CLINICAL TECHNIQUES

Principles and Practice of Therapeutic Exercise for Horses

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ABSTRACT

Physical therapists are an integral component of the medical team in human health care. They are backed by a solid foundation of basic science and clinical research. Veterinarians have only recently begun to incorporate physical therapy into clinical practice, but without formal research that validates therapeutic interventions specific to equine patients. The purpose of this article is to present a series of therapeutic exercises adapted for horses based on knowledge and experience of human physical therapy, equine biomechanics, and the types of movement dysfunction commonly seen in the performance horse. Injuries, lameness and musculoskeletal pain syndromes, frequently encountered in equine practice, are disorders that may be successfully addressed with physical therapy. Incorporating standard therapeutic interventions based on clinical success in humans, basic science research, or expert opinion is possible with the understanding that these techniques will ultimately be accepted or refuted when their success or failure is formally documented. This review is designed to stimulate discussion and encourage research that will add to the knowledge base and lead to effective therapeutic protocols in the equine patient.

Keywords: Physical therapy; Therapeutic exercise; Modalities; Rehabilitation; Proprioception

INTRODUCTION

Physical therapy is a well-established branch of human health care, which has its origins in ancient Greek and Chinese medicine and owes its evolution in modern times to the needs of victims of wartime injuries, industrial accidents, and polio epidemics in the early 20th century.[1] Today, physical therapists are an integral component of the medical team, treating human patients with issues as diverse as postsurgical deficits, sports injuries, strokes and spinal cord injuries, birth defects, chronic and terminal diseases, cardiopulmonary disorders, industrial accidents, burns and wounds, geriatric disorders, and wellness and preventive health care needs. Physical therapy principles and techniques are based on a solid foundation of scientific and clinical research and adherence to evidenced-based medicine principles.

The American Physical Therapy Association defines physical therapy as follows[2]:

- The diagnosis and management of movement dysfunction and enhancement of physical and functional abilities;
- The restoration, maintenance, and promotion of not only optimal physical function but optimal wellness and fitness, and optimal quality of life as it relates to movement and health; and
- The prevention of the onset, symptoms, and progression of impairments, functional limitations, and disabilities that may result from diseases, disorders, conditions, or injuries.

Physical therapists are trained to provide specific noninvasive interventions to produce changes in the patient that are consistent with the examination findings and contingent on re-examination and progression toward defined goals and outcomes. Although the veterinarian and physician are trained to diagnose and treat pathologic conditions, the physical therapist's focus is on restoration of optimal function and quality of life. Interventions may include physical agents and mechanical modalities, electrotherapeutic modalities, manual therapy techniques, therapeutic exercise, and the incorporation of assistive or adaptive equipment.

The integration of physical therapy techniques into the veterinary setting has expanded rapidly in the last 25 years. Formal courses in rehabilitation principles and practices are not taught in most veterinary curricula; therefore, veterinarians traditionally have been unprepared to prescribe comprehensive rehabilitation programs for their patients. Typical recommendations for the surgical or injured patient include confinement and rest until healing is complete, and then resumption of normal activity. The incontrovertible benefits of physical therapy in human medicine have prompted many equine veterinarians to incorporate physical therapy practices into the treatment and rehabilitation of horses. The American Association of Equine Practitioners in its *Guidelines on Therapeutic Options* states that "the AAEP supports the rights of the veterinary practitioner to

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select and prescribe a course of therapy believed to be in the best interest of the horse and consistent with the Veterinary Oath of Practice" and defines the role of the equine physical therapist as follows:

An equine physical therapist uses noninvasive techniques for the rehabilitation of injuries. Physical therapy is defined as including the use of massage, stretching, laser, electrical stimulation, magnetic, ultrasound, rehabilitative exercises, hydrotherapy, heat, and cold. The work must be performed under a referral of a veterinarian after a veterinary diagnosis.[3]

This statement emphasizes the nature of the physical therapist–veterinarian relationship. Implementation of a therapeutic plan must be preceded by veterinary examination and diagnosis to rule out those pathologic conditions in which some interventions would be contraindicated. The referring veterinarian determines the optimum treatment plan, which includes analgesics, nonsteroidal anti-inflammatory drug (NSAIDS), casts and bandages, surgical interventions, and the integration of physical therapy.

The purpose of this article is to present a series of therapeutic exercises adapted for the equine, based on the clinical experience and basic research of human physical therapists. Formal research in horses on the effectiveness of therapeutic modalities and exercise is lacking. Most recommendations are based on clinical judgment, intuition, and common sense for rehabilitation of specific injuries and management of horses with neuromuscular disorders. Many approaches have been used intuitively in veterinary medicine for years without a clear goal, formal research, or understanding of mechanisms of action—such as bandages and support wraps, stall rest, or cold hosing of limbs after exercise. There is a need for thoughtful reconsideration of the application of modalities and movement therapies in veterinary medicine. Practices should be based on the best available evidence. Unfortunately, most evidence is based on expert opinion or extrapolation from human studies and is not based on large prospective case series or randomized, controlled trials in horses. The rationale for incorporating these exercises will be based on examination findings, human evidenced-based practice, and knowledge of equine biomechanics and dysfunction. In addition, therapeutic approaches to acute injuries, neurologic disorders, and back pain and dysfunction will be presented.

INCORPORATION OF PHYSICAL THERAPY TECHNIQUES INTO VETERINARY CARE

At the 1981 Annual Meeting of the Canadian Orthopaedic Association, Dr. Robert B. Salter delivered the Presidential Address entitled "Motion versus rest: Why immobilize joints?"[4] He eloquently described the history of orthopedics related to the debate over whether to rest or mobilize injured tissues. Without scientific validation, orthopedic surgeons had advocated rest and rigid immobilization for centuries until Salter performed his classic studies in the 1960s on the effects of immobilization on joints. He concluded the address with "Why immobilize joints? I have concluded that since immobilization of joints has been proven to be harmful and since joints are designed to move, we as orthopaedic surgeons should keep them moving whenever it is feasible to do so!"[4] This sentiment forms the basic premise of physical therapy: that movement is necessary for the health and healing of the body and that we should maintain or regain movement whenever and as soon as possible.

It is a common misconception from those outside the physical therapy profession that the practice of physical therapy emphasizes or consists exclusively of the application of passive modalities such as therapeutic ultrasound, heat, massage, and joint mobilization. Although these tools are valuable in reducing pain and supporting healing, the primary task facing the therapist is addressing the underlying neurophysiologic and pathophysiologic contributors to pain and movement dysfunction. Treatment focuses on alleviating sensory, neuromotor, and mechanical abnormalities through pain modulation, manual therapy, proprioceptive and motor retraining, therapeutic exercise, and functional and sport-specific activities.

The refinement of rehabilitation techniques over the past 40 years has benefited human patients in countless ways. Athletes with career-ending knee injuries are now returning to sport within a few months.[5] Using interventions that optimize the healing environment hastens recovery from ankle sprains and reduces the likelihood of reinjury.[6,7] New insights into the plasticity of the nervous system encourage stroke and spinal cord–injured patients to regain levels of function that was never dreamed possible.[8] Understanding the biomechanics of dynamic stabilization of the spine allows therapists to design core-strengthening programs, which reduce the chronic disability associated with recurrent back pain and injury.[9]

Equine patients with sports injuries, neurologic or musculoskeletal disorders, or during recovery from surgical procedures are likely candidates for physical therapy intervention. In contrast to the indiscriminate and routine prescriptions for stall rest, controlled loading of injured tissues based on scientific principles helps to minimize the detrimental effects of immobilization and stimulate soft tissue and articular cartilage healing. Biological tissues have tremendous capacity for adaptive change, and one of the most potent factors leading to adaptive responses is chronic mechanical loading or stress. The absence of mechanical loading within the musculoskeletal system induces maladaptive responses in bone,[10-13] muscle,[14-16] joint,[17,18] and ligamentous[19,20] tissues (Table 1).

