0195–5616/02 $15.00 + .00

MUSCLE DISORDERS AND REHABILITATION IN CANINE ATHLETES

Janet E. Steiss, DVM, PhD, PT

Human athletes can communicate information about muscle pain, but dogs cannot. Various degrees of muscle injury could go undetected in dogs. Muscle disorders associated with physical exertion in human athletes include delayed-onset muscle soreness, muscle strain, muscle tears, rhabdomyolysis, and acute and chronic compartment syndromes. Given that the structure of muscle is similar among different species, it is reasonable to expect that dogs experience the same phenomena. At times, sports medicine veterinarians need to function as athletic trainers and physical therapists to advise clients on physical conditioning, injury prevention, and rehabilitation as well as on diagnosis and treatment. It is advantageous if veterinarians who treat canine athletes are familiar with the activities that the dogs are required to perform.

Canine athletes participate in many different sports. This article focuses on several of the muscle disorders of bird dogs, namely, coccygeal muscle injury and infraspinatus muscle contracture, and on those of dogs involved in tracking-obedience-protection training, namely, fibrotic myopathy, with an additional discussion of muscle strain. Obviously, sporting dogs are also susceptible to the myopathies seen in all breeds of dog such as metabolic, infectious, and inherited myopathies, which are described elsewhere in this issue.

This study was supported in part by grants from the Scott-Ritchey Research Center and the Sports Medicine Program, College of Veterinary Medicine, Auburn University, Auburn, Alabama.

From the Department of Occupational Therapy, University of Alabama at Birmingham, Birmingham, Alabama

PHYSICAL EXAMINATION

The diagnosis of myopathies is covered elsewhere in this issue, but it should be pointed out that the clinician must modify his or her diagnostic approach when evaluating sporting dogs, because their myopathies tend to be focal. In contrast, the typical "myopathic syndrome" consists of generalized weakness that tends to be bilaterally symmetric.[6] Muscle pain may be difficult to elicit. Palpation may yield subjective evidence of muscle pain, but many sporting and working breeds are stoic. Radiographs do not detect muscle injury. More sophisticated imaging techniques such as thermography, scintigraphy, ultrasound, and magnetic resonance (MR) imaging may reveal muscle abnormalities. MR imaging has been helpful in the diagnosis of acute injuries in human athletes to localize edema and hemorrhage associated with muscle strain, for example. MR imaging is not a tool that is likely to be used routinely in veterinary medicine, however, because of the expense, limited availability, and need for general anesthesia. When evaluating clinical pathologic findings, the normal response to exercise must be considered. More research is needed to establish reference values for serum biochemistry and complete blood cell count panels for different breeds of sporting dogs. For instance, alterations in lactate and pyruvate levels are seen in healthy canine athletes after physical exertion.[26, 47] These alterations are distinct from the alterations in plasma lactate and pyruvate levels associated with dogs with exercise intolerance and muscle weakness, which may be muscle disorders associated with abnormalities of oxidative metabolism.[41]

MUSCLE STRAIN

Muscle strain is probably underdiagnosed in canine athletes. For example, muscle strain is probably one of the causes of fibrotic (gracilis) myopathy. Muscle strain is an indirect injury caused by excessive force or stress on the muscle. In human athletes, injury can occur when powerful contractions are combined with forced lengthening of the muscle (eccentric contraction).[60]

In human athletes, muscle strains of the lower extremity are among the most common injuries.[8, 60] Muscles commonly affected are the hamstrings and adductors, the same muscle groups that are affected in fibrotic myopathy. Some experts consider muscle strain to be endemic in runners. Athletes performing activities with high speeds of acceleration such as running, sprinting, jumping, and soccer are at increased risk.[60]

Diagnosis of mild muscle strain can be difficult. Minor strain may present no physical findings, although a severe tear shows extensive ecchymosis, swelling, tenderness, and a palpable defect.[8] The athlete's description of the pain is a key factor. Most injuries are first- and second-degree strains.[60] Grade I (mild) muscle strain, a "pulled muscle," is characterized by minimal tissue disruption, low-grade inflammation, and minimal alteration in strength, range of motion (ROM), or gait. There may be no obvious swelling or pain on palpation. Athletes may not be aware of the injury until they cool down, and they then complain of soreness. This grade of injury could go unnoticed in dogs. Grade II (moderate) strain is characterized by greater muscle damage and compromise of strength and ROM.[20, 60] Grade III (severe) strain is characterized by a tear extending across the whole muscle, resulting in total loss of muscle function.[20] Mild strains heal within a few days to a week. Most grade II strains take 1 to 3 weeks for recovery. Complete muscle ruptures may require an entire season to heal.[28] In some cases, a chronic condition develops with recurring tightness, which eventually restricts the athlete's ability.[8]

