus the training of the operator. In this study the measurements were taken by a veterinary surgeon who had 20 years' experience using the US equipment.

The veterinary surgeon was blinded to the grouping of each horse, in order to avoid bias occurring when taking the measurement of Multifidus. This effect would not be able to be measured unless repeated measures were carried out by more than one veterinary surgeon. In the study by Stubbs *et al.* (2011), which also examined Multifidus CSA change over a fixed period of time post DME, the examiner was also blinded to the horse and level being measured but as there was no control group in this study bias towards change over time may have existed. In the current study the veterinary surgeon took the measurements at the prescribed time intervals so whilst an effect of time may have been present, by not knowing the grouping of the individual horses, this could not have biased measurement.

The DME used in this trial were chosen as they are believed to activate Multifidus in the equine, as part of the ‘core muscle’ group as discussed by Stubbs *et al.* (2008). In human trials, Hides *et al.* (2001) selected their exercises on the basis that they activate Multifidus contraction, in co-contraction with the Transversus Abdominus (TrA) muscle. This was confirmed by firstly palpating the change of the muscles during contraction and subsequently visualising the movement of the muscle on the ultrasound screen (Hides *et al.,* 2001). Progression of research from using ultrasound imaging to identify muscle contraction to using the image to provide visual feedback to the subject has been shown to increase the skill of the patient in contracting Multifidus (Van *et al.*, 2006). This visual feedback would not be relevant to the equine subjects in this trial but visual feedback for the handler as they facilitate the horse to perform the DME. Providing visual feedback of the muscle activation by observing the muscle activation on the ultrasound screen, would ensure best practice of repetition of the exercise, for instance when maximal muscle contraction has occurred at the end of range. Ten different DME were used, as per Stubbs *et al.* (2011), and it is not known if all or only some specific DME activated Multifidus. The response of Multifidus to individual DME could be qualified by real time ultrasound imaging. This may enhance the specificity of the exercises and reduce any time spent repeating DME that do not activate Multifidus.

One method of contracting the ‘core muscles’ described in the Pilates method lay texts, such as Gavin (2002) and Herdman (2003), and is described as actively engaging the pelvic floor muscles at the same time as hollowing the lower abdominals to engage the TrA. This terminology has been more recently labelled the ‘abdominal hollowing exercise’ (Henry and Westervelt, 2005) or the ‘abdominal drawing-in manoeuvre’ (Teyhan *et al.*, 2005). In the horse the pelvic floor musculature has a different role to that in the biped upright human and is therefore not comparable. To date there are no published studies on horses that have measured the activity of the Internal Oblique muscles, the External Oblique muscles or the TrA muscle during either active or reflexive movement activity. Theoretically activation of these muscles in horses could be observed via real time ultrasound imaging when exercising as they are in humans (Henry and Westervelt, 2005; Teyhan *et al.*, 2005).

3.32 Multifidus CSA in the Control Group

The control group did not demonstrate an increase in Multifidus CSA despite undergoing the racing exercise training programme which was progressively demanding over the 12 week period. There was no correlation between stage of exercise programme at 0, 6 and 12 weeks and the size of Multifidus in either group. There are a few possible hypotheses into the reason that the Multifidus did not increase in CSA in the control group. Firstly, as in Daneels *et al.* (2001) study, the training programme was not sufficiently intense to cause physiological adaptations, such as increased muscle mass/hypertrophy. Although the type of exercise was recorded and the exercise intensity ranked, it was not measured during the study period and the exercises training programme may have benefited from collection of velocity and heart rate measurements.

Both groups of horses were undergoing a normal programme of flat race training using a progressive exercise programme. The training programme started with sessions at walk, then ridden walk and trot before introducing canter. The rate of progression of exercise and the rate of improvement in fitness, was determined by the racing trainer. This was based on anecdotal experience of the trainer and not on objective physiological markers such as heart rate or blood lactate accumulation. If these markers were used then standardised exercise tests, such as those used by Barrey *et al*. (1993) and Courouce *et al.* (1999), could have determined if the fitness of each horse was improving and between horse comparisons could have been made. Simple electronic devices are readily available that can record velocity and heart rate monitors that transmit data can be used to assess for V200. V200 is the velocity that corresponds to a heart rate of 200 beats per minute and this has been shown to be close to V4. V4 is calculated as the velocity at which the blood lactate accumulation reaches 4 mmol/L and it is related to racing performance and is reported to be an important measurement for the assessment of fitness (Courouce *et al.*, 1997 and 1999). Both V200 and V4 can vary depending on training or disease status and can be used to help a trainer monitor the horses' performance and provide information to confirm the appropriateness of the intensity of the training programme. These measures can also in the early detection of underlying diseases (Courouce *et al.,* 1999). The trainer of the horses used in this study was confident in his ability, which he reports was learned through many years of experience, that he was appropriately progressing the training of each horse (Millman, 2012 personal communication). Setting up the system required to monitor V200 would require significant resources, especially time and finance and the trainer did not wish to alter his current method of monitoring the training to increase the horses' fitness. This means that during this study there was no objective measurement of effort during the trial. However, the horses were randomly allocated to the groups and each contained a range of ages and sexes. The outline of the exercise programme, for instance which gait and distance each horse worked each day, was not significantly different between the groups. Therefore it would not be considered that the exercise training programme had an effect on Multifidus CSA in either group. If the hypertrophy in the Multifidus muscle was due to increase in load, an increase in its CSA would have been seen in both the experimental group and the control group. In this study the CSA of Multifidus in the control group did not significantly increase after either 6 or 12 weeks of training. It did, however, increase in those horses that undertook the additional DME exercises.

3.33 Muscle Control of the Equine Spine

Alternative possibilities for the lack of significant increase in Multifidus CSA in the control group are firstly that the exercise training programme did not create a large enough challenge to the body to activate the Multifidus muscle. This theory is suggested based on the results from Daneels *et al.* (2001) where a low level activation was not sufficient to reverse Multifidus atrophy in patients with chronic low back pain but a strengthening programme in combination with the stabilisation programme did restore the CSA. Secondly the lack of significant increase in Multifidus CSA was due to demand for stability of the spinal column being supplied via activation of other muscles, for instance Longissimus Dorsi (LD). If LD was maximally recruited, then Multifidus may not have been active to the level of overload, therefore not stimulating a physiological response and hence an increase in CSA. There is no evidence within equine literature regarding this but the presence of pain or pathology in the case of low back pain in humans has been reported to create this form of dysfunctional sequences of muscle contraction. Early and dominant multi-joint trunk muscle (Erector Spinae/LD) activation can lead to delayed or weak recruitment of the smaller and deeper stability muscles (Multifidus) and this has been termed muscle imbalance (Comerford and Mottram, 2001).

Electromyography (EMG) studies have shown that during locomotion the superficial epaxial muscles in the equine spine are active (Licka *et al.,* 2009; Cottriall *et al.*, 2009) and Licka *et al.* (2004) suggest that LD appears to function to stabilise the vertebral column against dynamic forces. EMG measurement of the LD and Multifidus muscle in the canine spine was considered by Schilling and Carrier (2009) to be a result of the increased need for the epaxial muscles to stabilise the trunk against moments imposed on the pelvis by extrinsic muscles of the hindlimb. This experimental evidence supports the theory of Panjabi (1992a) that the spine is stabilised by the active subsystem which consists of the surrounding muscle and tendons i.e. the epaxial muscles. The activity of the epaxial muscles increased with speed (Licka *et al.*, 2004) and with load (Shilling and Carrier, 2009). However the activity of Multifidus during gait via EMG has not been studied in the equine spine. It may be possible that the contraction and therefore splinting action of the LD muscle, with increasing speed, to stabilise the spine, negates the requirement for Multifidus to be maximally active and hence the lack of hypertrophy as a response.