Equine patients present a unique challenge to physical therapists in that horses must cope with the demands of

Table 1. Tissue adaptations to immobilization and remobilization[10–20]

Tissue	Effects of Immobilization	Effects of Mechanical Loading or Remobilization
Bone	Decreased bone mineral content within 3 weeks	After immobilization, efforts to increase bone mineral content and bone mineral density require greater than normal levels of activity
	Decreased bone mineral density within 3 weeks	Benefits are lost if activity is terminated early
	Decreased cross-sectional area	Mechanical properties restored with 11–16 weeks of exercise
	Decreased stress to failure for cancellous bone	
	Decreased mechanical properties	
	Inhibition of longitudinal growth	
	Decreased osteoblast numbers	
	Increase in apoptosis of osteocytes	
Joint	Articular cartilage degeneration and resorption	Cartilage preservation, but questionable recovery of cartilage thickness after remobilization
	Increased collagen crosslinks and stiffness within periarticular soft tissues	Maintained extensibility of periarticular tissues
	Synovial membrane atrophy	Maintained synovial structure, function and joint nutrition
	Intra-articular: fibrofatty proliferation, adhesions, and obliteration of joint cavity	Facilitation of healing
	Increased joint contracture, irreparable damage to hyaline cartilage, eventual ankylosis	Decreased edema in intra-articular and periarticular tissues
Muscle	Decreased cross-sectional area, muscle atrophy	Recovery of contractile properties in 60–90 days
	Altered sarcoplasmic reticulum	Recovery of muscle mass takes longer than 90 days
	Decreased calcium uptake in slow twitch fibers	Intermittent standing weight bearing attenuates fiber atrophy and partially restores peak isometric force
	Decreased neuromuscular control and voluntary recruitment	Increased cross-sectional area and muscle fiber numbers
	Decreased force production, shortened twitch duration, decreased peak force	Increased oxidative capacity and fatty acid utilization
	Immobilization effects are greater within slow twitch fibers	Decreased reliance on carbohydrate metabolism
	Non-weight-bearing induces greater atrophy than does immobilization with weight-bearing	Increased fatigue resistance
		Increased neuromuscular control and voluntary recruitment
Ligament	Decreased maximum load to failure	Increased collagen fiber diameter
	Decreased energy stored prior to failure	Conversion of Type III to Type I collagen fibers
	Increased collagen fiber crosslinking and random fiber orientation	Increased linear fiber orientation
	Decreased structural integrity at insertion sites	Minimal stresses can maintain 80%-90% of baseline mechanical properties
	Insertion sites remain weaker for a longer duration than the ligament proper	Mechanical deficits are not completely reversed even after 12 months of rehabilitation

carrying a rider in addition to their own body weight. Many riders have the erroneous belief that the horse is naturally adept at supporting the rider's weight. In fact, ill-fitting and improperly used equipment, novice riders, and heavy riders often interfere with the horse's self-carriage, balance, and movement, potentially causing or contributing to pathologic conditions. Successful rehabilitation of the equine requires that the therapist understand the biomechanical effects of skilled and unskilled riders and proper and ill-fitting tack on the horse. Selected strategies must address the unique requirements of the horse–rider team within diverse disciplines and athletic events.

PHYSICAL THERAPY ASSESSMENT

After a thorough veterinary examination, the equine patient will be presented to the physical therapist for evaluation and formulation of a treatment plan. Ideally, the veterinarian and physical therapist have reviewed pertinent physical examination, lameness, and diagnostic imaging results and a pathoanatomical diagnosis has been provided by the referring veterinarian. The physical therapy examination consists of obtaining a history, determining which activities provoke or alleviate relevant clinical signs, and selecting and performing specific tests and measures to gather additional subjective and objective data about the patient. The clinical data are assessed in an effort to diagnose movement dysfunctions as influenced by specific tissue or sensorimotor abnormalities, which can be followed up over time.

A plan of care is outlined, which includes the following:

- The implementation of evidenced-based interventions such as pain-relieving modalities, manual therapies, and therapeutic exercise to address the specific abnormalities.
- The timing of application and discontinuing interventions based on the stage of healing, response to each treatment, and progress toward treatment goals.
- The frequency of treatment.
- The expected response to each intervention.
- The expected overall functional outcome and timing of return to sport or work.
- Owner involvement in the plan of care.
- Indications for reevaluation and timing of veterinary re-examination for updates on progress.

The tests and measures performed during initial data collection include the following:

Pain

Subjective pain is assessed through owner questioning, behavioral observation, palpation, and provocation tests. A convenient method for scanning large areas of the horse's myofascial tissues is to run a needle cap along the muscle, noting where the horse reacts with a behavioral change or flinch, indicating pain. Pressure algometry provides a means of objectively quantifying pain in the horse. The pressure algometer is a compressive-force gauge, which measures the pounds of pressure that invoke a pain response, which is defined as the mechanical nociceptive threshold (Fig. 1). Reference mechanical nociceptive thresholds have been determined for the neck, back, and croup of the axial skeleton and for the forelimb of horses.[21,22] Provocation tests are performed while assessing joint range of motion and passive mobility and those activities that provoke pain are noted.

Figure 1. Application of a pressure algometer over the cranial thoracic region to objectively assess mechanical nociceptive thresholds within soft tissue or bony landmarks.

Posture

Posture is defined as the alignment and positioning of the body relative to gravity, the center of mass, and the base of support. Good posture is defined as "a state of musculoskeletal balance that protects the supporting structures of the body against injury or progressive deformity."[2] Conformation and posture are evaluated by performing a static visual examination. The therapist observes the animal's posture from lateral, cranial, caudal, and dorsal views (Fig. 2). Findings that deviate from the expected norm or ideal are noted. Characteristics assessed may include body condition, conformation, muscle mass and symmetry, height and symmetry of bony landmarks, weight distribution between the limbs, angulation and placement of limbs under the body, spinal curvatures, signs of muscle hypertonicity, and overall demeanor of the horse. Of particular importance is the relative degree of lordosis, or extension of the cervical and thoracolumbar spine. Horses that tend to adopt a lordotic posture with an elevated head and extended neck often have difficulty rounding up or doing collected movements during ridden exercise (Fig. 3). Posture may also be objectively assessed with flexible rulers, tape measure, goniometers, or photography. Taking a lateral view photograph against a rail fence, siding on a building, or a postural grid provides horizontal and vertical references for evaluation of changes in a horse's posture over time.[23]

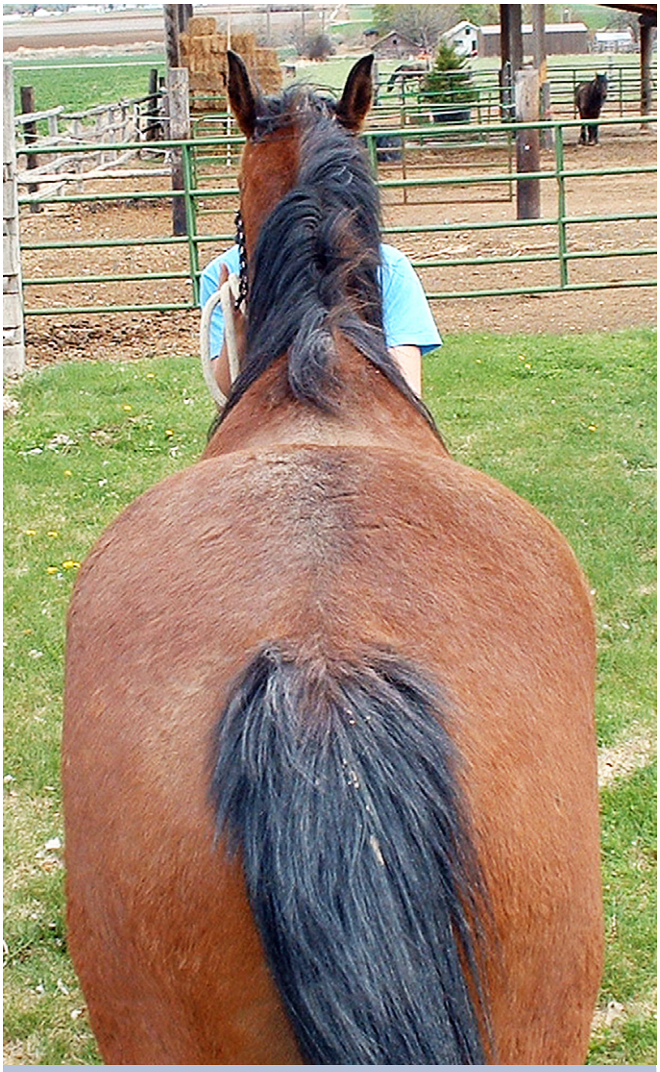

Figure 2. Caudodorsal view of spinal conformation and posture. This horse displays a straight spine, symmetric contour of the dorsal scapular region, and horizontally level and symmetric bony pelvic landmarks. Symmetric and well-developed epaxial and pelvic musculature is also noted.

Figure 3. Lateral view of spinal conformation and postural assessment. This horse displays an elevated head, cervical extension, slightly extended back, and a general appearance of tension and anxiety.

