Principles and Application of Hydrotherapy for Equine Athletes

Melissa R. King, DVM, PhD

KEYWORDS

• Hydrotherapy • Underwater treadmill exercise • Buoyancy • Osmolality
• Hydrostatic pressure • Viscosity

KEY POINTS

- Exercising in water is an effective treatment option for managing musculoskeletal injuries.
- Hydrotherapy provides an effective medium for increasing joint mobility, enhancing muscle activation, improving postural control, and reducing inflammation.
- Various forms of hydrotherapy are frequently prescribed for rehabilitation of equine musculoskeletal injuries with the goal of improving the overall function of the affected limb and preventing further injuries.

INTRODUCTION

Aquatic rehabilitation has long been recognized as having beneficial effects in humans. Hydrotherapy is a commonly prescribed treatment option for managing primary musculoskeletal injuries and reducing or limiting harmful compensatory gait abnormalities in people.[1] Exercising in water provides an effective medium for increasing joint mobility, promoting normal motor patterns, increasing muscle activation, and reducing the incidence of secondary musculoskeletal injuries caused by primary joint pathology.[2] Humans with lower extremity osteoarthritis show a significant increase in limb-loading parameters, improved joint range of motion, and a significant reduction in the severity of balance deficits following aquatic exercise.[3] The enhancements in muscle strength and function associated with aquatic exercise also significantly improve proprioceptive deficits, poor motor control, and abnormal locomotor characteristics typically found in osteoarthritic adults.[4]

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Department of Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, 300 west drake street, Fort Collins, CO 80526, USA
E-mail address: Melissa.king@colostate.edu

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PROPOSED MECHANISMS OF ACTION

Hydrotherapy interventions, such as underwater treadmill exercise and swimming, have been reported to reduce mechanical stresses applied to the limb, improve joint range of motion, decrease pain and inflammation, improve muscle strength and timing, and increase cardiovascular endurance.[5] The physical properties of water provide a medium where the mechanisms of increased buoyancy, hydrostatic pressure, and viscosity, along with the ability to alter temperature and osmolality, are applied in different combinations to play an important role in individualized musculoskeletal rehabilitation (Fig. 1). The increased resistance and buoyancy inherent in aquatic exercise increases joint stability and reduces weight-bearing stresses on muscles and joints.[6–8] Immersion of the distal limb causes circumferential compression, which increases proportionately with water depth. The increased extravascular hydrostatic pressure promotes circulation and reduces edema.[5] Hydrotherapy can also aid in decreasing pain through temperature effects. Immersion in warm water causes vasodilation, increased circulation, and decreased muscle spasms,[9] whereas cold water acts to reduce inflammation by restricting blood flow and reducing the accumulation of inflammatory mediators.[10] Aquatic conditions with higher solute concentrations provide an osmotic effect, which can ultimately reduce edema and decrease pain.[11] Hydrotherapy is a versatile treatment modality capable of producing a wide variety of therapeutic effects and therefore is considered an effective method for addressing sensory and motor disturbances associated with musculoskeletal injuries to achieve functional restoration of full athletic performance.[12]

Buoyancy

In the context of hydrotherapy, buoyancy is defined as a lifting force that acts to reduce axial loading of the joints by minimizing vertical ground reaction forces. Underwater force platform analysis of human subjects demonstrates a significant reduction

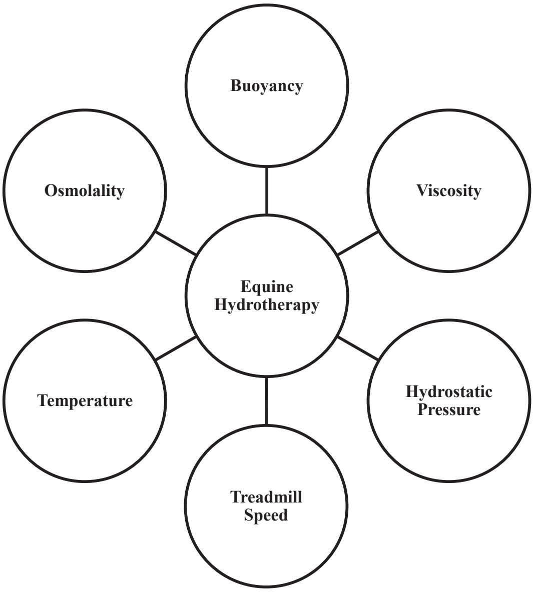

Fig. 1. Graph illustrating the combined variables involved in hydrotherapy.