In human patients with chronic low back pain, general stabilisation exercises and dynamic intensive lumbar training had no significant effect on the CSA of Multifidus (Daneels *et al,*

2001) although Hides *et al.* (1996) previously reported that their programme of training had increased the CSA of Multifidus in patients with acute low back pain. Daneels *et al.* (2001) hypothesised that these differences may partly be due to the specifics of the exercise programme but also due the possible differences between acute and chronic low back pain. It was suggested that in chronic back pain the recovery of Multifidus may be hampered by the changed recruitment patterns and muscle imbalance so other muscles become active instead of the Multifidus to compensate for this lack of activity. The relationship between the activity of the two epaxial muscles, LD and Multifidus, in the equine spine has not been measured, therefore in the equine suggesting compensation patterns would be anecdotal.

LD is active monophasically during the walk stride and biphasically during trot in the horse (Licka et al, 2009). In the canine the activity of the epaxial muscles in trot was also found to be biphasic per stride and bilateral, having a large burst of activity during the second half of the support phase of the ipsilateral hindlimb and a smaller amount of activity during the second half of the swing phase of the contralateral hindlimb (Shilling and Carrier, 2009). If, as quadrupeds, the activity of the epaxial muscles in the canine and equine are comparable, then their function would also be to stabilise the spinal column and pelvis against vertical and horizontal components of the hindlimb extrinsic muscles. This theory is supported by Stubbs *et al.* (2006) who reported that equine anatomy of Multifidus is comparable to that of man and therefore the response to exercise would potentially be similar.

Extrapolating from human research can provide suggestions for the detailed understanding of the function of this muscle in the equine spine. The activity of Multifidus, in response to rapid arm movements in humans, along with other trunk muscles such as TrA, have been shown to occur in advance to the limb movement (Moseley *et al.*, 2002) and different layers have been shown to have a different timing of activation. The deeper layers of Multifidus and TrA were activated independently to the direction of arm movements whereas the superficial layers of trunk muscles were active in response to the direction of the arm movement.

Measuring the CSA of the whole Multifidus using the method in this study is not specific to either the superficial or deep layers and cannot allow for measurement of change within these portions of the muscle in equine spine. Therefore the changes shown in the horses that undertook a programme of DME in this study may have had changes to the deep or superficial fibres, or a contribution could have been from both. However, it would be sensible, when using DME, to expect response from the deep fibres to control the intervertebral motion and the superficial fibres to control spine orientation (Moseley *et al.* 2002) due to their position being either close to or further away from the centre of rotation of the intervertebral joints (Macintosh and Bogduk, 1986; Stubbs *et al.,* 2006). Increases in either the deep or superficial fibres would cause total CSA changes throughout the whole muscle. On human skin EMG electrodes provide meaningful data collection to allow selection of specific exercises for stabilisation of the spine (Ekstrom *et al.* 2007) but until a study is conducted with fine wire needle EMG on horses, selecting one or more of the DME to target a specific response may be limiting the potential beneficial effects. Fine wire EMG is required due to the depth of the muscle fibres in the equine and using electrodes inserted into the muscle would reduce potentially confounding 'electrode noise' due to hair coat and skin at superficial collection sites. However fine wire needle EMG is invasive and therefore difficult to gain experimental approval, plus would require substantial veterinary involvement due to law as stated in the Veterinary Surgeons Act (1966).

The complexities of the activation patterns of TrA and its role within the presence of back pain have been under debate (Allison and Morris, 2008; Hodges, 2008; Lederman, 2010) but the effect of exercise programmes targeting the activation of this muscle in specific populations of patients with low back pain are positive (Hodges, 2008). A more recent review of the evidence in humans finds that motor control exercises have a favourable outcome compared with general exercise, manual therapy and minimal intervention (Freeman *et al.* 2010). Acknowledging that rehabilitation should not just target one muscle Hodges (2008) comments that the use of measures of TrA and Multifidus can serve as a marker of dysfunction in the spinal system. This warrants further use of Multifidus measurements to assess and record changes in the spine, with the design of exercise programmes that target the whole spinal system in both human and equine subjects.

The DME required the horse to move their neck and their trunk to reach for the bait which was a food treat to encourage the movement. The muscular activity required for the movement may be responsible for the increased demand on Multifidus in the DME group and the subsequent change in muscle CSA. The perturbation created by the DME may have required a different pattern of activation of Multifidus due to large range of movement (ROM) which includes flexion and extension as well as both rotation and side flexion. The ROM that the spine achieves during the movements required in the DME, although not measured in this study, has been shown to be greater than that during a normal gait cycle at walk, trot or canter (Clayton *et al.,* 2010). The movement range during DME varies through flexion, extension and lateral flexion which includes joint rotation and therefore not repeating all of the ten DME may reduce the stimulus to Multifidus and therefore potential benefits to the spine.

The deep muscles in the equine cervical spine have been described by Rombach *et al.* (2014c) during investigation into the relationship between pain, cervical pathology and muscle atrophy. The authors report that neck pain in humans causing atrophy of the cervical portion of Multifidus and Longus Colli and therefore they speculate this occurs in the horse. According to Rombach *et al.* (2014a; 2014b) the measurement of the CSA of these two muscles using ultrasound imaging in the live horse is reliable, based on the accuracy when comparing magnetic resonance imaging to ultrasonographic measurements. Investigation is now needed of the cervical portion of Multifidus and Longus Colli in horses with known pathology and then compared that to horses with normal cervical spines. This data will provide information on the cause and effect of neck pain in the horse and allow the assessment and translation of management practices from human medical and physiotherapy practice to equine veterinary and physiotherapy practice. The pattern of movement during DME creates a large cervical ROM (Clayton *et al.,* 2010; Clayton *et al*., 2012) and being shown to increase the CSA of

Multifidus in the thoracic region in this study and in the lumbar region (Stubbs *et al.,* 2011), it could be hypothesised that a similar effect would be seen in the cervical portion. Measurement of the effects of DME to the cervical Multifidus was outside of the objectives of the current study. However, DME could potentially have benefit to deep stability muscles in the neck and therefore have a role in the prevention and management of neck pathology in the horse.

3.34 Osseous pathology

The lack of change in Multifidus CSA in the control group could be due to the presence of osseous pathology at the level being measured. A significant relationship between the atrophy which creates asymmetry of Multifidus and the side of osseous pathology has been documented in 22 horses presented for euthanasia (Stubbs *et al.*, 2010). In the 12 horses used in this study no investigation was carried out to assess for pathological changes in their thoracolumbar spines although there were no significant differences between the CSA of Multifidus on the left and right sides of the 16th Thoracic vertebrae. However it could be possible that mild osseous changes were either present or developing as this type of skeletal pathology appears to be commonplace in racing thoroughbreds (Haussler *et al.,* 1999; Stubbs *et al.,* 2010). Therefore in order to exclude the presence of mild osseous pathology in the horses used further diagnostic investigation would have been necessary.