Muscle strain most often affects the muscle origin or insertion[60] but can also occur within the muscle belly. Hamstrings may be damaged at their origin at the ischial tuberosity or distally near the musculotendinous junction above the knee.[29] Muscles at highest risk are two-joint muscles. Motion at one joint can put increased tension on the muscle and make it more susceptible to injury.[60] The explosive burst from the sprinter's block and a lengthening stride put the hamstrings on a much fuller stretch. This same type of explosive burst also can be seen in dogs, for example, when competing in the protection phase of tracking-obedience-protection programs.

Muscle tissue is highly vascularized, leading to hematoma formation.[20] Healing begins with inflammation, edema, and localized hemorrhage. If the strain causes bleeding and clotting, an ischemic environment can be created, causing further muscle damage that leads to a localized compartment syndrome.[8] Inflammation is followed by fibrosis.[16] The muscle regains strength rapidly if reinjury does not occur.[8]

The American College of Sports Medicine lists the major causes of muscle strain in human athletes as poor flexibility, inadequate warm-up, fatigue, sudden forceful contraction of the hamstrings, or forced knee extension.[40] Some experts attribute the injury to strength imbalances between the hamstrings and quadriceps muscles, drills, intense interval training, and insufficient rest breaks.[53] Overtraining may be a cause in dogs.

Hamstring and adductor injuries are susceptible to reinjury.[20, 33, 60] Because strains heal with scar tissue formation, the muscle does not retain normal flexibility.[16, 28] Many human athletes experience reinjury within 2 months of returning to activity.[60] Such chronic or recurrent injuries are attributed to insufficient rehabilitation, inappropriate progression of activities, or premature return to competition.[8]

FIBROTIC (GRACILIS) MYOPATHY

Case Study

A 3-year-old male German Shepherd started training in an obedience-tracking-protection program at 6 months of age. Six months later, while playing outdoors, the dog seemed to experience acute pain in one hind limb while running after a ball and was reluctant to bear weight on the limb. The lameness did not resolve completely. Three months later, the dog was referred to a veterinary neurologist. No neurologic deficits were noted, but the dog had a "slapping" gait involving both pelvic limbs, decreased ROM in both stifles, and palpable bands of scar tissue in the gracilis and semitendinosus muscles, which were more prominent on one side. Biopsy revealed that the tight bands were composed of dense connective tissue surrounded by normal muscle fibers. A diagnosis of "fibrotic myopathy" was made. The owner was advised that surgical excision of the fibrous bands could be performed but that the condition would likely recur within several months.

Overview

"Fibrotic (gracilis) myopathy" has been documented in dogs.[9, 23, 31, 55, 57] Most are male German Shepherds, although other breeds such as Doberman Pinschers and Rottweilers have been affected.[49] In addition to the gracilis, the hamstring muscles (semimembranosus, semitendinosus, and biceps femoris) can be involved. Tight cords are palpable in the affected thigh muscle(s), and passive and active extension of the stifle is decreased. Fibrosis is often localized within the distal myotendinous region or muscle bellies of the gracilis or hamstring muscles; the extent of involvement of the muscle origins is not known.[23] Affected dogs have a distinctive lameness that affects one or both pelvic limbs (Fig. 1). The gait is characterized by a shortened stride with internal rotation of the

Figure 1. Fibrotic (gracilis) myopathy. Note the abnormal internal rotation of the right hind foot during swing phase in this German Shepherd. The gait in this disorder is characterized by a shortened stride with internal rotation of the foot, external rotation of the hock, and internal rotation of the stifle during mid-to-terminal swing phase.

foot, external rotation of the hock, and internal rotation of the stifle during the mid-to-terminal swing phase of the stride.[23] In one survey, 39% of affected dogs had unilateral lameness; in the remainder, the lameness involved both limbs at onset or started in one limb and progressed to bilateral involvement.[49] The neurologic examination is typically normal. Owners usually do not consider their dogs to be in pain, but clinicians may detect discomfort on palpation.[23, 49] The lameness can temporarily become worse if the dog's physical activity level is suddenly increased.[49] Dogs continue to function as pets.