in vertical ground reaction forces during walking,[3] which is inversely correlated with the depth of water immersion. Humans walking at a slow pace in water at the level of the manubrium have a 75% reduction in weight bearing, but only a 25% reduction in weight bearing when walking in water at level of the pelvis.[13] In horses, water at the level of the tuber coxae produces a 75% reduction in body weight, whereas water at elbow height has a 10% to 15% reduction in weight bearing.[14] Increased buoyancy reduces the effects of weight-bearing stress placed on joints and the surrounding soft tissue structures, which helps to reduce pain and inflammation associated with impact loading exercises. Underwater kinematic analysis in humans has also demonstrated that increased buoyancy improves joint range of motion. Humans with lower extremity osteoarthritis show increased limb flexion while walking in water compared with relatively decreased joint range of motion when walking on land.[15] The buoyancy effects of aquatic therapy can produce kinetic and kinematic effects that are directly applicable to the clinical management of musculoskeletal morbidities in horses.

Viscosity

The viscosity (fluid's resistance to flow) of water is about 12 times greater than that of air; therefore, the increased effort required to move through water causes increased muscle activation and improves muscle strength, motor control, and joint stability.[3] Electromyographic analysis during underwater exercise in human patients demonstrates increased activation of the agonist muscles during concentric contractions.[15] Increased agonist muscle activity is required to accelerate the limb in the direction of movement. However, during the same concentric contraction a reduced coactivation of the antagonist muscle group occurred.[15] Concentric muscle contractions during land locomotion cause the antagonist muscles to become activated to help decelerate the limb segments in preparation for foot contact. However, when exercising in water the increased resistance applied in the direction of motion requires minimal muscular braking of the limb segments.[15] Humans with knee osteoarthritis routinely demonstrate an inhibition of the quadriceps muscle group and a corresponding increase in the activity of the antagonist hamstring muscle group. The increased activation of the hamstring muscles is a normal compensatory mechanism that helps to stabilize the knee and to attenuate joint-loading forces during locomotion.[16] The increased resistance to limb movement provided by aquatic therapy reactivates the agonist muscles and reduces co-contraction of paired antagonist muscles, which enhances neuromuscular control and the coordination of muscle activity. These mechanisms are important contributors to the functional restoration of muscle function and motor control in the rehabilitation of various musculoskeletal injuries.

Hydrostatic Pressure

The immersion of the distal limb in water applies a circumferential compression of equal magnitude increasing extravascular hydrostatic pressure, which in turn promotes venous return and lymphatic drainage. The improved venous and lymphatic circulation reduces edema and decreases soft tissue swelling that ultimately increases joint range of motion and decreases pain.[5] Changes in hydrostatic pressure can also improve neuromuscular function by enhancing muscle spindle activity through the stimulation of skin surface sensory nerves and joint mechanoreceptors. These specialized receptors function as proprioceptors and as modifiers of muscle activity to increase joint stability and to protect joint structures from excessive or abnormal loading.[17] Reflex mechanisms mediated by joint receptors help to protect an injured joint from further damage via either inhibition or activation of muscular guarding in response to joint pain.[18] The joint mechanoreceptors also register mechanical deformation of the joint capsule and changes in intra-articular pressure during joint loading. The increase in intra-articular pressure associated with joint effusion and synovitis causes reflex afferent excitation of 1b interneurons located within the ventral horn of the spinal cord, which results in inhibition of the muscles that act on that joint.[19] Afferent excitation of joint mechanoreceptors induced by increased intra-articular pressure may be dampened by the effects of increased hydrostatic pressure when the limb is immersed in water.[5] The reduced inhibition of the spinal cord 1b interneurons causes increased activation of the alpha motor neurons, which produces increased muscle activation and tone. Reduced soft tissue swelling and joint effusion may further improve synaptic information from the joint mechanoreceptors and reestablish neuromuscular control critical for optimal joint motion and athletic activity.

