Muscles, Tendons, & Ligaments

BY STACEY OKE, DVM, MSC

When it comes to equine locomotion, it takes three to tango

COURTESY AQHA

The horse's body is both exceedingly powerful and capable of bending, turning around tight corners, and stopping on a dime, all thanks to his intricate combination of muscles, tendons, and ligaments.

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Muscles, Tendons, & Ligaments

As the poet Lily Whittaker eloquently penned,

"What is a horse?
A horse waltzes like breeze over rivers.
She curvets and leaps like rain shivers.
A horse is a marionette."

Indeed, the muscles, tendons, and ligaments function as the wooden cross and strings that drive the marionette's movement. Horses' beauty in motion is achieved via the culmination of a complex and highly integrated interaction between muscles, tendons, ligaments, nerves, and a variety of other connective tissues. Successful coordination of all musculoskeletal system components is imperative for smooth, fluid, pain-free movement. Injury to or malfunction of any part of the locomotor apparatus will negatively impact performance.

By virtue of their remarkable athleticism, horses are prone to injury. Musculoskeletal injuries are the most common cause of poor performance in horses. Understanding the intimate relationship between these three different types of structures is an important first step in keeping them healthy. This article reviews the structure and function of skeletal muscles, tendons, and ligaments, looks at some common concerns associated with each of these structures, and briefly discusses means of keeping them healthy.

Skeletal Muscles

The muscles that attach to bones via specialized connective tissues called tendons are referred to as skeletal muscles. These muscles are made of bundles of long muscle fibers that are held together by a coating of connective tissue. Muscles are considered "contractile organs," as they cause movement once activated.

The long muscle fibers that make up skeletal muscle are made of hundreds to thousands of myofibrils—the basic units of skeletal muscle. Microscopically, these myofibrils contain long protein molecules called actin and myosin that exist in a functional unit called a sarcomere. It is these long actin and myosin molecules lying side by side inside the myofibrils that give skeletal muscle its classic "banding pattern" (also called striations) observable under a microscope.

In addition to contributing to the aesthetics of muscles, the interaction of actin