The history varies. Some dogs have an insidious onset and are presented to a veterinarian after fibrosis has occurred (suggestive of chronic or recurrent grade 1 muscle strain). Other dogs experience an acute onset of lameness during physical exertion, sometimes with muscle swelling in the thigh, suggestive of grade 2 or 3 muscle injury. Because the diagnosis of grade 1 muscle strain often depends on the athlete complaining of pain, without palpable evidence of muscle injury, this would likely be undetected in most dogs.

The etiology remains to be proven. In an early description of this disease, Vaughan[55] noted that affected dogs were extremely active and performed the sort of physical activity that could give rise to muscle strain caused by repetitive stress. Muscle strain is frequent in human athletes participating in sprinting and jumping activities. Many of the dogs affected with fibrotic myopathy also have been involved in sprinting and jumping exercises or other forms of drills. In our survey, 43% of affected dogs had participated in tracking-obedience-protection work; several had started training as early as 6 months of age.[49]

Pedigrees from 6 affected dogs yielded no evidence for a common ancestor within the previous four generations.[49] It is not known whether the conformation of the German Shepherd renders this breed more susceptible to fibrotic myopathy. Kinematic analysis comparing clinically normal German Shepherds with Labrador Retrievers indicated that German Shepherds have 11° less ROM at the stifle than Labrador Retrievers.[49] Histology of affected muscles shows nonspecific fibrosis.[23] Lewis et al[23] found no evidence that this disease is immune mediated. Affected dogs have no history of abnormal scarring associated with other surgical procedures.[49] It is unlikely that this condition is a peripheral nerve disease. Most dogs have no abnormalities on neurologic testing, and electromyography and nerve and muscle biopsies are normal. In our study, only 2 of 23 affected dogs were diagnosed with neurologic disease, namely, cauda equina syndrome concurrent with fibrotic myopathy.[49]

In racing Greyhounds, gracilis muscle tears tend to be the result of a single traumatic event, and the Greyhounds do not show the distinctive lameness of fibrotic myopathy.[4, 12] These dogs respond to surgical correction and routinely return to racing. In addition, palpable, tight, fibrous bands ("cording") of the gracilis muscle occurs in Greyhounds without associated lameness (R. Gillette, DVM, personal communication, 1999).

Surgical treatments have only resulted in temporary resolution, and the lameness recurs within weeks to months. The surgical techniques that have been tried include total excision of the gracilis muscle at its attachments, semitendinosus tenectomy or tenotomy, incorporation of autogenous fat grafts into the surgical resections, hyaluronate injections into the excision site, and postoperative exercise programs, including passive ROM of the stifle.[49]

It is possible that the inability to maintain the leg in extension during healing is the cause of the recurrence. Swaim et al[51] studied open wound healing in dogs and found that movement of open wounds in areas where movement was maximal such as over the flexion surface of the tarsus enhanced wound contraction and resulted in contracture deformity. Immobilization of such wounds in a cast inhibited wound contraction. In human beings, surgical incisions on the anterior aspect of the neck are braced with the neck in extension so as to avoid contracture. If this hypothesis is true, a suitable orthotic device fitted to maintain the stifle in extension after surgery might be beneficial. In comparison, surgical correction for fibrotic myopathy is more successful in horses.[1, 5, 54] It could be speculated that healing in horses occurs with less contracture because horses spend most of their time standing, whereas dogs spend much of their time lying down, with the pelvic limbs in flexion.

We have tested rehabilitation with therapeutic ultrasound and cross-fiber friction massage performed two to three times per week for 10 or more sessions in several affected German Shepherd Dogs that had not undergone surgery. This protocol resulted in only slight improvement. We have also tried postoperative rehabilitation in one affected Doberman Pinscher, using cross-fiber friction massage, passive ROM, and controlled exercise two to three times daily for a period of 8 weeks, but the contracture recurred.

Recommendations

Prevention

The hypothesis that muscle strain is a cause of fibrotic myopathy is speculative at this time. Nevertheless, it seems prudent to consider the recommendations regarding training in human athletes. Prevention of muscle strain is based on factors such as adequate warm-up and cool-down, avoiding fatigue and excessive repetitive activity (overtraining), and avoiding muscle strength imbalances between the hamstring and quadriceps femoris muscles.

Early Detection

Blythe et al[4] have provided guidelines for detecting and grading muscle injury in racing Greyhounds that could be adapted to other breeds. Diagnostic procedures used by sports medicine physicians could also be adapted by veterinarians, such as measuring the restriction of passive extension of the knee with the hip flexed to 90°[8] and the popliteal angle test to measure range of hamstring muscle movement.[33] Early detection might be improved if owners and trainers of dogs at risk could be instructed in methods for palpating the hamstring and adductor muscles (origins, insertions, and muscle bellies) on their dogs on a routine basis. Evidence of muscle soreness or tightness would be an indication for reducing activity and following the treatment protocols listed below.