3.35 Lameness

The 12 horses used in this study were all in full work and there were no reports of altered movement or lameness during the trial period. However, there could have been a mild lameness, affecting back movement and hence the activity of the epaxial group, limiting normal hypertrophy through training. A mild lameness would lead a horse to slightly alter its gait pattern without it being visible to the human observer so called ‘sub clinical’. Even when lameness is visible to the observer there is reportedly only low agreement on the amount and the limb it is observed in (Keegan *et al.,* 2010). Altered movement and back pain secondary to the lameness may lead to alterations in the epaxial muscle function (Alavrez *et al.,* 2007;

2008) and subsequently response to training. On a subclinical level this may have affected the horses in this group but would be expected to be equally as likely to affect both groups as there was random allocation of the subjects to the experimental and control groups. The horses used in this study had regular gait monitoring by a veterinary surgeon and by a physiotherapist who did not report any presence of lameness. However a full lameness evaluation with diagnostic investigations was not carried out during the trial period.

3.36 Change in Range of Movement

The DME take the horse's cervical, thoracic and lumbar spine through a large ROM. In this study the horses were positioned in the corner of the stable so they could not cheat and move their feet to reach the food that was being used to encourage the movement. At the end of the movements of chin to flank and tarsus, between knees and fetlocks movement the horses were observed to have to alter their body position to reach to the food. Movement of the cervical spine in the median plane to reach between their legs results in a flexion movement (Clayton *et al.*, 2010) and a combined rotation/side flexion occurs in the spine during the lateral DME (Clayton *et al.,* 2012).

An observation during the programme of DME was that the ROM in the cervical spine increased during the repetitions over the initial six week period, despite these exercises differing from passive stretches (Clayton *et al.*, 2010). The ROM was not measured, either at the start of the DME, after a single session of DME or to assess for change over the duration of the DME programme. Measurement of ROM required kinematic analysis, either in 2D for flexion extension in the sagittal plane or 3D for lateral movements that are a combination of side bend/flexion and rotation. To record meaningful data, markers need to be placed on the horse and, using video or equipment such as 3D PROREFLEX camera, software can be used to quantify the excursion of these markers (Faber *et al., 2001 and 2002)* as in the studies by Licka and Peham (1998), Alvarez *et al.* (2007 and 2008), Clayton *et al.* (2010 and 2012), Johnston *et al.* (2004) and Wennerstrand *et al.* (2004). Kinematic analysis was not accessible during this study although it would have added further objective support to the rationale for using DME in horses.

A continuation of this study would be to measure the effects of the increased Multifidus CSA, along with any change of spinal ROM, as a result of the DME. Examination of the gait of horses, that have undergone a programme of DME, would allow a link between the findings in this study and their effect of performance of the horse.

3.37 Motivation to Perform DME

An issue that did arise in this study was with the choice of bait as a reward. Some horses did not find the value of the ‘bait’ large enough to be rewarding. Cooper (1998) discusses the relationship between value food reward and motivational state. The value of the food reward depends on their motivational state, with satiated horses less responsive to a food reward that a hungry horse. Horses in race training are fed a diet of concentrate feed at regular intervals during the day and the DME exercises were conducted in the afternoon, approximately two hours following the horses’ previous feed. Some of the feed was still in the feed buckets which would suggest that the horses had ingested an amount that had satiated them. This was anecdotally linked with the reduced desire to follow the carrot to perform the DME. In these cases the ‘bait’ was changed to an alternative reward such as a Polo mint. This was found to create a higher drive to perform the DME in horses that were not motivated by carrots. Polo mints were not used instead of carrots in those horses that did respond to carrots as a bait, because of the increased cost and also the increased chance of injury due to biting of the hand holding the Polo mints. Where carrots could be held with fingers away from the horse’s mouth, the Polo mints needed to be held flat on the palm, or between finger tips to make them available to the horse, but with the operators hands and fingers close to the horse’s mouth, lips and teeth.

3.38 Relationship between the Dorsal Thoracic Transverse Profile and Multifidus CSA

The LD muscle is active during walk, trot and canter (Licka *et al.*, 2004; Cottriall *et al.*, 2009; Licka *et al.*, 2009), and hence would be active during the exercise training programme in the study horses. The LD muscle overlies Multifidus in the equine thoracolumbar spine and being superficial, the external dorsal transverse profile of this region of the spine changes with changes in LD shape and size. Multifidus is deep and medial to LD and not visible by the human eye, but changes in Multifidus CSA may have impacted on the shape of LD. The relationship between changes in LD CSA and Multifidus CSA has not previously been studied.

Saddlers often use the FCR to record changes in the thoracic profile but this is for a saddle that is to sit over the area measured and the individual muscle sizes are not of concern. Greve and Dyson (2013 and 2014) have used the FCR to record the transverse profile shapes of horses under examination for lameness. The width of the transverse profile was recorded at two distances from the top of the dorsal spinous process but it was not possible to evaluate the relationship between individual muscles.

In the second part of this study, two measurement methods used to evaluate the outcome of the DME programme on the thoracic dorsal transverse profile and Multifidus were compared. The CSA of the left and right Multifidus muscle at the T16 spinal level measured by ultrasound imaging and the transverse external profile at T16 measured by FCR were taken at the start of the trial. There was found to be no correlation between the Multifidus CSA measured by ultrasound imaging and the external profile area measured with a FCR at T16. This lack of relationship demonstrated that the FCR was not reliable to use as a measurement tool when assessing for change in Multifidus and therefore to determine whether the DME had an effect on the Multifidus. The FCR measurement takes into account the size of LD plus any adipose tissue that may cover the area plus the dermal and horsecoat thickness. An extension to this study could be to examine the LD thickness, as suggested by Abe *et al.* (2012), for any changes in response to the DME. This, however, requires the use of an ultrasound imaging machine and operator which would require further funding due to the costs involved in this form of measurement.

Chapter 4

Study Two: Measurement of Equine Posture

To be able to quantify equine thoracolumbar posture, and therefore the effects of interventions that may alter the thoracolumbar posture, an objective method of recording is required. A complicated and expensive procedure would not be valuable to the clinical physiotherapist working in the field consequently a simple method to record these data are needed. The following repeatability study was carried out to validate basic two measurement methods to record the thoracolumbar posture in the standing horse.

4.1 Materials and Methods

4.11 Subject selection

Six horses of mixed sex, age and breed were opportunistically sampled from the horses at Duchy College Equestrian Centre, Stoke Climsland, Cornwall, U.K. Each horse wore a headcollar and an experienced handler brought the horse out of their stable to stand on the level concrete area in front of the yard. The assistant was asked to stand the horse 'square' with its weight evenly balanced over its front and hind legs with the feet from the right and left sides aligned as if on parallel lines and this position was maintained throughout the period of time when measurements were taken. The horse was positioned with a neutral head and neck position which was achieved when the horse's neck was in line with the thoracolumbar spine with no lateral flexion or rotation and the nose was vertical, with the height of the chin level with the height of the shoulder joint.

4.12 Experimental Protocol

A lateral photograph (P) of each horse was taken from 2m away with a visible marker of known length in the frame. The marker used was a sheet of card, A4 size with dimensions of 280mm by 210mm in five out of six photographs, and a slate square size 205mm by 205mm for one grey horse which the original card would not be visible against this coat colour. These markers were used to calibrate the scale on the photographs during the analysis. After the photograph was taken the horses were returned to their stables. This procedure was repeated three times (P1, P2 and P3) at 30 minute intervals for each horse (Horses A – F).

Two methods of measurement were used to collect data for analysis after the photographs were uploaded onto computer for analysis.

Area Method: ImageJ™ software was used to draw a line following the profile of the dorsal thoracolumbar region and a straight line between highest point of withers and tuber sacrale. The software then calculated the area within the resultant shape, with the marker used to set the scale (Plate 4.1). P1 was measured three times, P2 and P3 measured once.