POLYSACCHARIDE STORAGE MYOPATHY (PSSM) AND THE GYS1 MUTATION

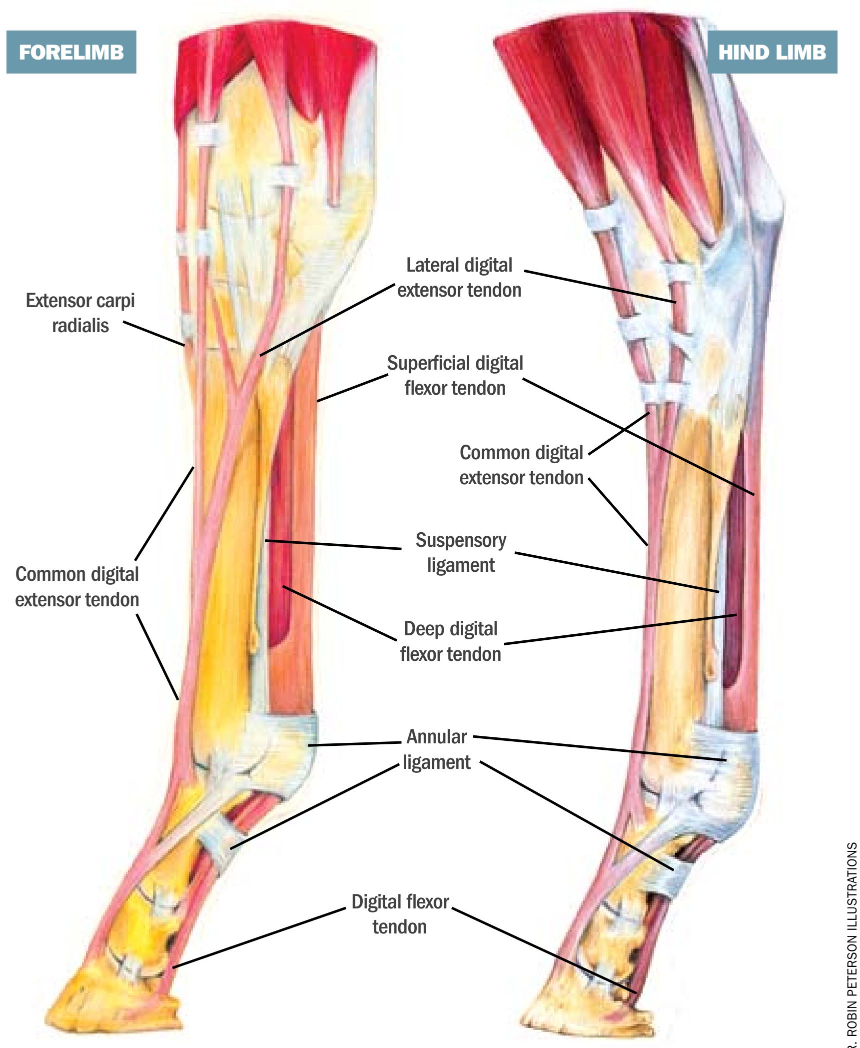
"PSSM is a form of exertional rhabdomyolysis (tying-up) characterized by the abnormal accumulation of the polysaccharide glycogen—long chains of sugar molecules used for storing energy—in the skeletal muscles," explains Molly McCue, DVM, MS, PhD, Dipl. ACVIM, assistant professor at the University of Minnesota's College of Veterinary Medicine. McCue is a colleague of Stephanie Valberg, DVM, PhD, Dipl. ACVIM, who is widely considered the "pioneer" of PSSM research.

"It is now known that at least two different forms of PSSM exist," relays McCue. "Horses with Type 1 PSSM have a genetic mutation in the enzyme glycogen synthase 1 (GYS1). This mutation is a gain-of-function mutation, meaning that the enzyme is overactive, which causes glycogen to be overproduced in affected horses."

Until recently, many thought PSSM primarily affects draft and Quarter Horse breeds. According to McCue and colleagues, the GYS1 mutation has been identified in over 36 different horse breeds in North America and Europe, including Quarter Horses, Appaloosas, Warmbloods, polo ponies, Thoroughbred crosses, Connemara crosses, and Cobs.

For $65, you can have your horse tested for the GYS1 mutation. Details are available at www.cvm.umn.edu/umec/lab/Advances_in_PSSM/home.html.—*Stacey Oke, DVM, MSc*

TENDONS & LIGAMENTS OF THE LEGS



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[1] Scott A, et al., What do we mean by the term "inflammation"? A contemporary basic science update for sports medicine, *Br J Sports Med.*, 2004; 38(3): 372-80.

[2] Jiang N, et al., Respiratory protein–generated reactive oxygen species as an antimicrobial strategy, *Nat Immunol.*, 2007; 8(10): 1114-22

* Data on file

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Muscles, Tendons, & Ligaments

and myosin is ultimately responsible for muscle contraction.

The structure and exact function of both the actin and myosin molecules are complex. Essentially, each of the myosin molecules has "fingers" at its head that "walk along" the actin filaments, resulting in contraction (shortening) of the sarcomere.

When all of a skeletal muscle's sarcomeres contract (shorten) due to that "walking" of myosin along actin, movement occurs.

One of the best examples for illustrating how muscle contraction results in movement is the equine stifle: a simple hinge joint. When the horse contracts muscle groups on the caudal aspect (back) of the femur that connect via tendons to the caudal aspect of the tibia, he lifts the tibia and the rest of the limb closer to his body. In contrast, when he contracts the muscle groups on the cranial aspect (front) of the femur extending from the pelvis to the tibia, he pulls the tibia in a rostral direction (forward).