Integument and Subcutaneous Tissue Integrity

The epidermis and dermis should be evaluated for wounds or signs of inflammation. The presence of heat, redness, and swelling or edema should be recorded on a body diagram. Heat can be measured with an infrared thermometer gun (purchased at most automotive stores). Redness is documented with serial photographs using standardized lighting. Changes over time in the surface area of cutaneous abnormalities can be measured with an overlying transparent grid. The circumference of edematous limbs can be measured and compared to the contralateral unaffected limb or structures with a flexible tape measure that has a tensiometer on the end of the tape, which standardizes the tension applied to the tape (i.e., Gulick tape measure). Restrictions of skin or fascial mobility and glide due to swelling or edema should be noted. Tissue extensibility can be documented by gliding the skin mediolaterally and craniocaudally over subcutaneous structures and by pinching and elevating the skin. Careful assessment of signs of inflammation is necessary during the early stages of healing because serial re-evaluations will be used to determine whether healing is progressing as expected. If signs of inflammation persist, the patient will have to be reassessed for possible infection or the presence of nonhealing or necrotic tissue. The therapist will also have to consider whether the therapeutic plan is too aggressive. Excessive or repetitive forces may compromise tissue healing in the early stages. However, delayed therapy can also predispose to increased fibrosis and reduced tissue mobility.[18,24,25]

Joint Integrity, Accessory Mobility, and Range of Motion

The quality and quantity of joint motion is a key factor in locomotion. The physical therapist assesses individual articulations for joint hypermobility or hypomobility. Passive joint range of motion is measured in both flexion and extension with a goniometer (Fig. 4). In addition, the therapist will assess the end-feel of passive joint motion. This qualitative assessment will be abnormal in joints affected by inflammation, osteoarthritis, or loss of ligamentous stability. Physiologic joint motion corresponds to the movement

Figure 4. Measurement of passive joint range of motion of the carpus during flexion with a goniometer. The arms of the goniometer are aligned with the long axis of the bones proximal and distal to the articulation of interest.

performed by the joint during functional activities and under volitional control. Conversely, accessory joint motions are small, translatory movements that occur between opposing joint surfaces and are not under voluntary control. These translatory movements, or glides, are required for normal biomechanical function of the joint to occur. Examples of glides are the medial and lateral motion of the proximal sesamoids at the fetlock joint or internal and external rotation of the distal interphalangeal joint. The quality and quantity of joint glide informs the therapist about the presence and severity of pain, muscle hypertonicity, stiffness, or loss of joint integrity.[2,26] Abnormal accessory joint motions will adversely affect active joint motion and locomotion. Active joint range of motion assesses the willingness of the horse to move and the quality and degree of movement. Active movements of the spine are assessed with baited stretches in flexion–extension and lateral bending movements. Watching the horse rise and lower from a recumbent position, step over obstacles, or negotiate hills will help the observer to assess active movements of the extremities.

Neuromotor Control

Tests of neuromotor control assess weakness, diminished muscle fiber recruitment, abnormal patterns of movement, loss of coordination, and abnormal proprioception. Motor control is a complex function that relies on intact sensory and proprioceptive input, central processing of motor planning and coordination, adequate motor neuron recruitment of muscle fibers, and an intact contractile mechanism. Traumatic injuries damage not only connective tissue structures but also the sensory neural elements contained within joint capsules, ligaments, musculotendinous junctions, and muscle spindles. Loss of proprioceptive input alters the force and timing of muscle contraction, ultimately affecting balance and coordination.[27–31] The horse is observed during performance of functional activities such as, negotiating obstacles or inclines, getting into and out of a trailer, circling, turning, and backing up. External perturbations may be applied to the horse such as lateral tail pulls, balancing against examiner-induced sway, or hopping to assess the horse's ability to sense changes in tissue stretch and center of gravity and organize a coordinated response that will prevent loss of balance and potential injury.

Gait Evaluation

Gait is evaluated for the presence of lameness, but to the physical therapist, additional parameters and the overall quality of locomotion are also important. The horse is assessed for symmetry and fluidity of limb movement and the range, symmetry, and coordination of spinal movements throughout the gait cycle. Stiffness or lordosis of the spine, combined with elevated head and neck, during the gait evaluation is an important finding to the examiner that the horse may be having difficulty relaxing the spinal muscles responsible for extension (e.g., longissimus) and activating the spinal flexors (e.g., psoas major and minor), abdominal (e.g., rectus abdominis), and core muscles (e.g., multifidi). The core muscles are those muscles that stabilize the spine and pelvis and play an important role in posture, balance, and stability of the spine during locomotor activities. Major core muscles include the multifidi, transversus abdominis, internal and external obliques, rectus abdominis, erector spinae, and diaphragm.

Serial Re-evaluation

During physical examination and data collection, the therapist will record abnormal findings and attempt to relate them to a pattern of movement dysfunction or compensatory gait. Selected parameters will be re-evaluated on a regular basis (at least weekly). The results of serial re-evaluations will be used to assess progress toward goals, alter the treatment plan as necessary, and guide the progression of therapeutic exercises. If pain or inflammation increases, the therapist will be alerted immediately so that the veterinarian can be consulted and the therapy modified accordingly or additional diagnostic assessments may be pursued (e.g., ultrasonography or nuclear scintigraphy).

BIOPHYSICAL EFFECTS OF MODALITIES

Physical therapists use a variety of physical modalities to help optimize tissue healing and minimize the effects of disuse or immobilization. The decision to employ a particular modality should be based on stage of healing, reported clinical effects of the modality, and contraindications for its usage.

Cold Therapy, Ice (Cryotherapy)

Cold therapy is delivered through the application of ice packs, cold packs, ice-water circulating boots, or ice massage. The therapeutic effects of cold therapy are generated through reducing tissue temperatures to 15°C–19°C; temperatures below 10°C may cause tissue damage.[32,33] Cold therapies penetrate 1–4 cm and depth is dependent on local circulation and thickness of adipose tissue.[34,35] Hair coat and air trapped between the tissue and cold source will decrease the conduction of heat from the body and diminish the ability to cool the tissues. Cold should be applied for 10–20 minutes every 2–4 hours during the first 48 hours after acute injury. Reflex and motor function can be impaired for up to 30 minutes after cold therapy, which renders the patient more susceptible to injury if excess activity is resumed.[36] Cold therapy studies in humans have demonstrated that wet ice (i.e., chipped ice encased in a damp terry cloth towel) is superior to dry ice (i.e., ice flakes enclosed in a plastic bag) or commercial cold packs in cooling the skin surface.[37] Kaneps[38] reported that ice-water immersion was the only technique that resulted in skin and subcutaneous tissue temperatures that exceeded the therapeutic threshold of 19°C in the distal limbs of horses when compared to commercial cold pack.

Cold therapy is most effective when applied immediately after injury. After 48 hours the opportunity to derive maximal benefit from cold therapy is diminished. The biophysical effects of cold therapy include vasoconstriction and decreased vascular permeability, which reduces hemorrhage and local edema formation; decreased nerve conduction velocity, which diminishes pain sensations; and decreased metabolic rate, which reduces secondary hypoxic injury and death of healthy tissue immediately after injury.[32] One potential significant benefit of cold therapy is that lowering the metabolic requirements of surrounding tissue reduces secondary hypoxic injury, preserving tissue viability and ultimately reducing healing time. It is hypothesized that this mechanism may be responsible for the more rapid return to full activity (13.2 days compared to 33.3 days) after ankle sprain when cryotherapy is initiated immediately versus 36 hours after injury.[6]

A number of equine studies have demonstrated the effects of cold therapy on skin and tissue temperatures within the limbs.[38–40] Cooling the foot in ice water reduces laminar temperature and perfusion.[41] These authors propose that the decrease in temperature may be sufficient to reduce the activity of enzymatic mediators of acute laminitis and prevent some of the detrimental changes occurring in the acute phase. No studies have been performed in the horse that demonstrate clinical effectiveness of cryotherapy in decreasing inflammation, aiding healing, or improving rate of recovery and return to function.

Superficial Heat Therapy

Superficial heat involves the application of hot packs to the skin (moist hydrocollator packs heated to approximately 75°C, wrapped in several layers of towels) or immersion of the extremities into hot-water baths. Superficial heat effectively penetrates to approximately 1 cm.[32] Physiologic effects occur at tissue temperatures of 40°C–45°C; temperatures above 45°C may cause tissue damage.[32] In humans, mottled erythema may be a sign of overheating, but this sign does not appear in pigmented skin of horses. Avoiding areas of diminished circulation or sensation, manually monitoring skin temperature increases, and observing for signs of discomfort are methods of assessing thermal injury in horses.

The biophysical effects of superficial heat include decreased pain; increased blood flow and vascular permeability; decreased muscle spindle firing, which relaxes hypertonic muscles; and decreased tissue viscosity and increased elasticity, which enhances the effects of stretching.[32] There are no studies in horses which demonstrate clinical effectiveness of superficial heat. Kaneps[38] reported that subcutaneous and deep tissue temperatures never exceeded the therapeutic threshold of 41°C with the use of hot water hosing or hot packs.