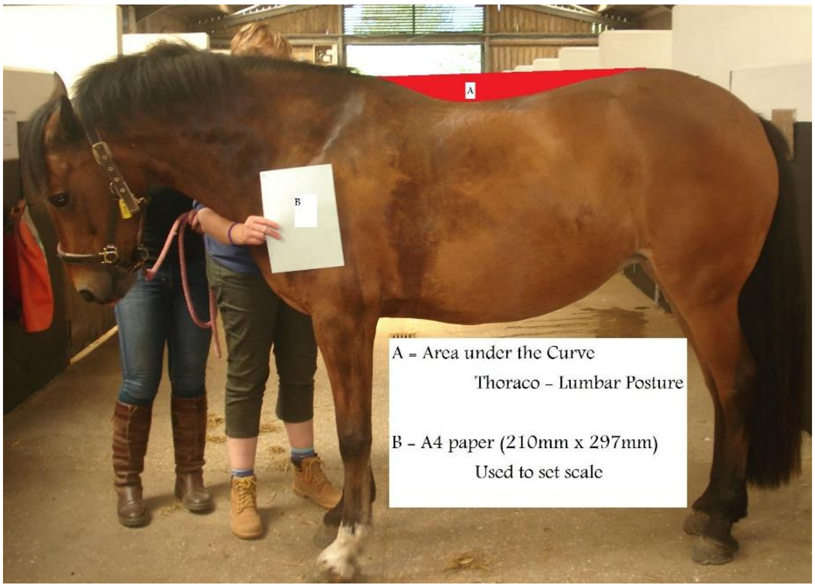


Plate 4.1: Horse F with dorsal thoracolumbar area marked in red.

1) Angle method: ImageJ™ software was used to measure the angle between the highest point of the withers, lowest point of the thoracolumbar spine and the highest point of the pelvis (Plate 4.2). P1 was measured three times, P2 and P3 measured once.

Plate 4.2: Horse F with dorsal thoracolumbar angle marked in blue.

4.13 Single Horse Pilot Study.

A trial with one horse was completed to investigate if the area and angle method of measurement could show any changes of posture over a short time period using Dynamic Mobilisation Exercises (DME). The horse was stood square and head aligned in a neutral position, as previously used. Both the area dorsal to the thoracolumbar region and the angle of the thoracolumbar region were measured in standing using the above method. A video recorder (Panasonic HX-WA30) was used to capture the initial standing position and then three repetitions of DME chin between fetlocks were performed with carrot as the bait, before finishing at the neutral starting position. This specific DME was chosen as it results in the most flexion of the T10 to T16 joints (Clayton *et al.*, 2010). The video was uploaded onto computer for analysis. To take the measurement the video was paused when the horse's nose had reached the greatest movement between the fetlocks and the area and angle of the thoracolumbar region were calculated as before using ImageJ™ software.

4.14 Ethics Approval and Risk Assessment

Approval for use of Duchy College horses was given via the College procedure for working with horses in-hand, Risk Assessment EQ00034 (Appendix one).

4.15 Statistical Analysis

The raw data collected for this part of the study were collated in Microsoft Excel 2010 and descriptive statistics applied initially to explore the results. For further analysis data were transferred to Minitab v 16. All data were tested for normality using Andersen-Darling test of normality prior to further inferential quantitative statistical analysis. Pearson Product-Moment Correlation test was used to test the association between the measurements of the dorsal thoracolumbar area and the dorsal thoracolumbar angle. The AnoVa test was used to examine the data for differences in repeated measures. Significance values were set at alpha = 0.05 for all statistical tests.

4.2 Results

4.21 Repeatability of Dorsal Thoracolumbar Profile Measurements

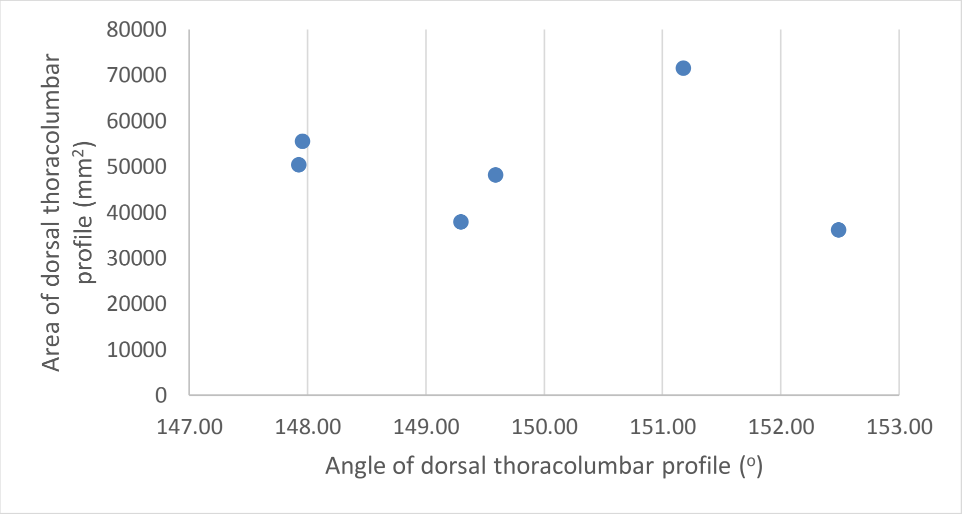
1) Area of dorsal thoracolumbar profile

The data were normally distributed (AD = 0.273; n = 18; p>0.05) and there was no significant difference in repeated measurement of Photograph (P) 1 ($F_{2, 15}$=0.01; p>0.05). No significant differences were seen between the measurements of P1, P2 and P3 ($F_{2, 15}$=0.26; p>0.05).

2) Angle of dorsal thoracolumbar profile

The data were normally distributed (AD = 0.220; n = 18; p>0.01) and there was no significant difference in repeated measurement of Angle (AN) 1 ($F_{2, 15}$=0.67; p>0.05). No significant differences were seen between AN1, AN2 and AN3 ($F_{2, 15}$=0.64; p>0.05).

Pearson Product Moment correlation was conducted on the mean of the area measurements (P1, 2 and 3) and the mean of the angle measurements (AN1, 2 and 3). There was no correlation between the area of the dorsal profile and the angle (r_{11}=0.68; p>0.05, Figure 4.1).

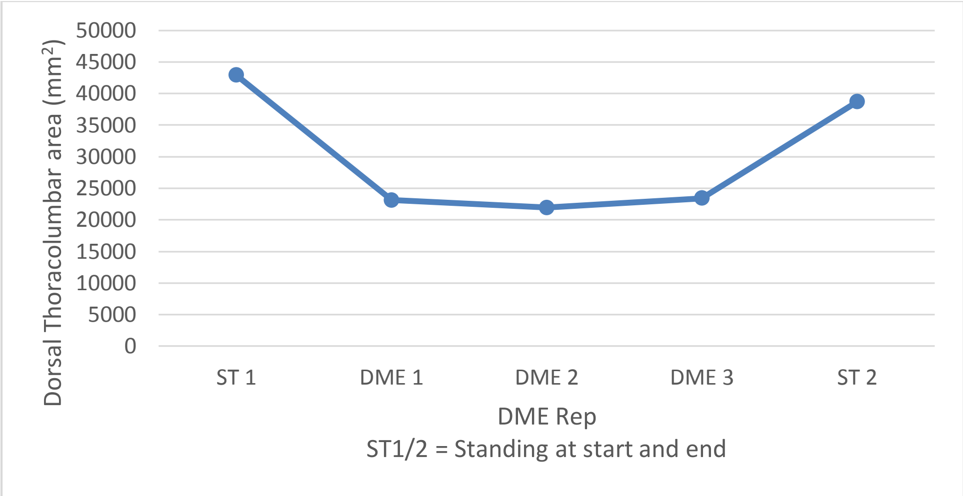


Scatter plot illustrating the relationship between the area (mm^2) and the angle (º) of the dorsal thoracolumbar profile in each horse (n=6).