NUTRITIONAL SUPPLEMENTS

There is no shortage of dietary supplements designed for the musculoskeletal system, including joints, muscles, tendons, and ligaments. Due to a lack of government regulation of veterinary nutritional supplements, poor-quality supplements are widely available that recommend subtherapeutic doses, are potentially contaminated with harmful ingredients, and do not contain the type or amount of ingredient listed on the label. Scientists encourage owners, trainers, and veterinarians to identify, purchase, and administer high-quality supplements that are likely to be beneficial. You can achieve this using the ACCLAIM system, selecting products with:

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For more information see TheHorse.com/11958.

—Stacey Oke, DVM, MSc

When Things Go Wrong: Skeletal Muscles

Common muscle injuries horses sustain include tears and strains. They might also develop muscle metabolism abnormalities such as exertional rhabdomyolysis (tying-up) or a form of it called polysaccharide storage myopathy (PSSM, see sidebar on page 24). Nonetheless, other skeletal muscle abnormalities are also important.

At the World Equine Veterinary Association (WEVA) 2009 Congress, held Sept. 24-28 in Guarujá-SP, Brazil (See page 32 for a wrap-up of this meeting.), Stephanie Valberg, DVM, PhD, Dipl. ACVIM, professor of large animal medicine and director of the University of Minnesota Equine Center, described three newly recognized myopathies in horses. Each appears to have an immune-mediated component (i.e., the horse's own immune system contributes to the disease), and the bacterium *Streptococcus equi* subspecies *equi* appears to play a role in both.

The first of these newly described conditions is an acute severe rhabdomyolysis characterized by a stiff gait and firm, swollen, and painful back and gluteal muscles. The second myopathy is an infarctive purpura hemorrhagica, meaning that the horse loses blood supply to a particular region of muscle, causing tissue death and resulting in severe swelling. These horses typically present with painful lameness and muscle stiffness, and they can also become colicky. Finally, veterinarians have also reported a rapid onset of muscle atrophy with stiffness and general malaise. This condition is referred to as an immune-mediated polymyositis.

To date, veterinarians have only reported these conditions in a small number of horses. Since the fatality rates are high in affected horses, researchers are eager to delve deeper into these novel diseases to understand them better.

Tendons

Tendons are strong bands of soft connective tissue that attach skeletal muscles to bones. Tendons are comprised of many parallel strands of collagen—a distinct type of protein found in connective tissues, cartilage, and bone. Collagen molecules link together and aggregate first into microfibrils, then into larger collagen fibrils. The collagen fibrils further aggregate to form collagen fibers, which are the basic units of a tendon. A thin sheath wraps each collagen fiber, and a number of fibers aggregate into primary, secondary, and tertiary bundles, which ultimately make up a tendon.

Tenocytes—specialized tendon cells that secrete collagen, which arranges into fibrils outside the cells—also are responsible for synthesizing a small amount of elastin (a protein similar to collagen) fibers and various other molecules (e.g., proteoglycans). Tenocytes make small, gradual, biomechanically relevant adjustments to extracellular matrix composition when mechanical forces on the tendon change, such as those forces tendons encounter during growth, weight gain, or exercise.

The basic function of any tendon is to transmit the muscle's force to the bone to produce movement.

Due to the normal structure of the Type I collagen fibers, tendons are "crimped." When the tendon is loaded during motion, the collagen fibers uncrimp, but only to a point. If uncrimped and stretched too much, the collagen fibers fail and injury occurs.