Therapeutic Ultrasound

Therapeutic ultrasound is a method of deep heating of tissues. Alternating electrical current induces vibration of synthetic crystals contained within a sound head, which produce pressure waves known as ultrasound. Sound waves associated with therapeutic ultrasound penetrate the skin and subcutaneous tissues with minimal to moderate attenuation or absorption, to depths of 3–5 cm.[32] Tissues with high protein or collagen content or tissue interphases (e.g., periosteum or entheses) readily absorb sound wave, which results in energy transfer to the surrounding tissues and a localized increase in tissue temperature.[32,42] The primary biophysical effects of therapeutic ultrasound can be classified as thermal—determined by the degree of elevation in tissue temperature—or nonthermal—effects attributed to a mechanism other than an increase in tissue temperature. Nonthermal effects may be a result of the expansion and compression of small gas bubbles present in tissue fluids and the movement of fluids along the boundaries of cell membranes.[32] Various treatment parameters determine the biophysical effects of therapeutic ultrasound, which include the following:

- Frequency of the sound waves, which determines depth of penetration. The absorption of sound increases as the frequency increases. Common wavelengths of ultrasound devices are 1 and 3 MHz. At 3 MHz most of the energy is absorbed within a depth of 1–2 cm, making this frequency useful for treating superficial structures such as tendons and ligaments. At the lower frequency of 1 MHz minimal absorption occurs by the skin and superficial tissues and more energy is available for heating tissues up to depths of 3–5 cm.
- Continuous versus pulsed sound waves relate to the duty cycle or on-off time of the stimulation. Continuous mode creates a greater thermal effect within tissues.
- Intensity of the sound waves, which is the rate of delivery of the sound wave, is measured in Watts/cm^2. The higher the intensity, the faster and greater the temperature increases are produced.
- Sound head size, which is determined by the area to be treated. Small head are able to focus ultrasound waves in a smaller area or specific tissue; whereas larger heads are more effective for treating larger areas.
- Treatment duration. Shorter treatment times have fewer effects than longer treatment times.

Ultrasound energy is attenuated in air and is completely reflected at air-tissue interfaces. Therefore, a coupling medium (e.g., water-soluble gel) is used to eliminate as much air as possible to maximize transmission of the sound wave from the transducer head to the tissue surface.[32] Patient variables such as size of treatment area, depth of the lesion, tissue characteristics of the lesion, and stage of healing will determine which clinical parameters the therapist will choose. The dosage of ultrasound to a given area is determined by machine settings, relative collagen content of the underlying tissues, the size of the treatment area relative to the size of the treatment head and how rapidly the sound head is moved over the treatment area. It is not possible to calculate or control the exact dosage of ultrasound to a specific tissue. At higher intensities, thermal effects can become excessive, and tissue burns may occur. Employing ultrasound requires that the therapist be competent with the technique and have knowledge of the contraindications as well as the pathophysiology of the patient's condition. One caveat to the application of ultrasound in the veterinary patient is the large absorption of sound waves by the hair coat. Attenuation of the sound wave, by even the short coat of a clipped horse, is significant to decrease thermal effects in underlying tissues. The hair coat must be clipped to the skin for adequate transmission of the sound waves to occur.[43] The biophysical effects of therapeutic ultrasound include increases in tissue blood flow, enzyme activity, collagen synthesis; increased collagen extensibility secondary to increased temperature; and a decrease in pain.[32] In human physical therapy, ultrasound has been widely used for muscle and ligament strains, tendinopathies, bursitis, arthritis, joint contracture, calcific tendonitis, fractures, superficial and chronic wounds, and chronic pain syndromes.[32] Sufficient numbers of controlled studies in humans are still lacking; therefore, recommendations for the optimal application of therapeutic ultrasound in clinical situations are yet to be determined. There are no studies in horses that demonstrate tissue effects or clinical effectiveness of therapeutic ultrasound.

Long-wave (or kilohertz) ultrasound is a relatively new modality that involves the application of sound energy in the 40–50 kHz range instead of the 1–3 MHz range of the conventional therapeutic ultrasound. Ultrasound beams at frequencies greater than 800 kHz are well collimated, allowing a selected area to be targeted, while at lower frequencies the sound waves diverge and are not focused. There are no studies regarding tissue penetration or the physiologic effects of long-wave ultrasound. Maddi et al demonstrated an osteoblastic response to long-wave ultrasound, which may stimulate bone regeneration.[44] Long-wave ultrasound also had effects comparable to heating with a hot water bottle on functional ankle mobility as measured with a weight-bearing lunge test.[45] No studies exist on the use of long-wave ultrasound in horses.

Electrotherapy

Electrotherapy encompasses a wide variety of techniques in which electrical currents are introduced into the body for therapeutic effect.

Transcutaneous electrical stimulation (TENS) utilizes pulsed alternating current of variable frequencies and intensities applied via surface electrodes. The goal of TENS is the alleviation of pain. The mechanism of pain relief is thought to be through the stimulation of inhibitory interneurons at the spinal level or the release of endogenous endorphins within the central nervous system.[46-48] The effectiveness of TENS is variable because it is interacting with the extremely complex issue of the neurobiology of pain, which is typically patient specific. The TENS mode of action differs from that of NSAIDS; therefore, it may complement their use, but it will likely not add to the analgesic effect of opiate administration because of reliance on similar receptors. The value of incorporating TENS into the treatment plan may be that it will provide some immediate relief of chronic pain, which allows the patient to perform therapeutic activities that would otherwise be too painful. Although there is some evidence of analgesic effects of TENS in humans, these effects are often temporary or short-lived. There is no alleged effect of TENS on tissue healing or permanent pain relief. There is no evidence on the effectiveness of TENS use in horses.

Neuromuscular electrical stimulation (NMES) generates contraction of a targeted muscle, up to 80%–90% of maximum voluntary isometric contraction. Multiple studies have demonstrated strength gains in subjects undergoing NMES compared with unexercised controls, and comparable gains to subjects in voluntary exercise groups.[46] NMES can also aid in maintaining muscle development and neuromuscular control during early recovery phases when the patient is unwilling or unable to produce an effective voluntary contraction. NMES of denervated muscle remains controversial.[46] Although there is some evidence that NMES can delay denervation atrophy, there is no evidence that this treatment is significant in terms of recovery. Unfortunately, optimum parameters and frequency of treatment have not been determined. There are no studies on the use of NMES in horses. The forced contraction and possible discomfort induced by muscle stimulation can cause apprehension in the horse; therefore, the therapist must be very familiar with the application of this modality in horses.

Iontophoresis is the transdermal delivery of medication to soft tissue structures using a mild direct electrical current. Specialized surface electrodes impregnated with an ionized drug are subjected to direct current; the electrode will repel a drug of similarly charged ions into the tissues. Iontophoresis is used to treat painful or inflammatory musculoskeletal conditions, such as synovitis, tendonitis, or bursitis where the targeted structure is within the effective depth of penetration of the drug, approximately 1–1.5 cm.[46] The clinical use of iontophoresis is widespread in humans but there is limited evidence from controlled or clinical studies to support its use. Conditions such as plantar fasciitis, acute epicondylitis, and carpal tunnel syndrome have responded positively to iontophoresis with dexamethasone.[49–51] Equine studies on dexamethasone iontophoresis of the tibiotarsal joints failed to demonstrate detectable levels of drug in the synovium[52] or therapeutic levels of dexamethasone within the synovial fluid.[53] Differences in the ultrastructure of the dermis in horses may require alterations in the parameters of iontophoresis delivery. There have been no studies on the clinical effectiveness of iontophoresis in horses.

REHABILITATION OF POSTSURGICAL OR ACUTE INJURIES

Therapists use the characteristic physiologic and mechanical properties of traumatized tissue at various stages of healing to determine therapeutic goals and plan of care. It cannot be emphasized enough that continuous re-evaluation of the response to treatment is necessary to guide the decision-making process and revisions in the plan of care. It is beyond the scope of this article to present an in-depth discussion of the rehabilitation of multiple categories of tissue injuries or surgical procedures. However, general rehabilitation principles as they apply to the postsurgical or acutely injured patient will be presented.

Healing of soft tissues proceed through a sequence of events in which each stage builds upon and is dependent on the success of the previous stage. Tissue healing can be divided into four separate phases: clot formation, inflammation, fibroplasia and repair, and maturation and remodeling. The timing or progression from one phase to the next depends on the tissue type, the severity of injury, and the presence of complications such as infection or suboptimal health status of the patient. The phases of tissue healing are not distinct, but often overlap; therefore, different areas of the traumatized tissue undergo different phases of healing at the same time.

Phase 1 – Clot Formation (Immediately Post-Injury)

This phase is characterized by hemorrhage and release of fluid and inflammation-mediating cells into the traumatized area. Initially, neutrophils predominate to rid the site of bacteria and debris. Transient vasoconstriction occurs and the coagulation cascade is activated forming a hemostatic plug.

The therapeutic goals for the first 48 hours are to control pain, control bleeding, promote perfusion, avoid mechanical stresses to damaged tissues, and to protect the newly formed clot.

Therapeutic interventions for Phase 1 include pharmacologic pain control (with NSAIDS or opiates), enforced rest, intermittent icing, and compression wraps. In humans, elevation of the affected limb of body segment to assist fluid return to the central circulation is advocated, but is often difficult or impossible to implement in horses.

