

Epaxial Musculature, Motor Control, and Its Relationship With Back Pain in the Horse: Objective Clinical Physical Therapy, Pathological, and Imaging Studies

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1. Introduction

Equine back pain often presents with more than one lesion or problem area, including the presence of limb lameness. Osseous lesions of the thoracolumbar (TL) spine and the lumbopelvic complex are widely recognized as significant causes of equine back pain, poor/loss of performance, and altered back and limb kinematics.¹⁻¹⁰ Improved diagnostic capabilities combined with increased clinical and research interest have raised the awareness of the importance of equine back pain and the ongoing need for research into rehabilitation strategies and a long-term management of chronic and recurrent back pain in horses, as is the case in the human.

Specific causes of back pain that have been identified include muscle strain^{2,11} ligamentous lesions,^{2,12,13} fractures of the TL and/or lumbo-pelvic complex,¹⁴⁻¹⁹ vertebral body osteophytes and spondylosis,^{2,18,20,21} osteoarthritis and ankylosis of the inter-transverse and/or lateral inter-transverse joints^{18,22-24} impingement of the dorsal spinous processes,^{9,25-28} sacroiliac disease,^{2,18,29-31} degenerative

intervertebral disc disease,^{3,5,28,32,33} and, more recently, osteoarthritis of the synovial intervertebral articulations (facet joints) as a source of pain and dysfunction.^{2,8,9,18,34}

Haussler et al.¹⁸ and Stubbs et al.⁸ highlighted the potential underdiagnosis of TL vertebral or pelvic lesions in postmortem studies of Thoroughbred racehorses euthanized for reasons unrelated to back pain. An alarming rate of osseous lesions was reported in the mid-caudal thoracic and lumbar regions (T9-sacrum), with all specimens having moderate to severe lesions, many of a degenerative nature and/or related to excessive cyclical loading such as stress fractures of the facet joints. Stubbs et al.⁸ reported that 77% had evidence of severe osseous pathology at various sites in the TL spine and pelvis. However, the relationship between the changes observed at necropsy examination and the presence of pain or loss of function has to date not been fully established in the horse. Pain in the TL region of a horse is very complex because it can originate from various pain receptor structures.

NOTES

Stubbs et al.⁸ utilized ultrasonography of the deep epaxial muscles in the horse (*multifidus* and the *sacrocaudalis dorsalis* complex) to demonstrate a relationship with muscle function and unilateral osseous pathology. This is a validated technique widely used in human back pain and motor control models to establish a functional relationship with muscle size/function and the presence of unilateral osseous pathology. Within the clinical equine literature, it is frequently suggested that gross muscular dysfunctions occur secondary to underlying bone pathology in horses with back pain, hypothesizing this to be a result of an underlying lesion in the spine and/or peripheral joints, with pain and or inflammation causing reflex inhibition of motor neurons resulting in weakness and atrophy of associated muscles.³⁵

2. Motor Control and Back Pain

Dynamic control involves a spectrum of control strategies during locomotion, ranging from muscular co-contraction causing stiffening to more dynamic control strategies that involve carefully timed muscle activity and movement. An essential element of motor control is accurate internal and external receptor activity, especially regarding proprioceptive feedback on joint position during locomotion, which can be altered due to pathology. Much of the research in human musculoskeletal disorders in recent decades has focused on the neurosciences including neuromotor control, dynamic stability, pain, and the interrelationship between pain and function. Research in this area has allowed major advancements in the prevention and treatment of major problems in people including pelvic pain³⁶ and low back pain.^{37,38} In human back pain research, it is now recognized that the central nervous system's control of the muscular system is probably of greater importance to the muscular system's ability to satisfy the needs of spinal movement and stability. The central nervous system must plan suitable strategies of muscle recruitment, co-ordination, and levels of activity to meet the demands of internal and external forces and initiate appropriate responses to unexpected disturbances of movements and function. Research in these areas for horses is clearly warranted and in the very early stages of development.

A key area of research in the human and animal models has shown that the deep local muscles of the TL region (*transversus abdominis* and the segmental lumbar *multifidi*) play vital roles in modulating the stiffness of the lumbar spinal segments and pelvic joints during limb and lumbo-pelvic movements.^{36,39-42} It has also been shown that the central nervous system pre-programs activity in these trunk muscles in preparation for limb movement. For instance, the *transversus abdominis* and *multifidus* activate prior to limb movement, regardless of direction. This serves to increase dynamic segmental stiffness for spinal segmental support