Temperature

The thermodynamic properties of water provide markedly different therapeutic effects depending on temperature.

Cryotherapy

Cryotherapy is widely used in horses with the goal of decreasing acute soft tissue inflammation, pain, and swelling. The optimal therapeutic effects of cold hydrotherapy are generated through reducing tissue temperatures to 15°C to 10°C.[20] The application of cryotherapy produces peripheral vasoconstriction and decreased soft tissue perfusion (up to 80%), which can reduce edema formation and swelling at the site of tissue injury.[21] Reduced blood flow to the extremities also decreases tissue metabolism and provides an analgesic effect by decreasing nerve conduction velocity.[10] Local mechanisms of action include decreased tissue metabolism via reduced inflammatory mediator release, inhibition of degradative enzymatic activity, reduction of cellular oxygen demands, and decreased subsequent hypoxic injury.[22] Cold therapies can penetrate up to 1 to 4 cm in depth, which depends on local circulation and adipose tissue thickness.[23] Human studies have documented the analgesic benefits of cryotherapy with a 15- to 20-minute application providing pain relief for 1 to 2 hours.[24,25] In horses, a single report described the use of cryotherapy to treat lipopolysaccharide-induced synovitis, which concluded that twice-daily treatment for 2 hours was not effective for controlling inflammation.[26] However, ice water immersion for 30 minutes reduced the superficial and subcutaneous tissues in the distal limb to within optimal therapeutic range compared with cold pack application.[27] Although temperatures measured during cold pack application to the equine distal limb for 30 minutes did not fall within the optimal therapeutic range. Application of a compression boot with continuous circulating coolant applied to the distal forelimb of horses for 1 hour significantly reduced the Superficial digital flexor tendon (SDFT) core temperature to 10°C.[20] Similarly, a dry sleeve perfused cuff with continuous circulating coolant was as effective as ice-water immersion that included the hoof and distal limb in reducing hoof wall surface temperatures to less than 10°C during an 8-hour period.[28] In humans and dogs, circulating cryotherapy and intermittent compression provides a significant reduction in pain, swelling, lameness, and an increase in joint range of motion after orthopedic surgery.[29,30] The recent results of tissue cooling being as effective with circulating cryotherapy units compared with ice water immersion enhances efficacy and safety in the clinical application of cryotherapy. Further in vitro research has demonstrated that the viability of tenocytes exposed to cold treatment (10°C) for 1 hour did not significantly differ from those cells maintained at 37°C.[28] Cryotherapy research in horses has focused primarily on applications within the distal limbs and on inflammatory responses associated with laminitis.[31] The exact effect of cryotherapy on various equine musculoskeletal injuries has not been fully elucidated. Additional studies are needed to create evidence-based guidelines on the use of cryotherapy. These must address effective duration, frequency, temperature, and safety of application that will optimize outcomes after injury.

Thermotherapy

Thermotherapy often used in humans following the acute inflammatory phase is defined as an optimal therapeutic tissue temperature ranging from 40°C to 45°C.[27] Warm water immersion at 36°C causes vasodilation, which reduces peripheral vascular resistance and increases tissue perfusion.[9] Increased soft tissue perfusion may aid in dissipating inflammatory mediators associated with local inflammation and pain.[5] Water temperature during aquatic exercise may also play an important role in nociception by acting on local thermal receptors, and increasing the release of endogenous opioids.[32] Horses that stood in warm (38°C–40°C) spring water for 15 minutes demonstrated an increase in parasympathetic nervous system activity, indicating that immersion in warm spring water may have a relaxing effect that aids in decreasing pain, muscle spasms, and improves healing.[33] In humans, exercising in warm water has been shown to be an effective method for decreasing pain and enhancing joint range of motion. To date, there are no studies that demonstrate a clinical effectiveness for the use of warm water in the management of musculoskeletal disorders in horses. However, the physiologic effects of cold and warm water on vascular tone and tissue metabolism provide a useful tool to address the different inflammatory stages of musculoskeletal injury.