Phase 2– Inflammation (Days 1–5)

Pain, swelling, and loss of tissue integrity characterize the inflammatory phase. Vasodilation, increased vascular permeability, chemotaxis of inflammation-mediating cells, and release of chemical mediators of inflammation follow the initial vasoconstriction.[54] This phase involves a cascade of cellular and chemical events that prepare the wound for healing and initiate tissue repair; inflammation is not inherently bad or abnormal, but is a necessary part of the healing process. However, control of excessive swelling and assisting lymphatic and venous drainage will promote tissue perfusion and removal of damaged cells.

Therapeutic goals at this stage of healing include pain control, tissue protection, edema control, maximizing perfusion, and preserving function. Complete rest at this stage is detrimental to healing tissues and should be avoided as long as the stresses applied with controlled activity will not overwhelm and further injure damaged tissues.

Therapeutic interventions for Phase 2 include the following:

- Pharmacologic pain control
- Confinement and the application of protective wraps as necessary to protect injured tissues
- Ice and compression
- Low-intensity pulsed ultrasound for its nonthermal effects
- Effleurage, a form of gentle superficial massage to encourage lymphatic drainage (reported to increase lymphatic drainage by 22-fold in humans[55])
- Pain-free passive range of motion and gentle joint mobilization to decrease pain and encourage circulation and movement of fluids
- Controlled, limited activity to preserve function, usually limited to hand walking

Phase 3 – Fibroplasia and Repair (Days 5–21, Longer in More Severe Injuries)

Proliferation and migration of fibroblasts, formation of new collagen fibers, and vascularization characterize this phase. The immature tissue is fragile, unorganized, and easily injured.

Therapeutic goals include optimizing the healing environment, enhancing circulation and perfusion of the injured area, promoting alignment of collagen fibers along the lines of stress, preventing the formation of adhesions, restoring neuromotor function and proprioceptive awareness, and preserving or enhancing strength. Active exercises at this stage must be very carefully tailored to the severity of the injury and strength of the repair.

Therapeutic interventions for Phase 3 include the following:

- Modalities including heat, therapeutic ultrasound, laser, or acupuncture to improve circulation and stimulate healing.[56]
- NMES for muscle contraction and neuromotor stimulation.
- Joint range of motion, light pain-free stretching, and joint mobilization.
- Stretching to the point of mild discomfort and tension after 2 weeks to maintain and gain joint range of motion and flexibility and to stimulate collagen fibers to orient along the lines of stress.
- Deep tissue and scar massage to reduce and prevent adhesions and maintain mobility of the scar. Clinical judgment is required to avoid subjecting tissues to tensile forces before the strength of the repair is adequate to resist those forces.
- Neuromotor and proprioceptive retraining: balancing and sway activities; hand walking over various surfaces (such as turf, sand, gravel, asphalt), progressing to uneven surfaces; changes of direction; circles; stepping over ground poles and bridges; and sensory integration techniques (to be discussed). Very slow, controlled walking is an excellent neuromotor retraining activity.
- Core strengthening (to be discussed).
- Light strengthening activities: adding gentle grades for eccentric and concentric strengthening; gradually increasing speed, which increases load applied to tissues.
- Move out of box stall to small paddock to allow limited activity as soon as it is safe to do so as judged by the degree of tissue healing and the personality and demeanor of the individual horse.
- Monitor and address compensatory issues such as contralateral limb laminitis, trigger points and secondary neck and back pain. Neck and back pain may develop in response to compensatory movement patterns; if allowed to persist, chronic pain mechanisms may interfere with optimal return to function.[57]

Phase 4 – Maturation and Remodeling (Begins at 21 Days and Lasts up to 1 Year or More)

Collagen fibers mature from Type III to Type I and become oriented parallel to the lines of stress, which increases tensile strength; if no stresses are applied, collagen fiber orientation remains random. Collagen crosslinks form, which help to stabilize the repair tissue. Where scar tissue is present, the repair will be unorganized, lack mobility and extensibility, lack resistance to tensile forces, and will have abnormal proprioceptive input.[58] Lesions that heal with excessive amounts of this weak, unorganized scar tissue are prone to repetitive microstrains, progressive retraction, and degeneration.[59]

Treatment goals during this stage are to regain joint range of motion, flexibility, neuromotor function, balance, coordination, and strength, with a gradual return to normal function and sport activities.

Therapeutic interventions for Phase 4 include the following:

- Precede all therapeutic sessions with a gradual warm-up and flexibility exercises
- Stretching and joint mobilization
- Neuromotor retraining, which gradually progresses to activities that require greater degrees of coordination and agility
- Progressive strengthening and conditioning
- Thoughtful reintroduction of sport-specific activities on an individual basis

REHABILITATION PROGRAM FOR OSTEOARTHRITIS

Osteoarthritis has been described as a problem of joint failure.[60] Once the joint has developed signs of osteoarthritis, the structure has already begun to fail. Current evidence attributes the etiopathogenesis of osteoarthritis, not to a disorder of cartilage, but due to deleterious mechanical loading or tissue stresses. According to Brandt "osteoarthritis is a mechanically induced disorder in which the consequences of abnormal joint mechanics provoke biological effects that are mediated biochemically, for example, through cytokines, matrix-degrading enzymes and toxic oxygen radicals."[61] Abnormal joint biomechanics may be attributed to (1) joint instability, hypermobility, or malalignment caused by ligamentous laxity; (2) loss of shock absorption secondary to weakness or atrophy of muscles that are responsible for deceleration of joint movement as the limb strikes the ground; and (3) diminished proprioceptive acuity, which decreases coordination of muscle fiber recruitment; coordinated muscle activity is necessary to provide dynamic joint stability and to protect joints from injury during strenuous activities. Diminished function of neuromuscular or ligamentous structures may be a result of injury or deterioration with aging. Repetitive, excessive forces such as those seen in obese individuals or extreme athlete will compound the effects of altered mechanical stresses. The articular cartilage then becomes a secondary effect of abnormal and excessive biomechanical forces.[61] If the biomechanical aberrations that initiate joint pathology are not corrected, then reversal of structural damage present is unlikely.[62] Although some disease-modifying osteoarthritis drugs and regenerative therapies hold promise, as clinicians we currently do not have the ability to cure the osteoarthritic joint. The multitude of different therapies available to treat osteoarthritis suggests that no single form of therapy is superior or highly efficacious. The future of osteoarthritis management will likely combine early detection and correction of abnormal intra-articular mechanical stresses with pharmacologic or restorative therapies that slow matrix destruction or promote its repair.

Current osteoarthritis research is attempting to define the molecular, biomechanical, and functional outcome parameters that are useful for identifying the prevalence, progression, and therapeutic effectiveness of modalities for the management of osteoarthritis. A 3-year study of osteoarthritis of the knee in humans identified factors that are most predictive of poor physical function in individuals with osteoarthritis. They include joint laxity, proprioceptive inaccuracy, age, body mass index, and knee pain intensity. Additional factors that protect against a poor functional outcome include measures of strength, participation in a greater amount of aerobic exercise, mental health, self-efficacy, and social support.[63] Individuals with a history of joint injury are at significantly increased risk of developing osteoarthritis later in life. On the basis of this knowledge, appropriate intervention should be initiated before or in the early stages of the onset and development of osteoarthritis. There is a growing body of evidence that rehabilitation programs that focus on reducing pain, maintaining or improving proprioceptive acuity and strength, and enhancing joint stability through neuromuscular training may have the potential to improve function and alter the progressive course of osteoarthritis.[64-68]

Multimodal management of the osteoarthritic patient involves pharmacologic pain management, chondroprotectants and nutraceuticals, nutritional management, weight control, physical therapy, and surgical intervention, when necessary. Many of the signs associated with osteoarthritis are amenable to physical therapy interventions, which include pain, joint stiffness and loss of range of motion, pain and hypertonicity in adjacent muscles, proprioceptive deficits, and progressive weakness.[69] In addition, the biomechanical abnormalities associated with the pathogenesis of the disease may be addressed with strengthening, endurance, balance, coordination, and proprioceptive retraining activities. Physical therapy interventions emphasize modalities for pain management and appropriate low impact, consistent exercise.

