Proceedings of the American Association of Equine Practitioners - Focus Meeting

Focus on the Foot

Columbus, Ohio, USA – 2009

Next Focus Meeting:
July 18-20, 2010 - Focus on Upper and Lower Respiratory
Salt Lake City, Utah, USA

September 22-24, 2010 - Sport Horse Symposium
Lexington, KY, USA
(Joint with Alltech and Rood and Riddle Equine Hospital)

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Objective Measures of Somatic Pain and the Effects of Manual Therapies in Horses

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Take Home Message

The clinical assessment of musculoskeletal pain is always subjective. Objective measures of somatic pain and dysfunction are needed to address equine welfare issues, to assess the sensitivity and specificity of existing diagnostic procedures, and to evaluate the effectiveness of traditional and integrative treatment modalities. Manual therapy techniques include therapeutic massage, mobilization and manipulation. Currently, there is limited evidence to suggest that these conservative forms of treatment are effective in managing acute or chronic pain in horses.

Pain Perception

Pain serves as an important physiological function by warning and protecting horses from actual or potential tissue damage, helping to prevent further tissue damage, and promoting healing. Processing painful stimuli requires both nociception and pain perception, which are neurophysiologically integrated to provide immediate recognition and elimination of the painful stimulus. Nociception within the musculoskeletal system involves detection of noxious stimulation produced by mechanical, chemical, thermal, or electrical stimuli. Pain perception is a multi-stage process that involves 1) transduction of a noxious stimuli perceived via skin, muscle, bone, or joint receptors at nerve endings into electrical impulses (action potentials); 2) transmission of those action potentials from the peripheral nerves to the spinal cord; 3) modulation of pain signals within local spinal cord segments; 4) projection of the modified pain signals from the spinal cord to the cerebral cortex; and 5) perception of the pain stimuli within the cerebral cortex and thalamus.

Pathological (or maladaptive) pain exists when the primary inciting stimulus produces exaggerated pain responses or abnormal pain responses distant to the initial site of injury. Hyperalgesia and allodynia are two examples of pathological pain perception. Hyperalgesia is characterized by an exaggerated response to noxious stimuli applied to a painful area and allodynia is present when non-noxious stimuli produce pain. Peripheral sensitization is produced by endogenous algesic substances acting on nociceptive fibers that sensitize local tissues to further stimuli. Peripheral sensitization lowers nociceptive thresholds and activates nociceptors, which produces an exaggerated pain response. Unremitting pain produces changes in the central nervous system that contribute to the development of chronic pain syndromes. Central sensitization produces a generalized reduction in nociceptive thresholds at sites distant to the original site of musculoskeletal injury due to changes in sensory processing within the spinal
cord. Continuous nociceptive input overrides normal endogenous inhibitory controls at the spinal cord and supraspinal levels, which causes allodynia.  

**Musculoskeletal Pain and Dysfunction**

Optimal musculoskeletal function is characterized by the absence of pain and the presence of proprioception, coordination, balance, flexibility, strength, and endurance. Depending on severity, musculoskeletal injuries often cause a dramatic reduction or complete loss in function and increased pain. Fortunately, we have a diverse armamentarium of pharmaceutical agents to address and manage acute pain conditions in horses; however, few of these drugs are indicated for chronic or recurrent pain and inflammation. Another issue of concern is that as we focus our attention on effective pain management, and if a horse is no longer in pain (i.e., not lame), then we often judge our treatment a success and the ‘problem’ is resolved. However, many horses with musculoskeletal or neurologic injuries also have concurrent and substantial limitations in proprioception, flexibility, strength, and endurance associated with chronic pain and compensatory gait. Complete rehabilitation requires addressing each individual aspect of musculoskeletal dysfunction, and not pain only, to the best of our abilities. The integration of physical therapy, rehabilitation and manual therapy modalities into equine practice provides unique tools to help diagnose and manage certain aspects of musculoskeletal pain and dysfunction that is not currently available in traditional veterinary medicine.

**Acute Somatic Pain Attributes**

Acute pain in horses produces behavioral, physiologic and functional changes. Behavioral changes include restlessness, reduced appetite, depression, agitation, pinning of the ears, teeth grinding, and tail swishing. Behavioral changes indicative of pain may be too subtle or take too long to recognize in routine clinical situations and sporadic observation of behavior may not reveal signs of pain. Owner’s observations of behavioral changes may be one of the first indications of acute pain. Physiological changes associated with acute pain include sweating, tachycardia, tachypnea, elevated arterial blood pressure, and dilated pupils. However, the longer a conscious patient experiences pain, the less reliable physiologic parameters are in assessing the degree of pain. Functional changes include abnormal posture, reluctance to move, reduced joint mobility, marked lameness, and constant lifting of the limb. Head pain often elicits head shaking, snorting and restlessness. Physical indicators of potential pain include external signs of inflammation and tissue disruption.