prior to loading,^{38,43-45} with the *multifidi* contributing two-thirds of the total increase in spinal stiffness imparted by muscular action.⁴⁶ In vivo studies in pigs confirmed that the *multifidi* are also a major stabilizer of the quadrupedal lumbar intersegmental motion.⁴⁷ Back pain patients display delayed activation of the *transversus abdominis* and *multifidus*, depriving the painful and injured spinal segments of timely support. This dysfunction continues even once the pain subsides.²⁸ In both acute and chronic low back pain, ipsilateral reduced cross-sectional area (CSA) of *multifidus* was observed at the same intervertebral level where pathology was present, suggestive of inhibition, and the onset of these changes is present within 24 hours of injury.⁴⁹⁻⁵² In a recent study, the density of *multifidus/erector spinae* was associated with facet joint osteoarthritis, spondylolisthesis, and disc narrowing.⁴¹ This also occurs within 3 days after a unilateral experimental lesion to an intervertebral disc in pigs.⁵⁰ Further, *multifidus* does not automatically resume its normal function following recovery from or resolution of an episode of acute back pain.⁵³ Specific physiotherapeutic interventions (exercises) are required to restore the size and function of *multifidus* after an episode of acute back pain in people, and these interventions reduce the rate of recurrence of injury from 84% in untreated control subjects to 30%⁵³ in patients who received specific interventions.

In the horse, the epaxial muscles including *longissimus dorsi*, *iliocostalis*, and middle gluteal all have multiple compartments and a large variation of muscle architecture and fiber type, thus potentially there is marked variation in dynamic functional motor control, most of which is currently unknown. *Multifidus*, the most medial epaxial muscle group, has five distinctive multi-pennate fascicles crossing 1 to 4 intervertebral discs, emanating from each spinous process attaching to the mammillary process of the articular pillar of every TL vertebrae and sacrum.⁷ Interestingly, *sacrocaudalis dorsalis lateralis* appears to be a morphological extension of *multifidus*, attaching to the last 2 to 3 lumbar dorsal spinous processes and lateral sacrum, from where it continues with *sacrocaudalis medialis* into the tail. Preliminary biomechanical modeling suggests that the horse's multifidus function is comparative to the human, where the primary movement, if acting alone, is "posterior "(dorsal) sagittal rotation. However, the hypothesized primary function is preparatory dynamic stability, whereby the muscle action is to limit accessory motion during flexion and coupled rotation, as is the case in the human.⁷ The deepest fascicles of *multifidi* in the human and pig are predominantly type 1 fibers (as is the horse, unpublished equine data). The deepest fascicle attaches two adjacent segments relatively parallel to the dorsal aspect of the vertebral body, suggesting that *multifidi* play an integral role in joint position sense and proprioception, thus modulating motor control

and intersegmental and gross spinal motion.⁷ This theory is further supported by the neuroanatomy, as the innervation of the multifidus in horses is similar to that in the human spine.⁵⁴ Each lumbar articular facet and *multifidus* is innervated by the medial branches of the dorsal rami of the spinal nerves at the same level and one level caudally. One recent study adding evidence to this hypothesis reported altered back kinematics following local anesthetic injections into *multifidus*, confirming the functional role of the deep epaxial muscle.⁵⁵

3. Ultrasonography

In the field of human physiotherapeutic rehabilitation, ultrasonography has emerged as an invaluable tool for objective assessment and management of low back and pelvic girdle pain and dysfunction.^{36,56-58} In the horse, McGowan⁵⁹ reported on a series of papers currently in the process of publication, which determined the reliability of ultrasonography, for example, measurements of CSA of the *multifidus mm*, *longissimus dorsi mm*, and *sacrocaudalis dorsalis mm* complex. Stubbs et al.⁸ is the first in this series. Others to follow determine the intra-operator reliability of repeated measurements of muscle CSA. Magnetic resonance imaging was used as the comparative gold standard. The reliability of measuring *multifidus* CSA using a 4- to 7-MHz curved linear probe at a depth of 15 cm was established using two blinded examiners. In normal (non-back pain) horses, the epaxial muscles are relatively symmetrical on the left and right sides. Ultrasonography of thoracolumbar and sacral epaxial musculature revealed significant individuality and regional variation in the shape and size of *multifidus*, with *multifidus* being largest in the lumbosacral region. From a functional biomechanical perspective, this would be expected because maximal dorsoventral flexion and extension occurs at the lumbosacral junction, and the primary role of *multifidus mm* is stability and proprioception.⁷