Figure 4.1 Scatter plot of the area (cm^2) and angle (º) of the dorsal thoracolumbar profile

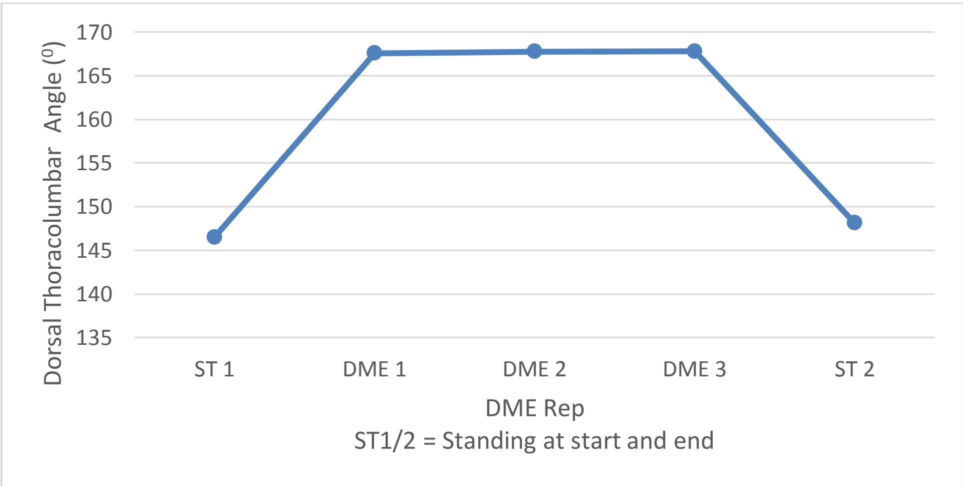
4.22 Single Horse Pilot Study

The thoracolumbar area and angle were measured on one horse stood square (ST1 and ST2) and three repetitions of DME with the horses chin between fetlocks (Plate 3.5, Chapter 3) was repeated 3 times (DME 1, 2 and 3). The area at each stage of the dorsal profile is shown in Figure 4.2 and the dorsal angle is shown in Figure 4.3.



Graph illustrating the thoracolumbar dorsal area (mm^2) measured in standing, at the start and finish, and at the point of maximal movement during three repetitions of chin between fetlocks DME in one horse.

Figure 4.2 Dorsal thoracolumbar area during DME



Graph illustrating the thoracolumbar dorsal angle (^{o}) measured in standing, at the start and finish, and at the point of maximal movement during three repetitions of chin between fetlocks DME in one horse.

Figure 4.3 Dorsal thoracolumbar angles during DME

Both the area of the thoracolumbar profile and the thoracolumbar angle measurements demonstrate a change in thoracolumbar posture when performing DME. Owing to being a single case no further statistics were performed on these results.

4.3 Study Two Discussion

Establishing a method of posture evaluation that would be simple, cost effective and reliable to use in the field, was the aim of this part of the study. The two methods used to establish a simple measure of equine thoracolumbar posture were first, to measure the area between the dorsal thoracolumbar region and a straight line between highest point of withers and tuber sacrale and second, to measure the gross dorsal angle of the thoracolumbar spine.

The starting position for both of these measurements was obtained with care, before the position was recorded for later measurement, via a digital image. This was because the position of the head affects the position of the thoracolumbar spine. The head position is determined by the cervical intervertebral angles and increasing cervical flexion alters the joint angles in the caudal spine (Clayton *et al.,* 2010). In a study by Berner *et al.* (2012) the intervertebral distances between thoracic DSPs was examined radiographically. Twenty-three horses, without clinical signs of back problems, were sedated and radiographed with the mouth positioned level with the shoulder joint, the carpal joint and the withers. A significant effect on the distances between the thoracic DSPs was found with these three difference head positions. The distance between the DSPs, the interspinous space, would have an effect on the position of the thoracolumbar spine. Therefore in this part of the study, it was essential to ensure that the measurements were obtained from a standardised starting point. It can take a significant amount of time, in the unsedated horse, to achieve this position but it would not allow confidence in the results obtained if this procedure was not followed.

To calculate the area of the thoracolumbar posture ImageJ™ software was found to be easy to use and the method was shown to be repeatable. Between the three measures, taken on the six horses used, the horses were returned to their stable for 30 minutes. The interval between measurements was chosen to allow a small amount of movement between obtaining the standardised position but not long enough to have any effect on the thoracolumbar spine. As there was no significant difference between the measures at time 0, 30 minutes and 60 minutes there were not any factors occurring that influenced the posture. Had the horse been interacted with in between measurements e.g. exercised, groomed or fed, the repeatability may be altered.

When using ImageJ™ software to measure the angle of the thoracolumbar profile, finding the highest point of the withers and highest point of the pelvis on each photograph was easily achieved. The lowest point of the thoracolumbar spine was more difficult to identify due to the posture of two of the horses having a flat, horizontal, top line in the mid thoracic region of the spine. Marking the lowest point either more cranial or more caudal would have a substantial large effect on the resultant dorsal angle and hence the low repeatability. In these instances the mid-point of the lowest area was taken as the vertex point, from which to calculate the thoracolumbar angle. A solution to increase accuracy of measurement was considered to be to place a marker on the horse's spine. Prior to a photograph being taken an anatomical landmark, for instance the tip of the T16 DSP could be located and a marker placed on it.

It is important to note that there was no correlation between the area and the angle of the thoracolumbar posture. If using one of these methods to record the profile of the horses' spine, and to be able to use these data to determine changes during a course of treatment, only one could be used. A further study involving pre- and post- test measurements would identify which method is the most suitable method of evaluating the thoracolumbar posture of the spine.

Following on from the repeatability study, to test whether either of these measures could be used to investigate for change in the thoracolumbar posture, a pilot study was conducted with one horse. The Standardised position was achieved and the horse did not move his feet during the chin between fetlocks DME, which was repeated three times and the horse was allowed to lift his head between each repetition. At the maximum ROM of each DME there was a reduction in both the area (between the thoracolumbar spine and horizontal line drawn between the highest point of the withers and pelvis) and an increase in the thoracolumbar angle. These data demonstrated that flexion of the thoracolumbar spine occurs, as this region moves dorsally. This was expected based on the evidence collected by Clayton *et al.* (2012) by 3D kinematic analysis. However, the ability to measure this movement by two methods used in this study has confirmed that a simple method of measuring could now be used to evaluate changes in thoracolumbar posture over a period of time. Exercises to specifically activate and train the isometric holding capacity of Multifidus, similar to DME, have been shown to reduce pain and disability in humans and importantly reduce the incidence of recurrence of back pain compared with subjects in a control group that only received advice and medical management (Hides *et al.*, 2001). Pain and Disability were measured at one and two years post intervention and self-reported by the patient which would not be possible with equine patients. These measurement methods used in this study give the physiotherapist the ability to measure posture changes, in the field, without expensive equipment.