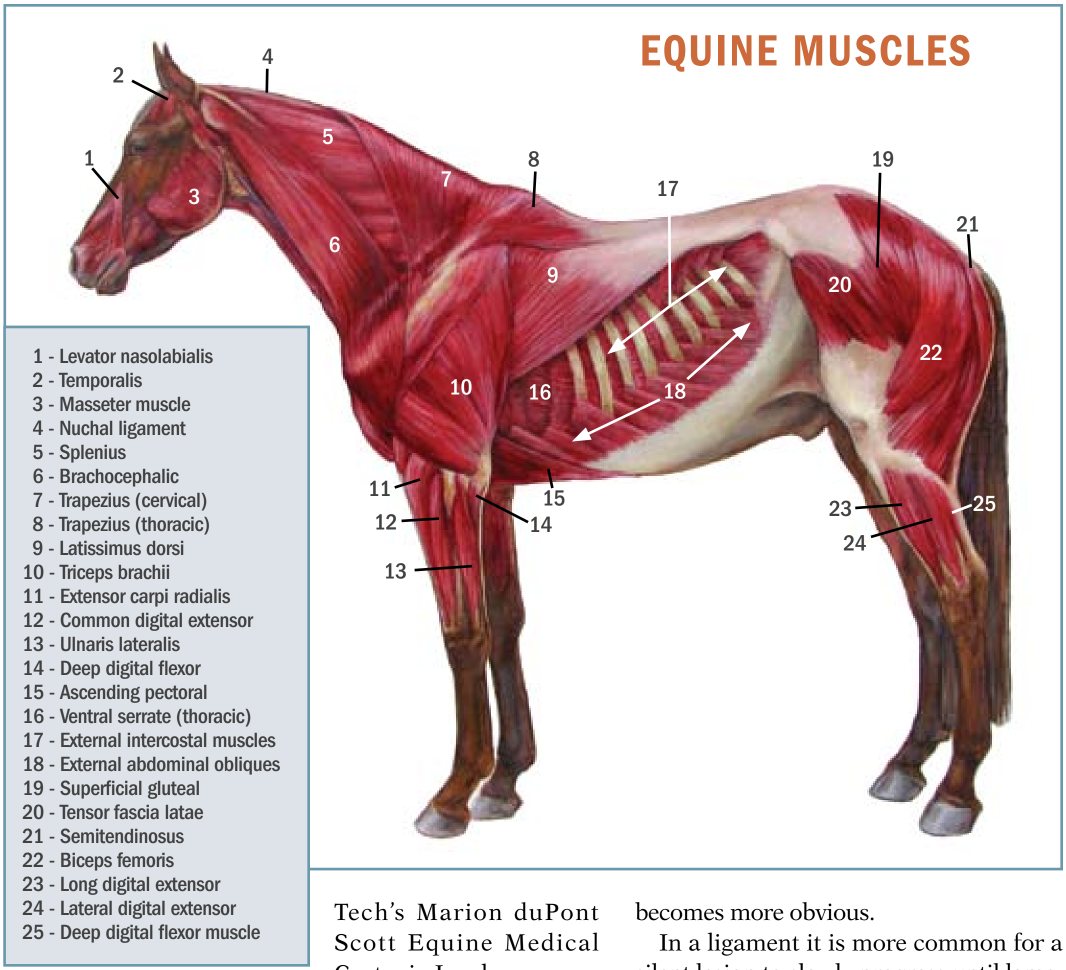
Thus, the high density of collagen fibers in tendons is a double-edged sword: the collagen makes the tendons extremely strong, but they are not very elastic.

To revisit the stifle as our example, the muscles on the cranial and caudal aspects of the femur (that contract to extend or flex the stifle) attach to the tibia via tendons.

Ligaments

Like tendons, ligaments are tough bands of soft connective tissue with a high proportion of collagen fibers arranged in a similar hierarchy as that described for tendons. The function of a ligament is to connect two bones or cartilages together. Ligaments differ from tendons not only in their anatomic location, but also in their composition. Ligaments have fewer collagen fibers than tendons; these are not as well-organized as tendon collagen and have more noncollagenous extracellular components. Nonetheless, the microscopic organization, function, and behavior of tendons and ligaments are relatively similar.

In the stifle, a surprising number of ligaments stabilize the joint. Fourteen, to be exact. Within the joint, for example, are the cranial and caudal cruciate ligaments and ligaments of the menisci. Outside the joint are the middle, medial, and lateral patellar ligaments and the medial and lateral collateral femorotibial ligaments.