**Chronic Somatic Pain Attributes**

Persistent or chronic pain leads to inappetence, reduced mental alertness, depression, standing with the head and neck lowered, head pressing, and reduced social interaction with other horses. Physiological changes associated with chronic pain include weight loss, immunologic compromise, poor hair coat, failure to thrive, and acceleration of the aging process. Functional changes include spending long periods lying down, abnormal head and neck posture, antalgic stance (i.e., habitual unweighting of a limb), compensatory gait patterns, and poor performance. Lowered pain thresholds are often due to hyperalgesia associated with peripheral sensitization and allodynia associated with central sensitization.
Clinical Pain Assessment

Clinical indicators of pain or distress include changes in appearance, attitude, behavior, facial expression, posture, activity, response to handling, gait, and willingness to work. Unfortunately, the majority of these clinical signs are subjective and do not have validated, objective methods of measurement. In addition, serial assessments of musculoskeletal pain over time are highly variable even within the same patient or the same practitioner. Subjective outcome parameters are often qualitative and nonpreserved; whereas, objective measures provide quantitative information that can be evaluated over time or between examiners. Musculoskeletal pain and dysfunction is most often characterized by localized pain, muscle hypertonicity, reduced joint motion, and subsequent functional disability. The most common categorization of musculoskeletal pain or dysfunction consists of subjective grades of mild, moderate, or severe. More recently visual analog scales of 0 to 10 (or 0 to 100) have been used in an attempt to objectively monitor changes in pain, with 0 representing the absence of pain and 10 being unrelenting and intolerable pain. Subjective parameters can then be semi-quantified by assigning a numerical value that can be assessed pre- and post-treatment. The progression or regression of the individual musculoskeletal parameters can also be followed over time since most musculoskeletal injuries tend to be recurrent or chronic in nature. More objective measures of pain are needed to help identify specific musculoskeletal structures affected and the intensity, duration, and location of pain. Objective measurements also have the potential to provide quantitative evaluation of the following issues: increase or decrease intensity of applied treatments, justify continued treatment or not, accurate assessment of treatment success or failure, document the efficacy of different treatment protocols, review of data to maximize treatment efficacy, and following progress over time.

Experimental Pain Assessment

Pain perception and the therapeutic effects of analgesic drugs or therapeutic modalities is difficult to measure in horses. Behavioral assays of somatic nociception and pain perception have been used in horses by measuring responses to various noxious thermal, electrical, and mechanical stimuli. Radiant heat applied to specific body regions is the most commonly used thermal modality for measuring cutaneous nociceptive thresholds. Within the limbs, a heat-evoked limb-withdrawal reflex consists of measuring the latency from onset of noxious thermal stimuli applied to haired or shaved skin to a reflexive withdrawal of the forelimb. A prolonged latency is used to predict analgesic properties of the drug or therapeutic modality of interest. This technique has been used as a nociceptive end point for analgesic studies in many species; however, it may be confounded by the spontaneous locomotor activity observed after administration of narcotic analgesics in horses. Therefore, a heat-evoked skin-twitch reflex has been developed as an alternative method of assaying narcotic analgesia that does not involve the equine locomotor apparatus. With the skin-twitch reflex, the pain perception threshold is measured as the latency from onset of noxious thermal stimuli applied over the skin of the trunk at a set distance (or in direct contact with the skin), which produces a visible contraction of the cutaneous musculature. The skin-twitch reflex is judged to be a more sensitive assay of narcotic analgesia in the horse than is the hoof-withdrawal reflex. Skin-twitch reflexes also allow assessment of the dermatomal distribution of nociception and the effects of caudal epidural...
Continued application of a thermal stimulus, beyond the skin-twitch reflex, produces an avoidance response which is characterized as purposeful avoidance movements of the head, neck, trunk, limbs and tail and turning of the head toward the stimulation site. The analgesic effects of acupuncture and electroacupuncture on cutaneous pain thresholds using heat stimuli have been quantified during control and electroacupuncture trials. Thermal stimulation via a telemetric device has also been used to investigate possible endogenous opioid and serotonergic mechanisms underlying cribbing behavior in horses. A limitation to measuring changes in pain perception with thermal stimuli is that sensitization to repeated thermal stimuli may increase variability and inconsistency in the results.