Treatment

Protocols recommended for treating human beings with muscle strain injury can be adapted for dogs.[8, 20, 28, 53, 60] Rest, ice, compression, and elevation comprise the conventional therapy for acute injury. Rest, ice application,[30] and possibly compression are appropriate for dogs with acute signs of lameness in addition to short-term administration of anti-inflammatory drugs. The recovery phase includes gradual return to physical exercise, with the intensity adjusted to the individual dog. Surgery may be indicated for grade III muscle strain with complete tearing of the muscle.[7]

COCCYGEAL MUSCLE DAMAGE (“LIMBER TAIL” AND “COLD TAIL”)

Case Study 1

“My 3-year-old black female Labrador Retriever has had three episodes of cold tail. When she was 2 years old, we were training in March, doing land work. She loves to train. After we were done, another member of the club showed up and offered to show me the ponds of the area. The ponds had a thin layer of ice on half of the surface. I figured it was too cold to do water work, but she went in for a swim by herself, and we did three water retrieves. That night, she was in pain. Her tail drooped from the base as if she had been given an epidural. I gave her Azium, and she was fine in 2 days. Later that summer, we did some work in a pond, and after we got home, I hosed her off for 5 minutes with cold water. She got cold tail again. This past New Year’s Eve, we were duck hunting on a small stream. The stream was open but had sheets of ice. I used her to pick up decoys. I did several land retrieves afterward to warm her up and help dry her off. When we got home, I put her in a crate in the garage so she would be warmer as she dried off. She seemed fine later in the day. The next day, she had cold tail again, the same as the other episodes. She recovered within 2 days.”

Case Study 2

“My 10-month-old female English Pointer started training a few weeks ago. Her training schedule is roading twice per week and running twice per week, 30 to 45 minutes each session. She is cage-transported to the training ground 15 miles from the kennel. We noticed limber tail the morning after a 45-minute run. Her sire is a champion that also exhibited limber tail on one occasion."

This dog underwent physical and neurologic examinations, with the following findings. The day after onset, creatine kinase (CK) was mildly elevated to 500 IU, she seemed sensitive to palpation around the tail base, and electromyographic examination 5 days later indicated abnormal spontaneous activity in tail muscles starting about 3 in from the tail base. The dog had mild improvement in tail carriage by the second day and was clinically normal on the third day after onset.

Overview

"Limber tail" is a condition familiar to people working with hunting dogs. Other terms such as *limp tail*, *cold tail*, and *rudder tail* also describe this condition. Breeds primarily affected are English Pointers and Labrador Retrievers, but the disease is seen occasionally in Beagles and other hunting breeds.[17] It also occurs in Dalmatians.

We conducted a survey of owners and trainers of Pointers in the southeastern United States.[44] The findings that emerged from the survey were:

1. In the acute phase, the tail seems flaccid and either hangs down from the tail base or is held out horizontally for several inches from the tail base and then hangs straight down or at some degree below horizontal (Fig. 2).
2. During recovery, the tail may hang to one side.
3. Dogs usually show spontaneous recovery within a few days to 2 weeks.

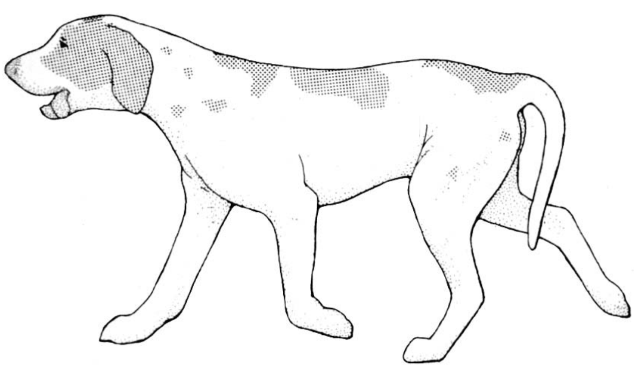


Figure 2. A Pointer with the typical tail carriage observed in coccygeal muscle injury *(limber tail)*. In the acute phase, the tail appears flaccid and either hangs down from the tail base or is held out horizontally for several inches from the tail base and then hangs straight down or at some degree below horizontal. (*From* Steiss JE: What is limber tail syndrome? Field Trial Magazine 1(1):12–13, 1997; with permission.)