When Things Go Wrong: Tendons and Ligaments

"The structures in the lower limb are particularly injury-prone, from the superficial digital flexor tendon to the suspensory ligament," says Jennifer Barrett, DVM, PhD, Dipl. ACVS, assistant professor of surgery at Virginia Tech's Marion duPont Scott Equine Medical Center in Leesburg.

According to Barrett, tendon injuries commonly arise from damage to the matrix that makes up the tendon, and cellular responses to that damage progress over time until the tendon inflammation becomes more obvious.

In a ligament it is more common for a silent lesion to slowly progress until lameness is apparent. Ligament changes are usually identified during ultrasonographic evaluation, when the veterinarian might notice the ligament has detached from bone, or a core area within the ligament

Muscles, Tendons, & Ligaments

has lost normal fiber pattern. To date, the exact processes that cause some tendons and ligaments to heal better than others are unknown.

"Current evidence suggests that after an injury to a tendon or ligament, there is an inflammatory reaction which causes swelling, constriction of the local blood vessels, and release of inflammatory mediators (called cytokines) that break down cells and recruit other cells that play a crucial role in the healing process," says Barrett.

"The tenocytes are capable of synthesizing new collagen fibers, but the type of collagen produced is often different (Type III fibers instead of Type I), and they are disorganized," she continues.

The resultant scar tissue in "healed" tendons and ligaments limits fiber and fascicle (small bundles of fibers) movement, and the healing process appears to alter the overall biochemical and biomechanical properties of these soft connective tissues.

"As a result, re-injury is a major concern in athletic horses, an economic burden, and an all-too-common career-limiting event that could even result in the loss of the horse," summarizes Barrett.

Keeping Connective Tissues Healthy

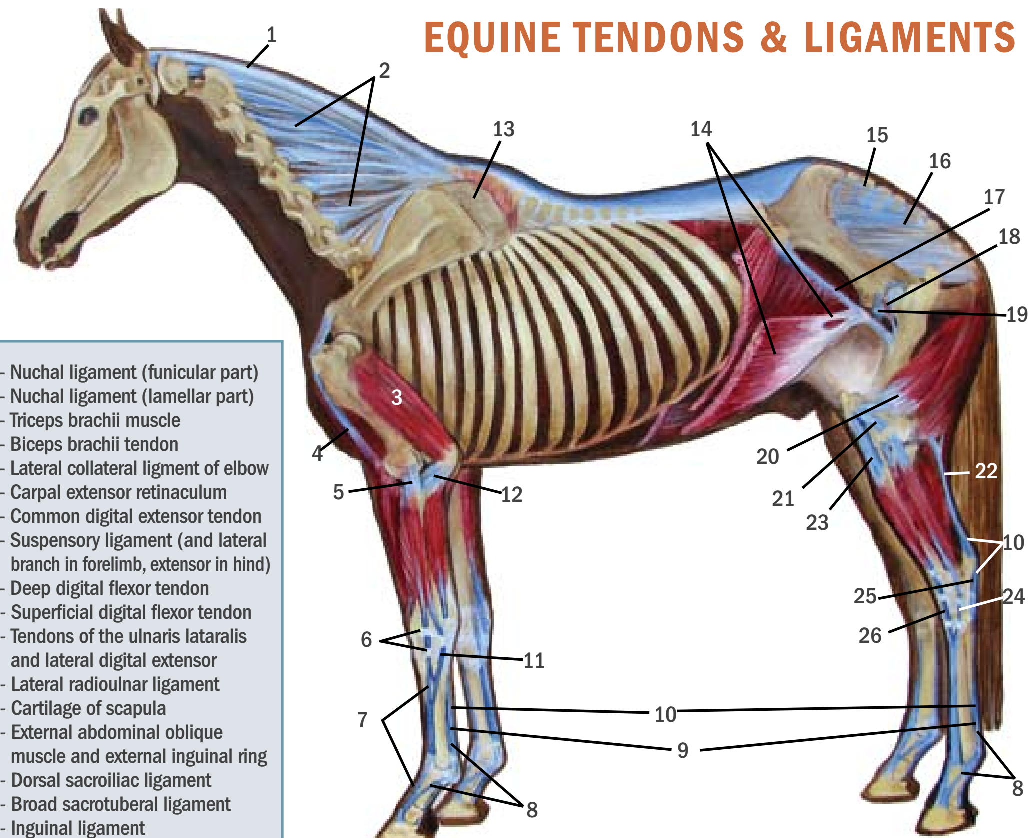
In an effort to minimize injury and maximize performance, some owners, trainers, and veterinarians go to great lengths to protect these delicate components of the musculoskeletal system. Hilary Clayton, BVMs, PhD, MRCVS, the Mary Anne McPhail Dressage Chair in Equine Sports Medicine at Michigan State University's College of Veterinary Medicine, studies the biomechanics of equine gait in sport horses. Clayton has authored several books on locomotion, biomechanics, and conditioning in athletic horses, and she believes regular exercise can help a horse's muscles, tendons, and ligaments become stronger and less prone to injury.