Noxious electrical stimulation has also been used to assess behavioral nociceptive responses to transcutaneous electrical stimulation. Direct electric current has been applied via surface electrodes placed over the coronary band of the fore and hind limbs with slow, incremental increases in current until lifting of the affected limb is noted. Horses with lower nociceptive thresholds are expected to have shorter times to onset of an avoidance reaction. Electrical stimulation of the limbs has also been used to assess the potential cutaneous analgesic effects of extracorporeal shock wave therapy. Direct electrical stimulation of dermatomes of the trunk and perineal regions has been used to assess epidural efficacy via avoidance responses to increased electrical stimulation. Electrode implantation in the dentine layer of teeth has been used to evaluate tooth pulp pain threshold responses as noted by a head lift response. Electrical stimulation of the oral mucosa has also been used to assess physical responses to inhalation anesthetic. Low variability, stability of the response over time, and the absence of desensitization to multiple electrical stimulations have been observed. However, these forms of direct electrical stimulation may not allow controlled activation of nerve fibers and may also include superficial chemical reactions and tissue electrolysis. Alternatively, electrical stimulation coupled to electromyographic recordings have been used to more precisely determine nociceptive withdrawal reflexes. Surface electrodes applied to the skin overlying peripheral nerves provide electrical stimulation as electromyographic electrodes record the onset of muscle activation in adjacent muscles. The latency and amplitude of the nociceptive withdrawal reflex occurs over a few hundred milliseconds and is recorded using sophisticated electrophysiologic equipment to assess specific spinal A-delta nociceptive activity. Temporal summation obtained by repeated stimulations of subthreshold intensity appears to represent a new tool for investigating nociceptive pathophysiologic processes in horses. Electrical stimulation applied to needles piercing the skin has also been used to record the time to onset and the magnitude of the electrical stimulation that causes an avoidance reaction. Electrical and mechanical nociceptive thresholds determined by lifting of the foot have been compared using an electrical stimulus applied to the coronary band and a pneumatically operated pin pressing on the cannon bone. Known analgesic drugs produce greater increases in nociceptive thresholds using electrical current testing, compared to the use of mechanical pressure testing.

Mechanical forms of musculoskeletal injury are more likely to occur and be observed clinically, relative to other mechanisms of injuries. Therefore, mechanical stimulation is likely to be the most clinically relevant form of noxious stimuli and the easiest to apply. The challenge arises in objectively interpreting the diagnostic and clinical relevance of the tenderness identified by palpation or other forms of mechanical stimulation. Von Frey filaments are a set of calibrated fibers that bend at known amplitudes of applied force, which are applied a pain site and the fiber
size that produces a consistent aversive response is recorded. Pain studies in humans and dogs have used von Frey filaments as an accepted method to quantify mechanical nociceptive thresholds. An electronic von Frey device consisting of a rigid tip (0.5 mm in diameter) and an electronic load cell has also been used in analgesia studies in dogs, which allows blinding of the operator to the recorded measurements. To the author’s knowledge, no similar studies have been reported in horses. Noxious skin pinch stimulation and needle prick stimulation of the skin or muscle have been used to assess the analgesic effects of acupuncture and electroacupuncture on cutaneous pain thresholds. Transient, but reproducible lameness has been induced with set-screws welded to the inside branches of horse shoes and tightened to create localized, increased sole pressure. Variable lameness scores can be produced depending on the shape of the tip of the set-screws in contact with the hoof and the amount of pressure applied by the set-screws to the sole. Mechanical nociceptive thresholds have also been measured using a pneumatically-operated pin pressing on the cannon bone. Pressure algometry uses a calibrated force gauge with a rubber tip to apply manually-applied pressure to specific soft tissue or bony landmarks within the trunk or limbs. Low pressure readings correspond to low mechanical nociceptive thresholds, indicative of increased pain. However, applying mechanical pressure to musculoskeletal structures stimulates many different tissues and nociceptive fibers from superficial to deep, depending on the type of stimulation and pressure applied, so it may be difficult to identify any specifically affected tissue or anatomic structure.

Lameness Examination

Lameness evaluation and flexion tests are the primary tools used to assess musculoskeletal pain within the appendicular skeleton. Unfortunately, lameness evaluation is subjective and dependent on the experience of the examiner. Mild lameness is difficult to evaluate and grade with an acceptable level of between-examiner repeatability. Flexion tests and the application of hoof testers also have a high level of subjectivity due to variations in the duration and amount of force applied during these orthopaedic assessments. The use of more objective measures of lameness using ground reaction forces measured by force plate analysis demonstrate that subjective lameness grades are significantly associated with peak vertical force and peak vertical impulse, depending on lameness severity. For horses with subclinical to mild lameness, ground reaction forces are significantly reduced and can be used to identify subclinical forelimb gait abnormalities; however, subjective lameness grading has poor repeatability. In contrast, horses with moderate to severe lameness have good repeatability of subjective lameness grading, but ground reaction forces have poor repeatability due to increased between-horse variability.