Osmolality

Exercising in water with higher solute concentrations has been reported to have anti-inflammatory, osmotic, and analgesic effects.[11] In humans, a 2-week course of daily exercise in mineral water demonstrated increased mechanical nociceptive thresholds (ie, reduced pain) over the medial aspect of osteoarthritic femorotibial joints.[34] Similarly, humans with fibromyalgia report significant improvements in pain scores lasting up to 3 months following exercise in a sulfur pool.[35] Horses diagnosed with distal limb injuries stood in hypertonic (20 g/L sodium chloride, 30 g/L magnesium sulfate) cold water baths (5°C–9°C) for 10 minutes, 3 days a week for 4 weeks (**Fig. 2**).[36] These horses demonstrated clinical and ultrasonographic healing of digital flexor tendon and suspensory ligament lesions.[36] Visual improvements in the degree of soft tissue swelling were also demonstrated within 8 days of the initiation of hypertonic cold water therapy.[36] In horses, tendonitis and desmitis monitored ultrasonographically demonstrated reduced peritendinous and periligamentous edema, decreased inflammatory infiltration, and improved collagen fiber alignment after the 4 weeks of hypertonic cold water therapy.[36] The added mineral components in water provide an increased osmotic effect, which reduces soft tissue inflammation and swelling, decreases pain, and ultimately improves joint range of motion. These osmotic effects can play an important role in managing soft tissue changes associated with musculoskeletal injury in horses.

EFFICACY OF HYDROTHERAPY

Although hydrotherapy is widely used in rehabilitation programs, there are few investigations into the benefits of this form of exercise for equine patients. Equine investigations involving hydrotherapy focus mainly on the horse's physiologic responses to exercising in water.[37–39] Swim training programs provide improvements in cardiovascular function, reductions in musculoskeletal injury (eg, tendonitis), and increases in fast-twitch, high-oxidative muscle fibers, which reflect improved aerobic

Fig. 2. Hypertonic cold water bath. (*Courtesy of* ECB Equine Spa, Sparta, NJ; with permission.)

capacity.[40,41] Fine-wire electromyography has been used to measure increased muscle activation of the thoracic limb musculature during pool swimming exercise, compared with overground walking.[42] More recently, changes in stride parameters have been assessed while horses walked in various depths of water.[43] Underwater treadmill exercise with water at the level of the ulna produced increased stride lengths and reduced stride frequencies, compared with walking in water at the level of the pastern joint.[43] A similar study assessed the influence of water depth on distal limb joint range of motion.[44] The varied depths of water (from <1 cm water height to the level of the stifle joint) significantly influenced the fetlock, carpal, and tarsal joint range of motion.[44] Results of this study demonstrate that water at varying depths promotes joint-specific increases in ranges of motion, therefore providing the ability to adapt therapeutic protocols to target certain joints. Changes in water depth also influence thoracolumbar lateral bending, pelvic flexion, and axial rotation. As water depth increases from hoof to shoulder level there is an increase in pelvic flexion and axial rotation but a decrease in lateral bending through the thoracolumbar region.[45] A study assessing the efficacy of underwater treadmill exercise to diminish the progression of experimentally induced carpal osteoarthritis was completed at the Colorado State University, Equine Orthopedic Research Center.[46] This project was established to provide an objective assessment of the pathologic characteristics associated with osteoarthritis and the potential clinical and disease-modifying effects allied with aquatic therapy. Underwater treadmill exercise was able to re-establish baseline levels of passive carpal flexion, returning the carpal joint to full range of motion. In addition, horses exercised in the underwater treadmill demonstrated evenly distributed thoracic limb axial loading, symmetric timing of select thoracic limb musculature, and significant improvements in static balance control under various stance conditions. The improvement in clinical signs of osteoarthritis in the aquatic therapy group was further supported by evidence of disease-modifying effects at the histologic level. Underwater treadmill exercise reduced joint capsule fibrosis and decreased the degree of inflammatory infiltrate present in the synovial membrane. Results from this study provide an objective assessment of the pathologic characteristics associated with osteoarthritis and the potential clinical and disease-modifying effects allied with underwater treadmill exercise, which is fundamental to providing evidence-based support for equine aquatic therapy.[46] However, additional studies focusing on developing methodology and the exact effect of hydrotherapy on more frequently treated musculoskeletal injuries are required.