Chapter 5

Relating Study One and Two to Equine Back Pain and Treatment

5.1 Kinematics of Horses with Back Pain

Horses with back pain show a pattern of movement that deviates from the normal accepted standard according to Wennerstrand *et al.* (2004), who studied a group of Warmblood riding horses with diagnosed clinical back pain. The spinal kinematics were then compared to the movements of the back with those previously measured in asymptomatic, fully functioning horses (Johnston *et al.*, 2004). It appeared that the horses stiffened their backs, by reducing dorsoventral movement in the caudal thoracic and at the thoracolumbar junction. Wennerstrand *et al.* (2004) believe that this was the way a horse with a sore back tries to alleviate the pain. In the human spine, experimentally induced low back pain by injection of hypertonic saline into the lumber LD muscle, delays the onset of TrA activation during voluntary arm movements (Hodges *et al.,* 2003). This adds weight to the evidence that there is a change in motor control in patients with low back pain that potentially could compromise spinal stability (MacDonald *et al.,* 2008). Compromised spinal stability could lead to pain and pathology and therefore a situation of muscle imbalance (Comerford and Mottram, 2001) and this altered motor control and therefore muscle imbalance may occur in horses, but requires further investigation.

Unridden horses with back pain, and horses without back pain with weight added to their backs, have a more extended spinal posture during walk and trot (Wennerstrand *et al.*, 2004; de Cocq *et al.,* 2004). The top of the DSP approximate when the thoracolumbar spine is extended (Berner *et al,* 2012; de Cocq *et al.,* 2004), narrowing the interspinous space and potentially allowing the processes to touch. A goal of treatment and rehabilitation of horses with back pain is to reduce this extension and create an increase in flexion throughout the spinal column. This flexion creates rounded posture, known as the ‘outline’, and in ridden horses this is considered the correct posture which assists in the ‘engagement’ of the hinds limbs (Denoix, 2014), which is a performance indicator in dressage horses. Treatment by physiotherapy techniques to increase flexion through the thoracolumbar spine could be monitored by the measurement techniques validated in this study. If the posture can be altered and maintained, and recorded objectively, then the value of any treatment could be evaluated. Whether this posture of the thoracolumbar spine in standing is related to the posture during ridden exercise is yet to be investigated. In theory, if there was a correlation between posture in standing and posture during gait, this could be used to predict performance in a competition horse, or conversely highlight any postural changes that could have a negative impact on the spine.

5.2 Dorsal Spinous Process Impingement (Kissing Spines)

To be able to relate the findings of this study to treatment of horses with back pain, would be a key contribution to the equestrian industry. Being able to measure physiotherapy treatment effects is essential and would help identify the clinical population of horses, which may benefit from using DME during rehabilitation. To do this the pathologies that occur in the spine of the horse must be considered. A soft tissue or osseous pathology in the spine is likely cause pain and this leads to a set of symptoms that is often a cause of an owner requesting a veterinary examination. These symptoms are varied and can be as obvious as the horse bucking the rider off, or a subtle performance issue only apparent when the horse is ridden to a high level. Resentment of tacking up, difficulty in travelling on downhill slopes, unequal lateral bending through the body, knocking poles down when show-jumping, lack of speed and a wide range of behaviour changes are often reported a signs the horse is suffering from back pain.

It is an unfortunate historical fact that horses which had altered behaviour which the owner/rider considered undesirable often meant the horse was euthanized. When horses were required to work and not just be leisure horses it would not be economically viable to rest the horse for a long period of time or to retire the horse. Diagnostic equipment is now available to investigate for a cause of the back pain in many horses that are considered problematic.

When there are behaviour changes in a horse, the majority of owners are keen to determine the cause of this behaviour change. This shift has most likely come because most horses are now kept for leisure purposes (http://www.bhs.org.uk/our-charity/press-centre/equestrian-statistics, 2011) and the welfare of horses is higher in an owners priorities. Additionally the access to advanced veterinary orthopaedic investigations has increased substantially, as has portability of said diagnostic kit. One of the first studies that focused on back pain in the horse, published over thirty years ago (Jeffcott, 1980), reported on 443 cases of horses' referred to the veterinary practice for investigation of back pain. This epidemiological study, although not representative of the wider equine population, as the referrals to this vet practice were all back pain cases and not a random selection of horses with performance issues, noted that in 173 cases there was one presenting pathology. The commonest cause of back pain in this group was impingement of the dorsal spinous processes (DSP) often described as kissing spines (Jeffcott, 1980). This DSP impingement problem occurs either as the horses age, in which case it is it probable that it has been present for some time before clinical signs occur (Walmsley *et al.,* 2002) or as a result of phenotypical factors such as the work of the horse or the management of the horse. Haussler (1999) reported on a series of post-mortem examinations of racehorses killed on the race track and 96% of the 36 horses studied had DSP impingement in the thoracolumbar spine. The horses used in this research trial, as reported in chapter three were racehorses and the evidence from Haussler (1999) suggests a high percentage of this sample may have had this spinal pathology but at the time of the DME programme were not exhibiting pain related symptoms.

Veterinary management of painful kissing spines consists of either conservative, medical or surgical management. Walmsley *et al.* (2002) describes resection of the dorsal 4 – 5cm of the DSP under general anaesthesia, with the horse in lateral recumbency. In this study 72% of 215 cases of impinging DSP associated with back pain were back in full ridden work at follow up, with a further 9% in some form of athletic work. Progressing from the technique used by Walmsley *et al*. (2002), Perkins *et al*. (2005) suggest that the risks of general anaesthesia and haemorrhage warrant the surgery being performed in standing with the horse sedated. In this position there is also improved visibility of the muscular attachments allowing for separation from the left and right surfaces of the DSP prior to a subtotal ostectomy of the affected DSP (Perkins *et al.*, 2005). A novel technique for treatment of kissing spines has been reported by Coomer *et al.* (2012) in which the surgery does not remove the DSP but is an interspinous ligament desmotomy (ISLD) in which the ligament between the affected DSP is snipped. The aim is to relieve tension on the afferent nociceptive receptors located in the ligament insertions and hence abolish the pain. This is then followed by rehabilitation including controlled exercise to release the epaxial muscle spasm and permanently resolve the kissing spines. Coomer *et al.* (2012) has had a 95% success rate following this treatment compared with 42% reported for medical treatment which involved injective corticosteroids into the areas surrounding the impinging DSP, for a group of 68 horses with back pain.

All three surgical methods described to treat this pathology (Coomer *et al*., 2012; Perkins *et al.*, 2005; Walmsley *et al*., 2002) will cut through the epaxial muscles adjacent to the DSP. One of these muscles is the Multifidus and none of these studies mentioned the effect of the surgery on the post-operative function of this muscle. Coomer *et al.* (2012) recorded that an inability to build or maintain epaxial muscle mass is sometimes a sign of kissing spines but did not discuss objective evaluation of the epaxial muscles. Following the ISLD treatment the horse is kept in their box and treated with anti-inflammatory medication. The authors recommend post-operative physiotherapy treatment which includes core strengthening and mobilisation of the spine with baited stretches akin to DME. DME which flex the thoracic spine may be beneficial to horses following this surgery DSP as the tips of the DSP are separated (Berner *et al.,* 2012) and not held restricted together following the ISLD surgery. In the chin to chest DME the cranial regions of the thoracic spine are flexed and with the chin to carpus and chin between fetlocks flexion in the caudal thoracic spine occurs (Clayton et al, 2010). Knowledge of the region with pathology could influence the choice of specific DME chosen for rehabilitation following surgery.