Diagnostic Local Anesthesia

Injection of local anesthetic around peripheral nerves or intrasynovially to block potential sources of pain is another mainstay of lameness diagnosis in veterinary medicine. A thorough understanding of anatomy and clinical experience is required to effectively apply and accurately interpret results of the injections. Complete analgesia and 100% resolution of the lameness is the ultimate goal of diagnostic analgesia; however, this level of pain relief is seldom achieved. After diagnostic analgesia is applied to one limb, a contralateral limb may then also display lameness, which makes definitive localization of the source of pain to one specific location or structure difficult. The diagnostic efficacy of perineural injections is based on proper needle
placement, the injectate volume, and the time elapse for post-injection lameness evaluation. Since horses respond differently to noxious stimuli, especially in chronic pain situations, it may be difficult to clearly identify the efficacy of the applied diagnostic analgesia. In addition, articular lesions may not be desensitized by intraarticular analgesia.\textsuperscript{41} Other factors that affect the response to diagnostic analgesia include individual neuroanatomic variations, the intermittent nature of some lameness conditions, and the inherent difficulty in localizing the source of subtle or mild lameness.\textsuperscript{42}

**Pain Scales**

Pain scales are inherently subjective since they are primarily based on assessing behaviors associated with pain.\textsuperscript{43} Ordinal and visual analog scales have been developed to help qualify signs of pain, muscle hypertonicity, reduced joint motion, and functional disability.\textsuperscript{9} Simple descriptive scales consist of a series of categories or descriptions of pain intensity, such as absent, mild, moderate or severe.\textsuperscript{6} A visual analog scale consists of a 100 mm line with no pain labeled at the 0 mark and worst possible pain labeled at the 100 mark. Patients are asked to mark the scale at the site that best represents the current pain or dysfunctional status. Numerical rating scales consist of multiple pain behavior categories and each contains several gradations and descriptive definitions of pain, in an attempt to provide an overall assessment of the multidimensional aspects of pain. Categories include observations of comfort, movement, appearance, behavior, interactive behavior, vocalization, heart rate and respiratory rate.\textsuperscript{6} Within each category the parameter of interest is graded 0 to 3 or 0 to 4, which correspond to absent, mild, moderate, or severe descriptors. All of these tools are easy to use for both owners and veterinarians. The disadvantage of using descriptive or visual analog scales in veterinary medicine is that the owner or veterinarian must identify and interpret signs of pain or pain behavior.\textsuperscript{6} However, owner observation is essential to detect subtle signs of chronic pain or disability. Affected horses may have a lack of activity, change in attitude or behavior, reduced social interactions, and reduce appetite.\textsuperscript{6} Daily or weekly assessment of pain or musculoskeletal disability provides a baseline from which to assess long-term improvements or reoccurrences of pain. The purpose of any pain scale is to help guide the use of analgesic, medical, surgical, and integrative therapies and to provide diagnostic and prognostic information about the healing process and resolution of pain.\textsuperscript{6,44} The disadvantage of all pain scales is that they have poor intra- and inter-examiner repeatability and lack validation by clinical or biomechanical studies.\textsuperscript{45,46}

**Functional Questionnaires**

Pain and functional questionnaires are used in human medicine to better capture the comprehensive effects and multidimensional aspects of pain and disability. To semi-quantify disability in humans with low back pain, several different questionnaires have been developed and validated, which include the Oswestry Disability Questionnaire, the Quebec Back Pain Disability Scale, the Rolland-Morris Disability Questionnaire, the Waddell Disability Index, and the Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36).\textsuperscript{47} Standardized self-report questionnaires provide a convenient method of collecting and synthesizing a large amount of information related to activity limitations. Many questionnaires consist of a series of questions related to pain, activities of daily living and ability to work, and have been designed to detect
subtle yet clinically relevant changes in the patient's functional status. Specific questionnaires have also been developed and validated for specific body regions, such as knee pain, shoulder pain, and neck pain and disability.\textsuperscript{48,49} In human medicine, affected patients fill out the questionnaires, which is an obvious limitation for the wide-spread use of pain questionnaires in veterinary medicine. However, the opportunity remains for development of scoring systems in horses to determine the rate and level of functional recovery and robust measures of quality of life and activities of daily living, as reported by owners or trainers.\textsuperscript{50-52}

**Palpation**

Passive manual examination is used to detect local tenderness, which is the primary manifestation of most, if not all, musculoskeletal pain.\textsuperscript{53} Palpation provides relevant information about both the underlying tissues and the nociceptive system.\textsuperscript{54} The assessment of soft tissue or muscle pain is subjective and dependent on the evaluator’s tactile skills, knowledge of regional anatomy, and interpretation of clinical significance. The clinical assessment of acute versus chronic pain is relatively straightforward, however, determination of the exact etiology and appropriate treatment regime are diagnostically challenging. Acute muscle pain is characterized by heat, firm swelling or edema, substantial hypertonicity and pain, and dysfunction of the affected muscle region. Acute muscle pain may be due to direct trauma (e.g., kick or other blunt trauma) or metabolic disorders (i.e., exertional rhabdomyolysis). Chronic muscle pain often is poorly localized, less related to direct inflammatory mediators, and has more of a neurogenic basis. Osseous palpation involves evaluating bony landmarks for signs of pain, morphology, asymmetries, and alignment. Bones within the distal limb are manually compressed and articulations are fully flexed, extended and stressed with varus or valgus forces to assess pain responses. Individual thoracic, lumbar and sacral spinous processes can be palpated for a painful response with firm digital pressure applied to the dorsal midline.\textsuperscript{55} Typical signs of discomfort include tossing the head upwards, extension of the back or withers away from the applied pressure, or the presence of localized secondary muscle spasms.