HYDROTHERAPY VARIABLES

Equine hydrotherapy primarily involves the use of underwater treadmills (above ground or in ground units), swimming pools (circular or straight), aquawalkers, and standing salt water spas or whirlpools. The in-ground underwater treadmills by design have the capacity to hold a greater amount of water and thus provide more buoyancy in comparison with the above-ground underwater treadmill units. The above-ground underwater treadmill units are able to change the depth of water between each patient, allowing for targeted rehabilitation protocols designed to improve joint range of motion (**Fig. 3**). Both underwater treadmill units can come installed with hydrojets creating additional turbulent fluid flow, which increases the resistance of limb movement through the water-enhancing muscle strength and timing. In addition, underwater treadmill units have the ability to vary the treadmill speed, water temperature, and solute concentration. Horses frequently require a period of 3 to 5 days to become acclimated and trained to exercise in the underwater treadmill units.

The aquawalkers are mechanical walkers fitted within a circular pool that contains a consistent depth of water. The diameter of the aquawalker dictates how many horses can be exercised at a time; most systems are able to exercise six to eight horses simultaneously. Horses are not completely buoyant and are separated from each other by dividers creating an individual “pen” for each horse. The depth of the water is dictated by the system design; some have just a shallow trough with water maintained no higher than the fetlock joint, whereas others maintain the water height at the level of the stifle joint. The speed of system is controlled; however, unlike the underwater treadmills the horse may not walk at the consistent speed set by the unit. Some horses choose to slow down and then rush forward was the divider approaches them from behind only to slow down again once they catch up to the divider in front of them. Similar to the underwater treadmill units the aquawalkers are able to vary the water temperature and solute concentration.

Fig. 3. Underwater treadmill. (*Courtesy of* Hudson Aquatic Systems, LLC, Angola, IN; with permission.)

Swimming horses typically takes place in linear or circular shaped pools with ramps installed for ease of entry and exit. Equine pools should be designed so that handlers on each side of the horse's head can walk alongside during each exercise session. To ensure complete buoyancy the water depth should be more than 12 feet deep. Linear pools may decrease cardiorespiratory stress as the horse is allowed to recover on exiting while being walked back to the entry point.[47] Conversely, continuous lap swimming in circular pools does not allow for cardiorespiratory recovery until completion of the exercise session. Horses are not natural swimmers and often use their thoracic limbs to maintain balance while the pelvic limbs are primarily used for propulsion. The explosive nature of the pelvic limb propulsion often results in extreme ranges of motion through the hip, stifle, and hock joints. In addition, on entry into the water horses often adopt a posture that results in cervical, thoracolumbar, and pelvic extension. In the authors opinion swimming horses with thoracolumbar, sacroiliac, hip, stifle, and hock injuries should be approached with caution.