The effect of a programme of DME, on the posture of the thoracolumbar spine, is an important next step for the progression of this research. It would be a significant finding if DME could be shown to improve thoracolumbar posture, thus increasing the space between the DSP, potentially reducing back pain in the horse. One hypothesis to be tested is whether DME can reduced the requirement for surgery in the mild DSP impingement cases where osseous pathology does not limit the available ROM in the thoracic spine. In advanced impingement cases, where the pathology has created a bony union between the tips of the DSP, and surgery is the management choice, the effect of DME post-surgery needs to be evaluated.

Chapter 6

Conclusion

This study aimed to investigate the effect of DME on the CSA of the Multifidus muscle in thoroughbred horses undergoing a normal exercise training programme. A significant increase in Multifidus CSA was demonstrated in the experimental group relative to the control group thus accepting hypothesis one (Ha1). It was also established that there is no relationship between the dorsal Thoracic transverse profile and the Multifidus muscle CSA, rejecting hypothesis two (Ha2). In view of changes in thoracolumbar posture seen anecdotally during this study two methods of objectively measuring equine thoracolumbar posture were trialled and validated allowing hypothesis three (Ha3) to be accepted.

The rationale for using DME within veterinary physiotherapy practice was initially supported by the findings of Stubbs *et al.* (2011) and the results from this study add to existing evidence supporting the use of these exercises in the management of racehorses without back pain. These exercises, in the form of the DME programme, now require further investigation to explore whether they would be appropriate to use in all horses, whether during rest or a rehabilitative treatment programme and for clinically normal horses undertaking a programme of equestrian discipline specific exercise, such as dressage or show jumping.

There were no detrimental effects evident during the experimental period suggesting that DME could be used in horses other than thoroughbred racehorses, for instance continental warm blood dressage horses used for dressage or show jumping or breed types native to the UK, commonly used as children's riding ponies.

Further research is now required to objectively determine whether exercises to increase the CSA of Multifidus benefit horses with back pain. This aligns with the goals of veterinary physiotherapy which are created following veterinary investigation and diagnosis, as well as physiotherapy assessment. These aims are wide ranging and include pain reduction, limitation of the pathology and its subsequent compensatory strategies, restoration of normal movement, correction of neuromotor control and enhancement of function, along with performance in the competitive horse. When treating horses to achieve any of these goals veterinary physiotherapists must be able to demonstrate successful outcomes and this can be done by using technology to quantify the efficacy of their clinical practice. This is essential for the credibility of the profession and its place within the industry, and also both from an economic perspective but more importantly, to achieve a high level of welfare for the horse.

Core stability is not a singular variable and as such, is not able to be measured *ex vivo, in vitro* or *in vivo*. As with the majority of biomechanics, the focus of research has to be on segmenting the elements relating to core stability, such as range of movement, muscle activation, function and pain, and then taking data collected under experimental conditions to understand these component elements, to allow conclusions to be drawn. Starting with the measured effect of the DME on a single muscle, this study aids the construction of the basis to underpin treatment and subsequent management strategies, for equine back pain. DME have been shown to have a positive effect on the Multifidus muscle in the horse and going forward, the effect of DME on the thoracic profile can be critically evaluated using the measurement techniques validated in this study.

APPENDIX ONE

Contents:

1. Project Submission Form for Ethical review
2. Risk Assessment Forms

Ethical Review Committee: Project Submission Form

Project Title & Proposed Start Date	The effect of dynamic mobilisation exercises on equine core stability. 3rd January 2012 – 27th March 2012
Principal Investigator	Dr H. Randle
Other Investigator(s)	Gillian Tabor
Project Objectives	1. Investigate the effect of dynamic mobilisation exercises on the cross sectional area (CSA) of the Multifidus muscle in horses. 2. Evaluate the relationship between the dorsal Thoracic transverse profile and the Multifidus muscle CSA after a programme of dynamic mobilisation exercises. 3. Examine the use of core stability and dynamic mobilisation exercises for horses and their owners/riders.
Species	*Equus caballus*
Nos. of Animals involved	12
Experimental techniques to be used	No Home Office regulated procedures will be used. Each horse will be measured at the start, 6 weeks, 12 weeks and 20 weeks (the end) of the investigation. Data will be collected for a) Cross sectional area of the Multifidus muscle adjacent to the 16th Thoracic vertebral level (T16) via Ultrasound imaging. A veterinary surgeon will use Ultrasound Imaging equipment to take the image and use electronic calliper software to measure Multifidus CSA, as described by Stubbs et al (2011). b) Thoracic transverse profile using a flexicurve rule shaped over the back overlying T14 and this shaped

	traced onto an A3 sheet of paper for comparison of changes of Multifidus CSA and Thoracic dorsal profile c) At the initial measurement session, a) and b) will be repeated three times to assess for repeatability. d) Weight (kg), via an electronic weighbridge, to provide data to highlight possible unrelated changes in the horse's general condition. The horses will be randomly allocated into two groups of six. Both groups will follow the same programme of ridden exercise as determined by their trainer (normal for the time of year / stage of fitness). One group will act as a control and the second will have additional exercises, performed in-hand, by a handler. These will include baited stretches in which the horse moves the chin to a specific position by following a piece of carrot (Stubbs & Clayton, 2008).
Duration of experience of animals	Horses in the exercise group will be with the handler for 10 minutes per day, five days per week, for 12 weeks. Horses in the exercise and control group will be measured as above (a-c), 30 minutes per horse at the beginning and 10 minutes at the following sessions. Total involvement per horse will be 11 hours.
Destination of animals after investigation	The horses will remain in their existing husbandry system after the study has been completed
Housing during investigation	Each horse will be kept in their existing housing – stable with at a minimum of 3.6m x 3.6m with a half door and one or two windows.

Final statement

***Scientific Outcomes*:**

In humans wasting of the Multifidus muscle in the spine has been shown in the presence of back pain (Hides et al, 1994) and exercises to increase Multifidus CSA have been shown to be of benefit in humans and can reduce the incidence of the back pain recurring (Hides et al, 1996; Stokes et al, 1997). Relating to non-humans species Denoix (1998) stated that in horses back pain is a major cause of poor performance and gait abnormalities. In a study of 22 racehorses, all had significant left/right asymmetry of Multifidus CSA and there was significant association between pathological grade and the degree of Multifidus asymmetry (Stubbs et al, 2010). A study by Stubbs et al (2011) has concluded that exercises are effective in increasing the CSA of equine Multifidus, which the authors interpret as being potentially beneficial in the rehabilitation of horse with back pain. This study used eight horses without back pain and during the three month period of the study they were not exercised. This proposed study aims to investigate the effect of exercises on the CSA of the Multifidus muscle in racehorses that are undergoing a normal exercise programme.

It would be useful to measure muscle size, in vivo, using an accurate imaging technique (Hides et al, 1992) as sources of error with some measurement methods include the amount of subcutaneous fat and the inability to isolate individual spinal muscles. Ultrasound evaluation of muscle in this region can offer direct measurement of the size of the Multifidus muscle (Tabor and McGowan, 2002). Despite Stubbs et al (2011) concluding that it is not difficult to measure the CSA of Multifidus, it is unlikely that Physiotherapists in vivo have access to the equipment necessary to measure with ultrasound imaging. As no study has compared changes in external profile, as measured by a flexicurve rule, with CSA muscle change via ultrasound imaging, it would be useful for Physiotherapists to evaluate this relationship.