**Pain Drawings**

In humans, pain drawings are used to localize the patient’s perception of pain and to score the percentage of total body surface in pain. Patients are given a drawing that represents the outline of a person’s body in frontal and caudal views and are asked to circle the painful body regions. Pain drawings have been postulated to help differentiate patterns of back pain and are useful for predicting treatment outcomes for musculoskeletal pain.\textsuperscript{56} In an effort to quantify pain drawings, a grid is placed over the drawing and the number of squares fully or partially covering the drawn in painful areas are counted. On grid assessment, human patients with disc herniation and stenosis with radiating pain or intermittent claudication have a significantly larger number of squares located within the extremities than patients with benign low back pain.\textsuperscript{57} Patients with more distributed pain report their pain as more disruptive to important areas of daily function and also report their pain as more intense and frequent, which suggest that pain distribution may be a useful clinical marker of disability status in chronic pain patients.\textsuperscript{58} Pain drawings have also been shown to be a stable instrument for use in chronic back pain patients to document the location and extent of pain over time.\textsuperscript{59} Patients can also be asked to draw in areas of different types of pain sensations, such as a deep ache, pins and needles, burning, stabbing, numbness, and
hypersensitivity. The challenge in veterinary medicine is that our patients cannot verbalize or
draw in sites of pain. However, mapping regions of clinically diagnosed pain sites versus non-
pain (or hypoalgesia) sites on schematic drawings of horses from several views (similar to those
used for identification purposes or mapping dermatological lesions) and following those
drawings over time can provide a semi-quantitative measure of the response to local or systemic
pain management.

**Pressure Algometry**

Pressure algometry is a repeatable clinical technique for quantifying and monitoring
musculoskeletal nociception in humans. It has been used diagnostically for fibromyalgia,
myofascial pain and osteoarthritis patients and used to measure pain responses associated with
analgescics, NSAIDs, physical therapy, acupuncture, and chiropractic treatment. Pressure
algometry uses a calibrated pressure gauge attached to a rubber-tipped plunger that is pressed
against a predetermined landmark until a perceived noxious reaction is produced. The
mechanical nociceptive threshold (MNT) is defined as the minimum pressure that induces a pain
response. High MNTs are indicative of reduced pain perception and low MNTs indicate
increased pain. In humans, pressure algometry accuracy and repeatability are improved by
anatomic localization of test sites, perpendicular application of pressure, consistent rate of
pressure application, and uniform endpoints.

Baseline MNTs have been reported within the axial skeleton and thoracic limb of normal
horses. Recently, pressure algometry has been used to assess MNTs in both acute and
chronic pain syndromes in horses. There is a slight acclimatization period to MNT
measurements in some horses, since horses instinctively step away from applied pressure. Once
the horses become accustomed to the technique, they stand quietly with predictable and uniform
endpoints readily identified. Stress, anxiety and diversions of attention alter the perceived level
of noxious stimuli. Therefore, MNTs should be recorded with minimal restraint in a quiet area in
a routine and systematic manner. Nociceptors in the skin, subcutis, fascia, muscle and
periosteum all contribute to detection of a noxious stimulus. Differences in bone, muscle and
nerve MNTs within certain regions may be due to variations in the concentration or depth of
nerve fibers. Using the median value of three consecutive measurements at each site improves
repeatability. More evidence is needed before we can confidently incorporate pressure
algometry use into clinical practice, but it has the potential to objectively assess pain related to
musculoskeletal injuries and the response to both traditional and integrative medicine.

**Biomechanical Assessment**

Qualitative gait analysis is used daily in clinical practice for the diagnosis of lameness and other
gait abnormalities, such as ataxia or weakness. Horses are typically evaluated for esthetics of
overall movement and the consistency and symmetry of body segment motion. Additional
assessment is made of changes in the stance phase associated with impact or support and the
swing phase, which is associated with altered limb protraction or retraction. Qualitative gait
analysis is important for subjective recognition of gait abnormalities related to pain, but it is
often difficult to consistently identify the specific limb or articulation affected with low-grade
lameness. Biomechanical or quantitative gait analysis includes the field of kinematics, which is
the study of the motion of body segments with respect to space and time, and the field of kinetics which deals with the study of the forces causing or resulting from motion. Clinically, kinematic analysis is used to measure body segment motion abnormalities and kinetic analysis is used to measure subtle changes in loading and unloading of limbs via measured ground reaction forces. Kinetics uses a variety of transducers such as strain gauges, accelerometers, force shoes, and force plates.