Therapeutic interventions for the management of osteoarthritis may include

- Superficial heat to decrease pain and stiffness and improve tissue extensibility.
- Cold therapy to decrease pain and joint effusion.
- Therapeutic ultrasound to decrease pain, improve circulation, and decrease stiffness. A study on the clinical effects of therapeutic ultrasound in knee osteoarthritis in humans demonstrated improvements in knee pain with movement and 50-m walking time and improved WOMAC scores (Western Ontario and McMaster Universities Osteoarthritis Index).[70] The studies on humans are incomplete regarding the ideal parameters for using therapeutic ultrasound in the treatment of osteoarthritis, and review articles conclude that the number of controlled trials not sufficient to demonstrate the effectiveness of therapeutic ultrasound.
- NMES for strengthening and neuromotor control.
- Iontophoresis to decrease synovitis and effusion. Iontophoresis has been shown to improve the signs and symptoms of temporomandibular joint disorders and knee osteoarthritis in limited numbers of human studies.[71,72]
- Acupuncture to decrease pain and improve function. Multiple studies have demonstrated the effectiveness of acupuncture in knee osteoarthritis in humans.[73]
- Regular massage can decrease pain and improve flexibility, diminish signs of stress, and induce relaxation.[74-78]
- Joint mobilization and joint distraction to decrease pain and improve joint range of motion.[79] Manual therapy may also decrease joint effusion and improve cartilage nutrition.
- Range-of-motion and stretching exercises. These exercises are important to decrease stiffness, swelling, and effusion and to maintain adequate range of motion to

complete functional activities. Deteriorating joint range of motion leads to diminishing muscle activity and progressive weakness.[80,81]

- Neuromotor training. Osteoarthritis and ligamentous damage result in impaired proprioception that may perpetuate joint damage. Joint effusion inhibits muscle fiber recruitment and coordination, balance, and proprioceptive retraining exercises may help to minimize these effects.[82-84]
- Strengthening the muscles that support the arthritic joint improves shock absorption, enhances neuromuscular activation, and may reduce repetitive impact on damaged cartilage surfaces.[66,85,86]
- Aerobic exercise. Regular participation in aerobic exercise decreases pain, maintains strength, and improves function.[67] Exercise prescription must be patient-specific and within the tolerance levels of the individual. The surface on which horses exercise should limit impact and torque; turf or shallow arena sand or synthetic surfaces are preferable to hard surfaces or deep sand.
- Aquatic exercise. In human patients, aquatic exercise has been studied in osteoarthritic patients because of its buoyancy effects. Although, intuitively it would seem to be a great modality for reducing impact, studies to date have not demonstrated significant benefits over land-based exercise.[87] Aquatic exercise in horses consists of either underwater treadmill or swimming. Swimming is an unnatural activity for most horses as it is a non-weight–bearing and unusual locomotor activity. Swimming horses often hold their head elevated and the thoracolumbar spine is held in extension. Because most horses are not natural swimmers; some will flail or possibly injure themselves. However, swimming has been shown to provide high levels of aerobic activity for horses.[88] Conversely, underwater treadmill exercise is a similar locomotor activity as walking is and it also reduces impact because of the buoyancy of the water. Few formal studies have been performed on underwater treadmill exercise in horses. Practitioners familiar with underwater treadmill use report that horses can begin a walking or training program earlier in the course of recovery. In addition, horses tend to exercise with greater flexion of the spine and activation of the ventral muscles, compared to swimming, which help to prepare the horse for transition to a land-based exercise program.[89]

REHABILITATION OF NEUROLOGIC DISORDERS

Neurologic disease in both human and veterinary patients encompasses a wide range of central and peripheral disorders, which may be degenerative, traumatic, infectious, or metabolic in origin. Musculoskeletal disorders may also compromise associated neural functions and, conversely, neurologic disease will alter dynamic function of the motor system; the two are inextricably connected anatomically and functionally. Rehabilitation of neurologic disorders is based on neuroplasticity: the stimulation and development of novel pathways within the nervous system after injury. Experimental models of spinal cord injury in the cat and rat demonstrate that active locomotor training decreases expression of inhibitory molecules, increases expression of neurotrophic factors, and alters electrophysiological properties in the spinal cord.[88] After cervical spinal injury in humans, intense repetitive training promotes cortical plasticity and cortical map reorganization.[8] In short; active exercise improves motor recovery after neurologic injury.[90]

Interventions in the treatment of neurologic deficits may include electrical stimulation, neuromotor training, and sensory stimulation. Electrotherapeutic modalities such as NMES and electroacupuncture stimulate the sensory and motor divisions of the nervous system.[46] Stimulation and firing of neural elements maintain integrity of the neuromuscular junction, stimulate production of neuropeptides and neurotrophic chemicals, and reduce weakness. Dogs with thoracolumbar intervertebral disk disease treated with electroacupuncture resumed ambulation in a shorter period than with medical treatment alone.[91]

Neuromotor training is an essential component of rehabilitation of the neurologic patient. Active exercises specifically designed to stimulate sensory and proprioceptive elements coupled with motor activity retrain feedback loops involved in balance, coordination, and agility.

- Balancing exercises, such as static balancing (maintaining antigravity control while lifting one or more limbs to alter the base of support), dynamic balancing (maintaining antigravity control while standing on an unstable or moveable surface such as trampoline or rocking board), and rhythmic stabilization (maintaining antigravity control while the therapist applies multidirectional, rhythmic external perturbations to the patient) promote proprioceptor activity, as well as, core and antigravity muscle activity. Induced movements increase firing from joint and muscle proprioceptors. Information received from proprioceptors is integrated in supraspinal centers and influences motor output to core stabilizing and limb extensor muscles. The motor response, if adequate, prevents loss of balance and falling.
- Locomotion over variable ground surfaces stimulate firing of sensory and proprioceptive fibers to a greater degree than an unchanging surface. Altering the surface every 3–6 m (e.g., turf, gravel, sand, and asphalt), walking over uneven surfaces or walking in water of various levels will stimulate the system to adapt to the variable sensory inputs and altered balance requirements.

- Changes in direction, such as serpentines, figure 8s, side passes, patterns around obstacles, and changes in direction while backing require increased dynamic balance control.
- Transitions and variations in gait: altering speed, stride length and cadence, upward and downward transitions, and backing improve coordination and neuromotor control of limb and body acceleration and deceleration. Transitions encourage the horse to step under the body with the hind limbs, maintain greater flexion of the hind limbs and utilize the core musculature for self-carriage and balance.
- Negotiating cavaletti poles in various configurations such as ground level, raised, uneven, and variably spaced while altering speed and stride length improves proprioception, neuromotor control, core muscle activation, and self-carriage. Negotiating obstacles slowly, one step at a time requires limb proprioception and activation of core and antigravity muscles as the horse collects itself and maintains the body's center of mass over the base of support.
- Baited stretches include inducing lateral bending and rounding or flexion of the neck and back. Active stretching exercises require balance and coordination to perform the maneuvers, while helping to increase spinal flexibility.
- Working on a slope: uphill, downhill, over obstacles, backing, and lunging in circles. Negotiating an inclined surface requires greater proprioception and dynamic balance control, as well as, additional muscular effort to ascend or descend a slope. Core stabilizing musculature is also activated to a greater degree when working on an incline.

Sensory integration is the process of providing tactile and proprioceptive cues to targeted structures. The goal is to enhance and coordinate motor activities through integrating the sensory stimulus into the functional activity. Some examples of techniques include the following:

- Placement of a body wrap that produces rhythmic sensory stimulus, which is timed with the gait cycle; helps to synchronize function of the hindquarters with the forehand; encourages contraction of the iliopsoas and spinal flexors (Fig. 5).
- Placement of an elastic Thera-Band around the caudal surface of the pelvic limb encourages pelvic limb protraction and contraction of the abdominal musculature, which assists in core muscle strengthening (Fig. 6).
- Kinesiotape: Placement of elastic tape on the skin; stimulates cutaneous sensory receptors. Placing tape from origin to insertion with tension facilitates kinesthetic awareness and contraction of the muscle. Placing tape perpendicular to muscle fibers is thought to have an inhibitory effect on muscle activity (Fig. 7).[92]

Figure 5. Placement of Thera-Bands in a figure-8 configuration around the horse's trunk produces a rhythmic, sensory stimulus that is timed with the gait cycle. The goal is to coordinate and synchronize the activity of the hindquarters with the forehand and to facilitate protraction of the pelvic limbs.

- Application of a lightweight strap with chains around the pastern provides a tactile stimulus that increases peak hoof height during the swing phase.[93]
- Application of support boots or athletic taping around the fetlock (circumferential ankle pressure) is thought to increase proprioceptive acuity.[94-96]

THERAPEUTIC EXERCISES FOR BACK PAIN AND DYSFUNCTION

In recent years, the concept of back pain as a significant contributor to poor performance in horses has received widespread attention. Horse owners are becoming more adept at recognizing signs of back problems. Veterinarians are incorporating multiple diagnostic and therapeutic modalities, which can elucidate and treat underlying spinal pathologies. Incorporating chiropractic, massage, acupuncture, and physiotherapeutic modalities has the potential to benefit equine patients by restoring mobility and alleviating pain. Human physical therapists have long recognized the detrimental effects that back injuries and chronic pain have on the muscular function and dynamic stability of the spine. Failure to recognize and address these dysfunction syndromes predisposes the patient to further injury. Veterinary researchers are characterizing the relationships between spinal joint biomechanics, muscular function, and locomotion in the presence of back pain.[97,98] Using these findings can assist in determining

Figure 6. Attachment of a Thera-Band to a surcingle and positioning of the band around the caudal aspect of the pelvic limbs facilitates proprioception and protraction of the pelvic limbs during exercise.