The final part to this research is to examine the use of core stability and dynamic mobilisation exercises for horses and their owners/riders. Relevant to the above objectives is whether horse owners and riders, who practice core stability exercises themselves, for example Pilates, consider the core stability of their horse. A questionnaire will be used to gain information from a sample of the horse owning population to examine this relationship. This will guide Physiotherapists in the future when teaching horse owners exercises to assist rehabilitation of horses with back pain.

Pain, Distress and Lasting Harm:

The horses will not be exposed to pain, or suffer distress or lasting harm, during the course of the proposed study.

Replacement:

It is not possible to replace live horses with a substitute if the proposed study is to achieve its objectives.

Reduction:

The number of horses proposed for inclusion in this study is 12. Previous comparable studies have used similar subject numbers. This is the minimum needed to generate sufficient data for analysis in order to address the objectives.

Refinement:

This study has been designed to avoid causing the horses any undue distress or suffering. The horses will remain within their usual environment for the duration of the study. For the data collection phase, a Veterinary Surgeon will assess them in their home environment, so as not to compromise the horse's welfare by transporting them to the Vet's practice.

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The effect of dynamic mobilisation exercises on the multifidus muscle in thoroughbred racehorses

A relationship between the spinal stabiliser muscles and back pathology has been established in human and equine studies. Wasting of the Multifidus muscle in the spine occurs in the presence of back pain and the cross-sectional area (CSA), as measured by ultrasound imaging, of Multifidus does not increase despite resolution of the back pain. Exercises to increase Multifidus CSA have been shown to reduce the incidence of the back pain reoccurring in humans. Similarly dynamic mobilisation exercises (DME) have led to an increase Multifidus CSA in horses on box rest. As part of an on-going study of the effect of DME on the core musculature of horses, this study investigated the effect of DME on thoroughbred racehorses in training. Ultrasound Imaging was used to measure the CSA of the left and right Multifidus muscle at the T16 spinal level on 12 Thoroughbred horses (2 mares, 9 geldings, 1 colt; mean age 4.5±1.83 years) randomly allocated to a control group or experimental group which underwent DME. All horses followed the same training regime as determined by their mutual trainer. The CSAs were normally distributed. One experimental horse was excluded from the analysis following an anomalous 20% CSA reduction. DME led to a significant increase in Multifidus CSA (time 0: mean 14.52±1.64 cm^2 vs. mean 15.26±1.05 cm^2 after 6 weeks; t_{10}=0.04; $p<0.05$), whilst no significant change was observed in the control group (time 0: mean 13.65±0.82 cm^2 vs. mean 13.61±0.78 cm^2 after 6 weeks; t_{12}=0.88; $p>0.05$). Further research is required to determine whether exercises to increase the CSA of Multifidus benefit horses with back pain. Effective treatment of equine back pain will improve welfare and performance.

Lay Persons Message Physiotherapy techniques designed to manage back pain in humans are frequently applied to treat equine back pain. Dynamic mobilisation exercises intended to strengthen the muscles that support and control the movement of the spine were applied to racehorses undergoing a normal training programme. These exercises led to an increased size in one of the deep spinal stabiliser muscles, which may assist in prevention and/or reduction of back pain in horses.

Keywords: *Multifidus; equine back pain; spinal stability.*

Tabor, G.F., Johansson, C. and Randle, H. (2012). 'A comparison of measurement techniques of thoracic epaxial musculature in the horse'. *Ninth International Conference of Equine Exercise Physiology, Liverpool, U.K*.

Introduction: A relationship between the spinal stabiliser muscles and back pathology has been established in human and equine studies. Wasting of the Multifidus muscle in the spine occurs in the presence of back pain and the cross-sectional area (CSA), as measured by ultrasound imaging, of Multifidus does not increase despite resolution of the back pain. Exercises to increase Multifidus CSA have been shown to reduce the incidence of the back pain reoccurring in humans. Similarly dynamic mobilisation exercises (DME) have led to an increase Multifidus CSA in horses on box rest. The effect of DME on the Multifidus muscle of thoroughbred racehorses in training was investigated and two measurement methods, used to evaluate the outcome of a treatment or exercise programme on Multifidus, were compared.

Methods: Ultrasound Imaging was used to measure the CSA of the left and right Multifidus muscle at the T16 spinal level on 12 Thoroughbred horses (2 mares, 9 geldings, 1 colt; mean age 4.5±1.83 years) and the transverse external profile at T16 was recorded with a flexible curve ruler (FCR) and the area under the curve was measured (cm^2). Both measurements were repeated 3 times on 12 Thoroughbred horses who were randomly allocated to a control group or experimental group which underwent DME. All horses followed the same training regime as determined by their mutual trainer.

Results: The CSAs were normally distributed. One experimental horse was excluded from the analysis following an anomalous 20% CSA reduction. DME led to a significant increase in Multifidus CSA (time 0: mean 14.52±1.64 cm^2 vs. mean 15.26±1.05 cm^2 after 6 weeks; $t_{10}=0.04$; $p<0.05$), whilst no significant change was observed in the control group (time 0: mean 13.65±0.82 cm^2 vs. mean 13.61±0.78 cm^2 after 6 weeks; $t_{12}=0.88$; $p>0.05$). Pearson correlation was conducted on the mean of the left and the right Multifdus csa and profile area ($r=0.344$; $df=22$; $p>0.05$). The coefficient of variation of area ranged from 0.38-4.71% and there is no relationship between the Multifidus CSA measured by ultrasound imaging and the external profile area measured with a FCR, at T16.

Tabor, G.F. and Randle, H. (2013) 'Validation of a simple method to quantify equine thoracolumbar posture'. *Proceedings of the ninth International Society of Equitation Science Conference.* USA p80

Conformation and postural alignment of the equine spine are repeatedly assessed by Veterinarians, Physiotherapists, owners and trainers. Thoracolumbar spinal posture can be altered with physiotherapy treatment and rehabilitative training. Where the thoracolumbar spine is extended the spinal posture is described as lordotic (sway backed). Abnormal extension may contribute to soft tissue injuries and is implicated in the pathogenesis of over-riding dorsal spinous processes (kissing spines). Objective methods to analyse the spine, eg radiography, ultrasonography or scintigraphy, often have high costs and require extensive training for the clinician. A simple measure of spinal posture that is able to objectively quantify changes would be beneficial and allow assessment of changes in posture with treatment. This study aimed to assess the reliability of a simple method designed to objectively measure thoracolumbar posture. Six horses of mixed sex, age and breed were stood square, with neutral head/neck position (nose vertical with chin level with chest). A lateral photograph of horse (P1) was taken from 2m with a visible marker of known length in the frame. This procedure was repeated three times (P2 and P3) at 30 minute intervals for each horse. ImageJ™ software was used to measure the area between the dorsal thoracolumbar region and a straight line between highest point of withers and tuber sacrale, with the marker used to set the scale. P1 was measured three times, P2 and P3 measured once. The data were normally distributed and there was no significant difference in repeated measurement of P1 ($F_{2,15}$=0.01; P>0.05). No significant differences were seen between P1, P2 and P3 ($F_{2,15}$=0.26; p>0.05). This method could be used to evaluate changes in the thoracolumbar spinal posture of a horse undergoing a rehabilitation programme following physiotherapy treatment for back pain and ultimately improve horse welfare.

Lay Person's paragraph:
The thoracolumbar posture of the horse's back has been related to back pain. Posture can alter over time and with rehabilitative physiotherapy treatment. The effect of treatment could be measured with expensive equipment but this study shows that a simple method could also be used to objectively quantify treatment effects.

Key words: Equine, Spine, Posture, Kissing spines, Back pain, Physiotherapy,