Kinematic analysis is an objective measurement technique using videography or optical systems that can detect small movement differences in limb or spinal motion, which help to clinically describe and objectively identify horses with musculoskeletal pain and dysfunction. Kinematic data includes temporal (timing), linear (distance), and angular measurements that describe body segment movement and changes in joint angle during various locomotor activities. Temporal data describes stride duration and limb coordination patterns. Distances are measured to define stride lengths, distances between foot placement, and the flight paths or movement of body segments. Angular data describes displacement, velocity and acceleration of body segments and joints. The most common angular displacements of the limbs include measurements of joint flexion and extension angles during locomotion. The advantages of current optical measurement techniques is that they are able to capture highly complex movements over extended periods of time and images can be immediately replayed for qualitative analysis. Kinematic systems are not used routinely in clinical practice because they require costly camera and computer systems and are limited by lens capabilities (e.g., focusing and field or depth of view).

Transient fore and hind limb lameness induced by pressure-induced sole pain by set-screws in modified shoes has been evaluated extensively by kinematic methods. Lameness and symmetry indices have been developed based on measured peak vertical displacements, velocities and accelerations of the head, withers, tuber sacrale and tuber coxae during different phases of the stride. The maximal vertical acceleration of the head and displacement amplitude of the tuber sacrale have been shown to be the best indicators to quantify fore- and hind limb lameness, respectively. The kinematic pattern of mild bilateral forelimb lameness demonstrates that fetlock hyperextension decreases; however, stride length and stance duration do not change significantly, compared to sound horses. Musculoskeletal pain causes low stride variability, possibly because the lame horse employs an optimum compensatory mechanism to reduce the pain in the affected limb, and deviations from this pattern increases pain. The body center of mass also is a key factor in the analysis of equine gait, as its position and movement determines the distribution and magnitude of loads on the limbs. During moderate forelimb lameness, vertical displacement of the body center of mass is decreased 34% during the stance phase of the lame limb and increased 9% during the stance phase of the sound forelimb. The clinical manifestation of back pain in horses results in diminished flexion-extension movement at or near the thoracolumbar junction. Functional relationships between limb lameness and spinal motion have been investigated, where subtle fore and hind limb lameness can provoke slight but detectable changes in thoracolumbar kinematics.

Kinetic analysis allows measurement of locomotor forces, both external and internal to the body. Force plates, pressure mats, and instrumented shoes are used to measure ground reaction forces during the stance phase. Subtle lameness in horses may be difficult to diagnose and methods to evaluate lameness objectively are useful when clinicians fail to reach a consensus.
Kinetic data includes stance duration, magnitude of the vertical, cranio-caudal, and mediolateral forces, time of peak forces, impulse (i.e., how force is applied over time), and the point application of force (or center of pressure). Lameness typically causes decreased vertical and cranio-caudal forces and impulses, as measured by force plate analysis. Detailed measures related to stance phase can be measured over time or compared pre- and post-analgesic administration. The advantage of force plate analysis is that it is accurate and easy to use once the equipment is installed. Disadvantages include issues related to velocity-dependent changes in ground reaction forces, the inability to measure all four limbs simultaneously and therefore the collection of nonconsecutive steps from different gait cycles that need to be averaged for each data collection session. Force parameters from lame and clinically normal horses are not always readily comparable, so ground reaction forces are normalized to body mass and collected over a narrow range of gait velocities. Breed differences in peak vertical forces have also been reported in sound and lame horses. Kinetic gait analysis has been used recently for detection, quantification, and differentiation of hind limb lameness and spinal ataxia in horses by assessing peak lateral forces and variations in vertical force. Changes in center-of-pressure values recorded from horses standing stationary with all four hooves on a force plate have been used to assess postural sway in horses, which may provide a simple and sensitive measure for assessing balance deficiencies in horses.

In-shoe pressure measurement systems have been developed to allow more flexibility in assessing lameness and ground reaction forces during treadmill locomotion or athletic activities, compared to limitations associated with a fixed, force plate system in a laboratory setting. Most instrumented shoes include measurement devices sandwiched between two metal plates attached to the foot, which allow measurement of ground reaction forces via cables and a computer attached to a surcingle. An accelerometer consists of a small mass enclosed in a housing and its movement or acceleration is measured relative to the body segment or surface to which the accelerometer is attached. Movements can be measured in a single direction (i.e., uniaxial) or in three orthogonal directions (i.e., triaxial accelerometer). In horses, accelerometers are most often applied to the hoof wall to detect initial ground contact, to measure accelerations associated with different ground surfaces, and to assess the efficacy of shock-absorbing shoes and pads. A pedometer contains an internal pendulum that records the number of steps or movements of the body segment to which it is attached. In cattle, pedometers have been used to predict lameness earlier than the appearance of the clinical signs. Physical activity has also been recorded in dogs and their owners. Similar applications have not been tested in horses to assess the onset and severity of lameness or physical activity. However, global positioning systems (GPS) have recently been applied to horses to record location and time, which in turn can be used to calculate physical activity, gaits, distance, and speed. GPS tracking has also been used to determine speed and position during Thoroughbred racing, which may help to identify causes and locations of lameness or racing injuries. The position data can provide the precise distance, velocity and pack positioning for an individual horse. The speed profile can be used to examine the level of exertion, effect of training programs and the influence of racecourse conditions (e.g., ground surfaces) on performance. Future studies are needed to utilize the full capabilities of all of the above kinematic, kinetic and GPS technology to help identify pain and discomfort in horses at earlier, subclinical stages and to objectively measure responses to treatment.
Manual Therapies