Figure 7. Placement of duct tape or similar form of kinesiotape parallel to the fibers of the internal abdominal oblique muscle (from the tuber coxa to the xiphoid process), with the intent of providing sensory stimulation and facilitation of abdominal muscle contraction during locomotion. A second tape is placed perpendicular to the fibers of the epaxial muscles in the lumbar region. Perpendicular placement may inhibit contraction of the underlying musculature, potentially decreasing the tendency to habitually contract the spinal extensors.

the optimal therapeutic exercise prescription that will return the horse to the highest level of spinal function and performance.

Proper spinal function in the unridden and ridden horse is achieved by selective contraction and relaxation of specific muscle groups that effect a change in the shape of the vertebral column. Pain-free spinal mobility enables the horse to support its own body weight and to carry a rider while maintaining fluid and elastic movement during locomotion or athletic events. The primary actions that allow for this change in posture and spinal function are as follows:

- Relaxation of the longissimus dorsi muscle. This ensures that the longissimus dorsi is free to contract and relax as needed to allow and control dorsoventral and lateral movements of the spine in sequence with the gait cycle.
- Contraction of the iliopsoas muscle, causing flexion of the lumbosacral joint (as well as abdominal muscle contraction, which flexes the thoracolumbar spine).
- Contraction of the longus colli and scalenus, which flexes the cervical spine and raises the base of the neck (telescoping maneuver).
- Relaxation of the dorsal poll muscles and contraction of the ventral muscles of the upper cervical region, allowing flexion of the poll.
- The nuchal and supraspinous ligaments are attached to the thoracolumbar spinous processes. Flexion and lowering of the cervical spine creates tension in nuchal and supraspinous ligaments, which causes elevation and separation of the thoracolumbar spinous processes and flexion of the thoracic spine.[99,100]

Factors Contributing to Spinal Dysfunction

If the longissimus dorsi is in a constant state of contraction or chronic hypertonicity and fails to or is unable to relax, the horse will be unable to elevate its back, produce lateral movements of the spine, or readily support the added weight of the rider. Factors that may induce a state of chronic epaxial muscle contraction include the following:

- Emotional or behavioral factors. Fear or anxiety will cause a voluntary elevation of the head, hypertonicity of the poll and back muscles, and spinal extension.
- Management factors. Stabled horses fed in elevated feed bins spend less time with the head lowered; the spinal extensors, nuchal ligament, and supraspinous ligament lose flexibility and have a reduced ability to lengthen. Long periods of stall confinement with no regular turnout are thought to reduce normal spinal flexibility compared to pastured horses.
- Back pain of any etiology promotes hypertonicity and guarding of the muscles responsible for spinal extension.
- Inability to contract the iliopsoas, abdominal muscles, or cervical flexors. Young or deconditioned horses, or a horse ridden to the point of fatigue will be unable to maintain contraction of the ventral abdominal musculature, which is responsible for producing spinal flexion. Passive support mechanisms are altered and the horse

Figure 8. Induced passive left lateral bending of the upper cervical region, specifically at the atlanto-occipital joint. It is important to do all stretching exercises with the horse standing squarely up against a wall to prevent the horse from stepping away from the applied pressure or stretch.

Figure 9. Active left lateral bending of the lower cervical region using a bait or treat. The goal of this stretching exercise is to increase active range of motion of the cervical and upper thoracic spine. The treat is first directed toward the point of the elbow and then is moved along the rib cage toward the ipsilateral stifle or tuber coxa.

is unable to support the rider and is at increased risk for back pain and injury.

Signs of Back Pain and Spinal Dysfunction

Signs of back pain vary and generally relate to either a behavioral change during a given activity or the inability to complete a functional task because of pain, biomechanical dysfunction, or hypertonicity of the longissimus dorsi muscle. Common signs of back pain include withdrawal from manual pressure, resenting grooming, saddling or mounting, sinking when mounted, bucking, rearing or bolting, and head tossing or tail swishing.[99] Persistent pain and hypertonicity of the epaxial musculature will interfere with normal function of the back and result in impaired performance. Clinical signs may include failure to bend or yield, stumbling and tripping, obscure lameness, short striding, inability to collect, and difficulty with lead changes or cantering. Sport specific activities such as jumping, dressage movements, transitions, impulsion, or speed around barrels may be affected.[101]

Biomechanics of Spinal Dysfunction

Understanding the biomechanical characteristics of the back and its supporting structures will enable the therapist to design rehabilitation programs that take advantage of these responses. Significant findings from various studies on spinal biomechanics and locomotion as they relate to therapeutic exercises include the following:

- Kinematic evaluation of the back in horses with and without back pain reveals significant differences in spinal mobility at the walk and trot. At the walk, affected horses have a smaller range of motion during flexion and extension at T13 and T17, greater range of motion in lateral bending at T13, reduced axial rotation of the pelvis, less symmetrical flexion and extension at L1, less symmetrical lateral bending at L5, and shorter stride length. At the trot, affected horses have smaller ranges of motion in flexion and extension at T17 and L1, but no other differences in parameters at the trot. Altered movement

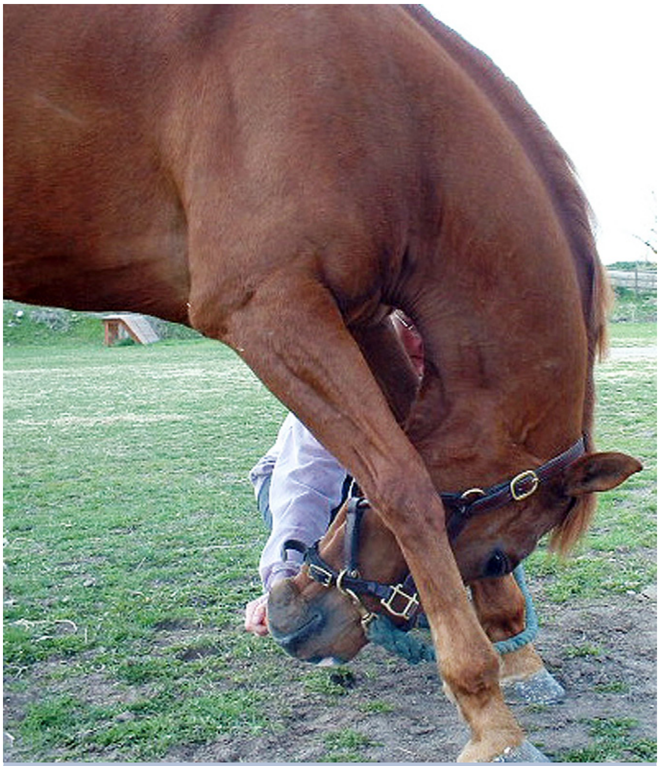

Figure 10. Active lower cervical flexion while using a baited stretch helps to elongate the nuchal ligament and cervical epaxial musculature and to elevate the thoracolumbar region. This stretch is useful for rehabilitation of horses with poor-fitting saddles and impinged spinous processes in the mid-thoracic region.

patterns and changes in range of motion in horses with back pain may be due to pathologic limitations or compensatory movements to alleviate pain.[97]

- Three-dimensional kinematics of the vertebral column reveal that flexion, extension, lateral flexion, and axial rotation vary regionally in degree and timing and are related to activity of the limbs.[102]
- EMG studies indicate that activity of the longissimus dorsi muscle is mainly for stabilization of the vertebral column against dynamic forces and that it is sequentially active at various spinal levels during the gait cycle.[103]
- EMG studies reveal that rectus abdominis and longissimus dorsi muscle activity increase linearly with increasing treadmill speed. Increasing the working slope from 0%–6% results in a longer duration of rectus abdominis and longissimus dorsi activity and an increase in EMG activity.[104]
- A horse carrying a saddle plus 75 kg of weight exhibits increased overall extension of the lumbar spine.[105]

Figure 11. Rounding spinal reflex elicited by drawing finger tips or needle caps bilaterally along the myofascial junction between the proximal biceps femoris and semitendinosus muscles (approximately 4 inches lateral to the tail head). The reflex stimulates contraction of the abdominal musculature, elevation of the thoracolumbar spine, and flexion of the lumbosacral joint, which assists in neuromotor training of collective movements.