Stubbs et al.⁸ reported that in 22 Thoroughbred (TB) racehorses there was a significant reduction in *multifidus* size (CSA) at the level of significant injury or pathology, as seen on postmortem examination. This is comparable with research in people with back pain⁴⁹⁻⁵² in which ultrasound imaging has shown a significant reduction in CSA of *multifidus* on the symptomatic side of the spine, indicating a relationship between pain and muscle atrophy.⁴⁹ The 22 racehorses presented for euthanasia for primary reasons other than back pain were also examined clinically; 91% of horses had asymmetrical development of biceps femoris muscle mass and 82% had asymmetrical gluteal muscle mass.⁵⁹ These regions may also be measured and monitored by use of linear ultrasonography measures; however, reliability studies on these regions are yet to be performed. All horses had significant left/right asymmetry of *multifidus* CSA at >2 spinal levels, most commonly at L5, with a total of 74 sites af-

fected in the 22 horses. Seventeen horses had severe pathology, and 16 of these had ipsilateral atrophy of *multifidus/sacrocaudalis dorsalis*. There was a significant association between the grade of pathology and the degree of *multifidus* asymmetry. Severe osseous pathological changes were common in this population of Thoroughbred racehorses, and these were associated with measurable left/right asymmetry in *multifidus* at or close to the level of pathology. Ultrasonography of *multifidus* muscles is a useful and reliable clinical tool in the functional diagnosis and rehabilitation of back problems in horses, potentially together with other ultrasonographic functional muscular measures (linear, and contraction measurements).

4. Rehabilitation Strategies

Knowledge gained from the aforementioned research related to the changes in neuromotor control that occurs with back pain has translated to the development of new rehabilitation strategies for the lumbo-pelvic muscles in human back pain patients. This is an example of where anatomical and biomechanical research creates an essential platform for future neuromotor control research in the horse, as has occurred in the human research model. MacDonald and colleagues⁴⁸ recently reviewed the evidence of these treatment strategies in clinical practice. Rehabilitation, in this context through use of ultrasonography-guided feedback, places emphasis on motor relearning to optimize motor control for spinal dynamic stability. The rehabilitation first uses the end organs of the neuromotor system (the muscles) with the aim that cognitive, repeated contractions of the muscles and correct movement patterns will result in a transition to automated use (i.e., skill training).⁶⁰ Initially, the deep muscles such as *transversus abdominis* and lumbar *multifidus* are repeatedly activated in the relearning process during rehabilitation. Movement patterns and strategies for all trunk muscles are then reeducated to retrain painless and controlled functional activities. Progressively, the stability system is functionally challenged with load (static and dynamic exercises) as control is improved. Most importantly, there is growing evidence that this exercise approach can reduce low back pain and possibly reduce its recurrence rate.^{48,53,60} Specific physiotherapeutic intervention in people with *multifidus* dysfunction following an episode of acute back pain reduced the rate of recurrence of injury to 30% in the physiotherapy intervention group, compared with controls, at 84%.⁵³

As previously stated, the human motor model can be applied to the horse, as seen by investigating the equine *multifidus* muscle, in which there are striking similarities in structure and function. These morphological characteristics also reflect the research findings in spinal kinematics, in which it was shown that the greatest volume of *multifidus* occurs at the point of greatest motion in the spine in the

lumbosacral region.^{3,7} Further anatomical variations that were noted in the equine lumbosacral region have previously been reported,¹⁸ occurring in at least one-third of horses. The predominant variation was a divergence of the dorsal spinous process between lumbar vertebrae 5 and 6, where L6 was a transitional vertebra, effectively functioning as part of the lumbosacral joint. These variations are likely to have a significant influence on the range of motion and function and hence on performance.

Stubbs et al.⁶¹ applied these physiotherapeutic and motor control principles to the horse. This study assessed the effect of dynamic mobilization exercises on size and symmetry of *multifidus* in the equine caudal thoracic and lumbar spine and found that hypertrophy of *multifidus* occurred over a 3-month period, during which dynamic mobilization exercises were the only exercise performed. Eight horses performed dynamic mobilization exercises (3 cervical flexions, 1 cervical extension, and 3 lateral bending exercises to the left and right sides) with 5 repetitions/exercise per day on 5 days/week for 3 months, during which time these horses were not ridden. Left and right *multifidus* CSA was measured ultrasonographically at 6 levels from T10 to L5 at the start (initial evaluation) and end (final evaluation) of the 3-month study. Changes in CSA of the right and left *multifidus* muscles and symmetry of *multifidus* CSA on the right and left sides between the two evaluations were sought using analysis of variance ($p < 0.05$). Between the initial evaluation and final evaluations, *multifidus* CSA increased significantly at all six spinal levels on both right and left sides. Asymmetries in *multifidus* CSA between the right and left sides decreased between the initial and final evaluations. These results are very encouraging, with further studies currently underway.

5. Conclusions

What has been discovered in the horse thus far is promising, as it appears that the results mirror human data. Changes in *multifidus* CSA seen through ultrasonography appear to be associated with ipsilateral osseous pathology, which can be positively affected by specific dynamic stability exercises. Further research through needle/fine-wire electromyography and ultrasonography is necessary to analyze the activation patterns of the epaxial and hypaxial superficial and deep muscles in normal horses and those with back pain and/or those with diagnosed pathoanatomical osseous pathology.

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