Manual therapy involves the application of the hands directly to the body, with the goal of treating soft tissue injuries or articular dysfunction. Chiropractic, osteopathy, massage therapy, stretching, therapeutic touch, and certain physical therapy techniques are considered forms of manual therapy. In humans, chiropractic is the most commonly used of these different modalities and is concerned with the diagnosis, treatment, and prevention of disorders of the musculoskeletal system and the effects of these disorders on the nervous system and general health.92 The practice of chiropractic focuses on the relationship between structure (primarily the spinal column) and function (as coordinated by the nervous system) and how that relationship affects the preservation and restoration of health. Joint mobilization and manipulation are two types of induced articular movements used in musculoskeletal rehabilitation to restore joint function. Mobilization is characterized as repetitive joint movements induced within the normal physiological range of joint motion. Joint manipulation (e.g., chiropractic treatment) occurs within the paraphysiological zone, which lies outside of the active (i.e., patient induced) and passive ranges of joint motion. In humans, joint mobilization and manipulation induce different physiological responses. Manipulation in humans has been shown to relieve adjacent spontaneous myoelectrical activity immediately, whereas mobilization has not.93 Chiropractic uses controlled impulses (i.e., adjustments), which are applied to specific joints or anatomical regions, to induce therapeutic responses through induced changes in joint structures, muscle function, and neurological reflexes. Human research has demonstrated reductions in pain and muscle hypertonicity and increased joint range of motion after chiropractic treatment.94,95

Chiropractic evaluation focuses on evaluating and localizing segmental vertebral dysfunction, which is characterized by localized pain, muscle hypertonicity and reduced joint motion.93 A thorough knowledge of vertebral anatomy, joint physiology and biomechanics is required for proper chiropractic evaluation and treatment. Alterations in articular neurophysiology from mechanical or chemical injuries can affect both mechanoreceptor and nociceptor function via increased joint capsule tension and nerve ending hypersensitivity.96 Mechanoreceptor stimulation induces reflex paraspinal musculature hypertonicity and altered local and systemic neurologic reflexes. Nociceptor stimulation results in a lowered pain threshold, sustained afferent stimulation (i.e., facilitation), reflex paraspinal musculature hypertonicity, and abnormal neurologic reflexes. The goal of chiropractic treatment is to restore normal joint motion, stimulate neurologic reflexes, and to reduce pain and muscle hypertonicity. Multiple theories have been proposed and tested over the years to explain the pathophysiology of vertebral segment dysfunction and its interactions and influences on the neuromusculoskeletal system.93,94 Chiropractic treatment is thought to affect mechanoreceptors (i.e., Golgi tendon organ and muscle spindles) to induce reflex inhibition of pain, reflex muscle relaxation, and to correct abnormal movement patterns.95,97,98 Anecdotal evidence and clinical experience suggest that chiropractic is an effective adjunctive modality for the diagnosis and conservative treatment of select musculoskeletal-related disorders in horses. However, therapeutic trials of chiropractic manipulations are often used since we currently have limited formal research available about the effectiveness of chiropractic procedures in equine practice.

The focus of recent equine manual therapy research has been on assessing the clinical effects of manipulative techniques on pain relief, improving flexibility and restoring spinal motion.
Obvious criticism has been directed at the physical ability to even induce movement in the horses' back. Pilot work in three horses that were instrumented with spinal transducers attached to Steinman pins implanted into dorsal spinous processes at adjacent vertebrae demonstrated that manually-applied forces associated with chiropractic treatment was able to produce substantial segmental spinal motion. The induced spinal motions were usually beyond the normal range of segmental motion that was measured during treadmill locomotion (i.e., up to 227% larger segmental spinal range of motion induced by high-velocity, low-amplitude thrusts than measured at the walk). The next logical research question is what, if any, are the therapeutic effects of these induced spinal movements. Two randomized, control clinical trials have used pressure algometry to assess mechanical nociceptive thresholds (MNTs) in the thoracolumbar region of horses and to evaluate if chiropractic treatment can reduce back pain, compared to a control group. The first study evaluated 24 horses in active exercise, with the treatment group receiving high-velocity, low-amplitude thrusts applied to the T13 to L6 region. At the 2 week comparison, 21 of 29 (72%) sites had increased MNTs, 6 (21%) sites had decreased MNTs, and 2 (7%) sites had no change in the treatment group MNTs, compared to the control horses. Even though all 10 sites within the T13 to L6 region had increased MNTs in the treated horses, only 7 (24%) sites demonstrated significant MNT increases, compared to the control group. The second study included 38 horses without clinical signs of back pain that where randomized into 5 treatment groups with MNTs measured at 7 bilateral sites within the T9 to S2 vertebral levels. Single applications of instrument-assisted high-velocity, low-amplitude thrusts and massage therapy were given at Day 0 in two groups at sites of pain, muscle hypertonicity or stiffness. Phenylbutazone was given orally at a dose of 2 grams, twice a day for 7 days in the third group and active and inactive horses were assigned to two control groups. MNTs were measured at Days 0, 1, 3, and 7. The Day 7 median MNTs had increased by 27% in the chiropractic group, 12% in massage therapy group and 8% in phenylbutazone group with less than 1% changes in both control groups. Future research is recommended to evaluate longer-term effects and the potential synergistic effects of combined therapies (i.e., chiropractic and massage therapy) for treating back pain.