- There is a strong correlation between limb lameness and the presence of back problems.[57]

Therapeutic Exercises for Rehabilitation of Spinal Dysfunction

The goals of a rehabilitation program for back pain and spinal dysfunction are based on the biomechanical requirements, age, and experience of the ridden horse. Many professional trainers believe that 2–3 years of proper riding and conditioning are required to develop and strengthen the structural elements responsible for self-carriage in horses, while supporting the added weight of a rider. Emotional tension, anxiety, fear, and pain promote tension in the poll and epaxial musculature. Therefore, many therapeutic exercises are directed at alleviating signs of pain and dysfunction. The goals of therapeutic exercise for back pain and dysfunction include the following:

- Eliminate management factors that promote tension within the epaxial musculature such stall confinement and isolation from other horses.
- Reduce or alleviate muscle hypertonicity and improve flexibility of the neck and back.
- Strengthen abdominal musculature.
- Strengthen the iliopsoas and muscles responsible for pelvic limb protraction (e.g., rectus femoris).

Figure 12. Axial traction applied to the tail. The procedure involves grasping the end of the bony tail with both hands and applying a caudally-directed force. The angle of the tail and the applied force should correspond to the angle of the sacrum. The therapist slowly and gently leans back to apply traction, while waiting for the horse to oppose the applied force. This technique should not be performed on a horse that exhibits apprehension or discomfort. The horse should be gradually familiarized to axial traction to the tail to avoid potential injury.

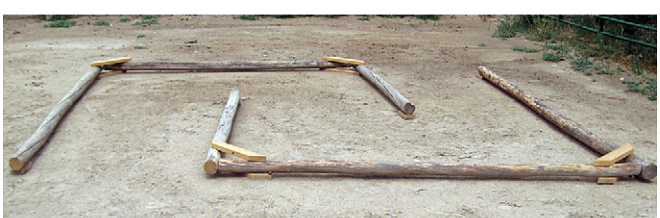

Figure 13. Ground poles laid out on the ground to form the labyrinth. Negotiating the labyrinth promotes focus and mental relaxation in horses.

- Strengthen and improve motor control of the muscles responsible for cervical flexion. The performance horse should be adept at recruiting cervical spinal flexors and avoid contracting cervical extensors. These movements support yielding to the bit, promotion of relaxation and decreased tendency to elevate the head and neck, contract the epaxial musculature, and extend or hollow the back.
- Improve balance and proprioception.
- Strengthen and improve proprioception of intrinsic muscles of the spine with core stabilization exercises.

Figure 14. Walking the horse through the labyrinth encourages lateral bending and facilitates stepping medially across midline with the inside pelvic limb. Lateral work tends to calm the anxious horse because the horse cannot adopt an elevated head and neck posture when the neck is lowered and laterally bent.

Figure 15. The star obstacle is constructed of poles laid out in a circular pattern and raised at the center of the circle. This complex proprioceptive activity requires lateral bending combined with constant changes in the amount of limb flexion and step length between the inside and outside limbs.

Core Strengthening and Neuromotor Retraining Exercises

Exercises should initially be performed as ground exercises until the horse demonstrates that it is capable of elevating the back and maintaining a relaxed longissimus dorsi while carrying a rider.

Figure 16. Walking across an elevated bridge provides stimulation of unique auditory signals and limb sensations. This exercise also facilitates lowering of the head and cervical flexion, abdominal muscle contraction, and increased limb flexion during entering and exiting of the obstacle.

Figure 18. Negotiating raised cavalletti poles at a working trot. This exercise stimulates contraction of the muscles responsible for cervical flexion, especially the scalenus as the horse flexes and lengthens the base of the neck. Abdominal muscle contraction is also encouraged, which elevates the back and stimulates neuromotor control of the core stabilizing muscles.

Figure 17. Ground poles placed at ground level at intervals equal to the step length of the individual horse. This exercise facilitates lowering of the head, cervical flexion, abdominal contraction, limb flexion, and pelvic limb protraction. Reaching farther under the body with the pelvic limbs improves impulsion. Negotiating the poles improves inter-limb coordination and cadence.

Figure 19. Negotiating raised cavalletti at a slow trot accentuates limb flexion, improves balance and proprioception, strengthens abdominal muscles and core stabilizers, and improves cadence.

- Upper cervical lateral bending stretches are used to reduce tension in the dorsal poll muscles and to stimulate neuromotor control of the atlanto-occipital joint during lateral bending (Fig. 8).
- Lower cervical lateral bending stretches are used to elongate soft tissues and to mobilize the cervicothoracic spine (Fig. 9).
- Lower cervical flexion helps to flex the base of the neck and to stretch and lengthen the topline (Fig. 10). It is important to place a hand on the dorsal carpus to prevent thoracic limb flexion and cheating during the active stretches.
- The rounding reflex stimulates contraction of the abdominal and iliopsoas muscles, flexion of the lumbosacral joint, and brings the pelvic limbs under the body (Fig. 11).

Figure 20. Walking up and over a pedestal improves proprioceptive control and balance and stimulates contraction of the ventral cervical and abdominal musculature. This exercise also strengthens the muscles responsible for limb extension through the efforts of stepping up to and down from the pedestal.

Figure 21. The horse is asked to stand on a pedestal with the goal of improving balance and limb proprioception.

- Tail manipulations are characterized by tail traction, with the intent of reducing tension in lumbar epaxial and gluteal musculature (Fig. 12). Rhythmically pulling and partially releasing the applied tension stimulates contraction of the core musculature and spinal stabilizers and aids in development of neuromuscular coupling at the lumbosacral junction. Pulling laterally on the tail is used to stimulate balance and stabilizing responses in the pelvic and proximal limb musculature.

Figure 22. A horse demonstrating a very relaxed demeanor and flexion of the cervical region while standing on a pedestal.

Figure 23. The horse is slowly stepped down off the pedestal, which demonstrates the proprioceptive requirements of negotiating a step from a restricted or limited base of support.

- Labyrinth or obstacle exercises are low-level neuromotor training exercises used to stimulate proprioceptive awareness (Figs. 13 and 14). Work over various obstacles and ground pole configurations stimulate increased

Figure 24. Walking uphill stimulates contraction of the abdominal and iliopsoas muscles and strengthens the pelvic limb muscles responsible for propulsion. Incline work induces increased flexion and protraction of the pelvic limbs. The goal of this exercise is to improve the ability of the pelvic limb muscles to act as decelerators and shock absorbers, which may serve a protective function for the joints of the pelvic limbs.

neuromotor responses, core strengthening, coordination, and agility than normal ground training on the flat (Figs. 15 and 16).

- Ground pole and cavaletti work during in-hand or ridden walking or trotting exercises are a high-level neuromotor training activities that facilitate abdominal and iliopsoas contraction (i.e., core strengthening); improves cadence and tempo and inter-limb coordination; encourages lowering of the head and relaxation of the poll musculature; facilitates pelvic limb protraction, elevates the forehand, and promotes work off the haunches and pelvic limb flexion (Figs. 17, 18, and 19).
- Pedestal work simulates "collection" by stimulating longus colli and scalenus muscle contraction and flexion of the base of the neck and trunk (Figs. 20 and 21). This is an example of high-level proprioceptive work, which emphasizes limb kinesthesia and core strengthening while also promoting relaxation and confidence (Figs. 22 and 23).
- Incline work facilitates abdominal contraction and strengthens the muscles responsible for propulsion; brings the pelvic limbs further under the body; and elevates the back (Figs. 24 and 25). Working at a very slow walk (one step at a time) or over obstacles is a high-level proprioceptive and balancing activity (Figs. 26 and 27). Walking downhill versus uphill requires eccentric contractions of limb musculature and deceleration of body

Figure 25. Walking downhill encourages the horse to reach farther under the body, which acts to eccentrically strengthen the pelvic limb and abdominal muscles. This exercise also improves dynamic balance as the horse resists gravity while descending the hill.

Figure 26. Walking uphill over a ground pole accentuates the demands and effects of ascending a hill. This exercise encourages the horse to shift their body weight toward the hindquarters and to lighten the forehand.

Figure 27. Walking downhill over a ground pole accentuates the demands and effects of descending a hill. Demands for balance and coordination increase as the horse prepares to step over a pole while resisting gravity during downhill locomotion. This exercise also stimulates significant activation of the abdominal muscles and strengthening of core stabilizers.

Figure 28. Backing uphill requires a high-level of proprioceptive and balancing activity. This exercise also strengthens pelvic limb muscles as the horse resists shifts in the center of gravity toward the forehand.

mass which requires greater neuromotor control. Backing uphill is a high-level proprioceptive activity and novel muscle activity (Fig. 28).

SUMMARY

The therapeutic exercises presented here are based on knowledge and experience of human physical therapy and equine biomechanics, as well as an understanding of equine behavior and training principles. The well-documented benefits of physical therapy in human medicine challenge veterinary practitioners to incorporate some of the same rehabilitative therapies into equine practice. The scientifically based principles presented are hoped to provide a starting point for adapting some of these techniques to horses. Unfortunately, most rehabilitation programs are based on intuition and clinical experience and not on well-designed randomized studies. Formal research and clinical studies are needed to further assess the mechanisms of action and effectiveness of physical therapy interventions designed to optimize function and reduce the morbidity in equine patients.

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