PRECAUTIONS

Swimming horses with respiratory disease should be avoided because the increase in hydrostatic pressure influences lung volume, preventing adequate ventilation.[38] Aquatic therapy should also be avoided if the horse has any of the following conditions:

- Unhealed surgical incisions
- Open, infected, draining wounds
- Upper pelvic limb lameness
- Thoracolumbar pain/injury
- Acute joint inflammation
- Acute myositis
- Elevated temperature
- Fearful or panicky animal
- Cardiovascular compromise

TREATMENT PROTOCOL CONSIDERATIONS

The development of hydrotherapy rehabilitation protocols should be designed to meet the needs of each individual patient following a complete assessment and understanding of the desired long-term goals for athletic performance. Not only should the injury and physical conditions be considered, but understanding the temperament, behavioral response to water exposure, and previous history of aquatic therapy are crucial to developing a solid therapeutic plan. The development and progression of a hydrotherapy program should involve three main components: (1) intensity, (2) duration, and (3) frequency of applied therapy. The depth of water, turbulence, and speed of walking can influence intensity of exercise in the underwater treadmill. It is difficult to control intensity while swimming, and most horses are allowed to select a self-determined pace. However, some linear pools can provide a higher intensity work load by having horses swim against a current. The initial duration of treatment is greatly influenced by the nature of the injury, body condition, fitness level preinjury and postinjury, and the presence of muscle weakness and/or atrophy. Initially horses may only be able to exercise in the underwater treadmill for 5 minutes in the first week of therapy. The goal is to be able to increase the duration of walking by 5-minute increments weekly until 20 minutes is reached. Similarly, swimming sessions may involve only being able to swim one or two laps initially (5–8 minutes), working up to swimming (continuously for circular pool) for a total of 9 to 12 laps. The frequency of treatment is often dictated by response of the horse to the rehabilitation program. Typically the more intensive the exercise program the faster the return to function as long as the injury is not overloaded and is given time to adapt and strengthen.[48] Most underwater treadmill protocols are designed for daily aquatic therapy, 5 days a week. Swimming protocols range from three times a week, to 15-minutes sessions three times a week combined with 5-minute sessions twice a week. It is critical to remember when progressing within a rehabilitation program that only one aspect of the protocol should be changed at a time. If intensity and duration are changed simultaneously, then these changes may be too much too soon.

MONITORING PROCEDURES

Monitoring recovery heart rates is a useful tool in recognizing when a horse can progress in their rehabilitation program. Heart rates and recovery rates can be monitored before, during, and immediately following exercise to quantify the level of intensity. The heart rate during aquatic therapy should not exceed 200 beats per minute and the time required for the heart rate to decrease to 60 beats per minute should be less than 10 minutes. Rehabilitation therapeutic protocols should not increase in intensity if target heart rate is exceeded or if there is an extended recovery period.

The ability to quantitatively assess injury regression is crucial to monitoring the efficacy of therapeutic interventions. Evidence-based practice requires the use of valid, reliable, and sensitive tools to monitor treatment effectiveness. Pressure algometry, goniometry, and limb circumference are reliable and objective methods of determining pain, joint range of motion, swelling, and muscle mass and are often used to assess articular responses to physical therapy.[49] Horses should be evaluated daily before each aquatic therapy session for any palpable musculoskeletal defects in the affected limb and for any alterations in the degree of lameness. If appropriate, ultrasonography should be repeated at monthly intervals to assist in adjusting the rehabilitation protocols.

SUMMARY

Hydrotherapy incorporates several different mechanisms of action, all of which have particular benefit in the management of equine musculoskeletal disorders. The current human and veterinary literature suggests that aquatic therapy has beneficial effects on multiple musculoskeletal morbidities, such as pain reduction and increased joint range of motion. Well-designed, controlled, clinical trials using hydrotherapy are needed in horses to determine dosages effects (eg, water level, duration, and speed) and to assess clinical changes in soft tissue swelling, joint stability, and motor control patterns associated with adaptive and maladaptive compensatory gait alterations. The diverse physical characteristics of hydrotherapy provide unique approaches to individualized rehabilitation of musculoskeletal issues in horses.

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