Additional studies have assessed the effects of equine chiropractic techniques on passive spinal mobility (i.e., flexibility) and longissimus muscle tone. The first study used 10 horses to objectively measure vertical displacement, applied force, and stiffness at 5 thoracolumbar intervertebral sites in an experimentally-induced back pain model using a randomized, crossover study design. The chiropractic treatment induced a 15% increase in vertical displacement and a 20% increase in applied force, compared with control measurements; indicative of increased spinal flexibility and increased tolerance to applied pressure. The second study measured changes in muscle tone and electromyographic (EMG) activity within the longissimus muscle immediately after spinal manipulation or reflex inhibition therapy, compared to a control group. Significant decreases in muscle tone and EMG activity were measured in both treatment groups, compared to no significant changes within the control group. Additional studies are needed to determine how long the increased flexibility and reduced muscle tone persist in horses treated with chiropractic techniques and if these therapies can improve performance.

Two final studies document the potential beneficial effects of chiropractic treatment on spinal movement patterns in horses with documented back pain. The first study is a case report on...
a dressage horse with back pain and severe loss of performance that underwent spinal kinematic assessment prior to and serial follow up 8 months after the last chiropractic treatment. A right lateral bending restriction (i.e., functional scoliosis) was diagnosed and two high-velocity, low-amplitude treatments were applied, 3 weeks apart. Symmetry of spinal movement indices improved dramatically after the first chiropractic treatment and remained improved above baseline even 8 months after the last treatment. It was concluded that manipulation had a measurable influence on kinematics of the thoracolumbar spine; however, this improvement was not judged equivalent to clinical improvement. A follow up study by the same researchers assessed limb and spinal kinematics prior to and 1 hour and 3 weeks after chiropractic treatment in 10 horses. Significant changes in spinal kinematics were noted at the walk and trot, but no changes were noted in limb kinematics. The main overall effect of the chiropractic manipulations was a more flexed thoracic region, a reduced inclination of the pelvis and improvement of the symmetry of the pelvic motion pattern. It was concluded that chiropractic treatment elicits slight but significant changes in thoracolumbar and pelvic kinematics and that some of the changes are likely to be beneficial.

Chiropractic is not a ‘cure all’ for all back problems and is not suggested for treatment of fractures, infections, neoplasia, metabolic disorders or nonmechanically-related joint disorders. Acute episodes of sprains or strains, degenerative joint disease or impinged spinous processes are also relative contraindications for chiropractic treatment. All neurologic diseases should be fully worked up to assess the potential risks or benefits of chiropractic treatment. Contraindications for massage include active skin lesions, open wounds, acute inflammation, or persistent muscle hypertonicity (i.e., exertional rhabdomyolysis). Serious diseases requiring immediate medical or surgical care need to be ruled out and treated by conventional veterinary medicine before routine manual therapy is begun. However, chiropractic care may contribute to the rehabilitation of most post-surgical cases or severe medical conditions by helping in the restoration of normal musculoskeletal function. Chiropractic care cannot reverse severe degenerative processes or overt pathology.

Summary

Compared to our human counterparts, veterinarians and equine athletes often have a very limited selection of options for the diagnosis and treatment of musculoskeletal pain and dysfunction. Currently, we have limited objective tools to specifically assess soft tissue or articular pain, reduced flexibility and joint stiffness, muscle hypertonicity and trigger points, and alterations in proprioception or coordination associated with musculoskeletal or nerve dysfunction. It is hoped that new insights into objective measures of musculoskeletal pain and the pathophysiology of acute and chronic pain syndromes will assist in assessing the effectiveness of many of the traditional and integrative modalities currently applied to horses with the rationale of reducing morbidity and improving overall performance.

References and Footnotes


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a Force gauge (Model FPK 60), Wagner Instruments, Greenwich, CT

b Activator adjusting instrument, Activator Methods International, Phoenix, AZ