Research has shown that regular exercise helps maintain bone structure, but scientists have said the jury is out on whether adult equine tendons or ligaments can become stronger with exercise. There is a suggestion that there is a window of opportunity in horses less than 18 months old to improve tendon structure, but authors of a study that showed exercise cannot modulate tendon structure in adult horses were unable to detect a significant change in tendon structure, even when foals were exercised from 3 weeks old.

Regardless, Clayton suggests an ideal approach to exercise for equine musculoskeletal wellness includes different gaits and speeds performed on a variety of surfaces and terrains to provide the limbs with a diverse loading pattern.

"When designing a conditioning program to strengthen the musculoskeletal tissues, it is important to introduce new types of exercise slowly, to build up the workload gradually, and to give the horse an easy day after a hard workout," advises Clayton. "Avoid doing the same type of exercise in the same arena day after day because this type of repetitive training may lead to an overuse injury, such as a bowed tendon or a pulled suspensory."

EQUINE TENDONS & LIGAMENTS



1 - Nuchal ligament (funicular part)
2 - Nuchal ligament (lamellar part)
3 - Triceps brachii muscle
4 - Biceps brachii tendon
5 - Lateral collateral ligment of elbow
6 - Carpal extensor retinaculum
7 - Common digital extensor tendon
8 - Suspensory ligament (and lateral branch in forelimb, extensor in hind)
9 - Deep digital flexor tendon
10 - Superficial digital flexor tendon
11 - Tendons of the ulnaris lataralis and lateral digital extensor
12 - Lateral radioulnar ligament
13 - Cartilage of scapula
14 - External abdominal oblique muscle and external inguinal ring
15 - Dorsal sacroiliac ligament
16 - Broad sacrotuberal ligament
17 - Inguinal ligament
18 - Capsularis muscle
19 - Tendon of rectus femoris muscle
20 - Biceps femoris attachment
21 - Lateral femoropatellar ligament
22 - Gastrocnemius tendon
23 - Lateral patellar ligament
24 - Lateral digital extensor tendon
25 - Plantar ligament (below)
26 - Long digital extensor

Take-Home Message

The musculoskeletal system is a complex network of various tissue types that must function in a coordinated fashion so the horse can move in an organized, fluid, and purposeful fashion. Going back to basics and understanding how these structures are put together is an important first step in understanding the science of locomotion and biomechanics, and how to keep the horse's musuloskeletal system sound and healthy.

ABOUT THE AUTHOR

***Stacey Oke, DVM, MSc**, is a freelance medical writer based out of Canada. Her areas of interest are nutrition, supplements and osteoarthritis, and she contributes to scientific journals, magazines, and tabloid publications.*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