4. The major predisposing factors are prolonged cage transport, underconditioning or overexertion, and changes in climate, especially exposure to cold.
5. Several experienced trainers considered that nonsteroidal anti-inflammatory drugs administered within 24 hours after onset seemed to speed recovery.
6. Most owners and trainers did not seek veterinary assistance.

The typical case consists of an adult dog that acutely develops a flaccid tail. The abnormal tail carriage is usually noted the morning after exercise. Less frequently, the signs are seen later the same day or even during exercise if the exercise is prolonged. With cage transport, the limp tail is often observed when dogs are unloaded. Owners of Labrador Retrievers tend to report that their dogs seem to be in pain in the acute stage. Treatment usually consists of rest, and dogs recover spontaneously within 2 weeks or less. Some dogs experience recurrences.

In Pointers, the major predisposing factors are prolonged cage transport, a hard workout the day before (especially in unconditioned dogs), and cold and wet weather the previous night. In Retrievers, the condition is often associated with exposure to water (i.e., swimming, bathing, water retrieves). Veterinarians may find that the number of cases varies during the year, with the numbers increased around the start of training season. In cases where the owner and veterinarian are not familiar with this disease, more serious conditions such as fracture or spinal cord disease might mistakenly be diagnosed.

We reported findings in a small group of Pointers showing typical signs of this disease.[48] Serum CK was mildly elevated in the acute phase. Needle electromyographic examination performed several days after onset showed abnormal spontaneous electric discharges restricted to the coccygeal muscles. Histopathologic examination revealed muscle fiber changes (Fig. 3). Specific muscle groups within the tail, namely, the laterally positioned intertransversarius ventralis muscles, were most severely affected (Fig. 4). Additional findings on thermography, MR imaging, and scintigraphy further supported the diagnosis. Neurologic, orthopedic, and radiographic examinations revealed no additional consistent abnormalities.

The intertransversarius ventralis coccygeus muscles are segmental muscles lying against the transverse processes of the third coccygeal vertebra distally. Their action is to produce lateral flexion of the tail, which is also the action of the intertransversarius dorsalis coccygeus muscles.[13] Tail movements are important for maintaining balance during locomotion.[56] Lateral movement of the tail corresponds with reciprocal activation between left and right tail muscles.

The distribution of muscle damage localized to specific muscle groups within the tail is suggestive of acute compartment syndrome.[39, 60] Measurement of intracompartmental pressures within the intertransversarius muscles would be needed to confirm this possible etiology. Muscle strain can also produce histopathologic changes.[42] Exercise consisting of

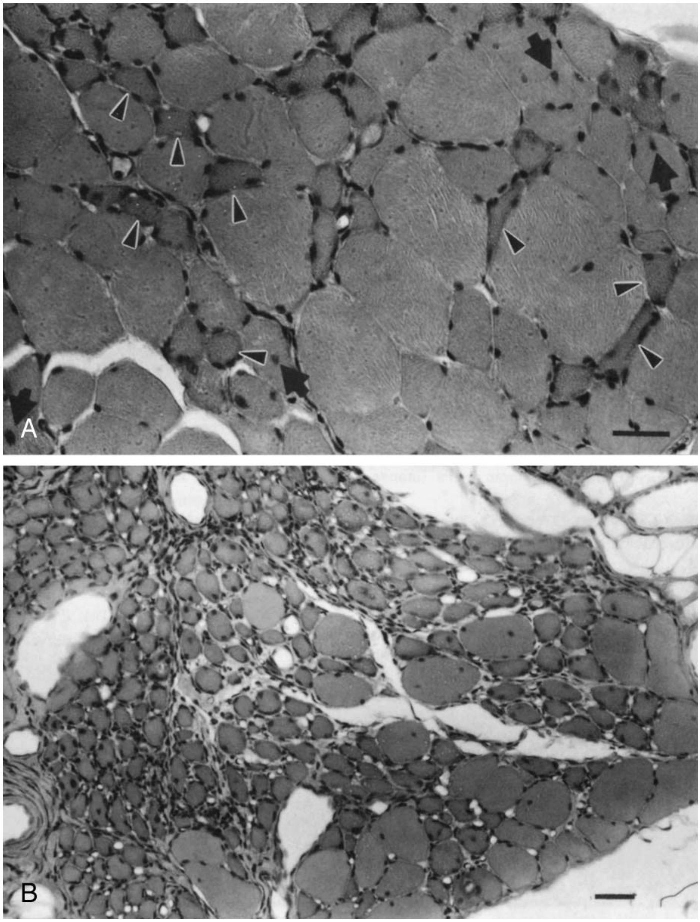
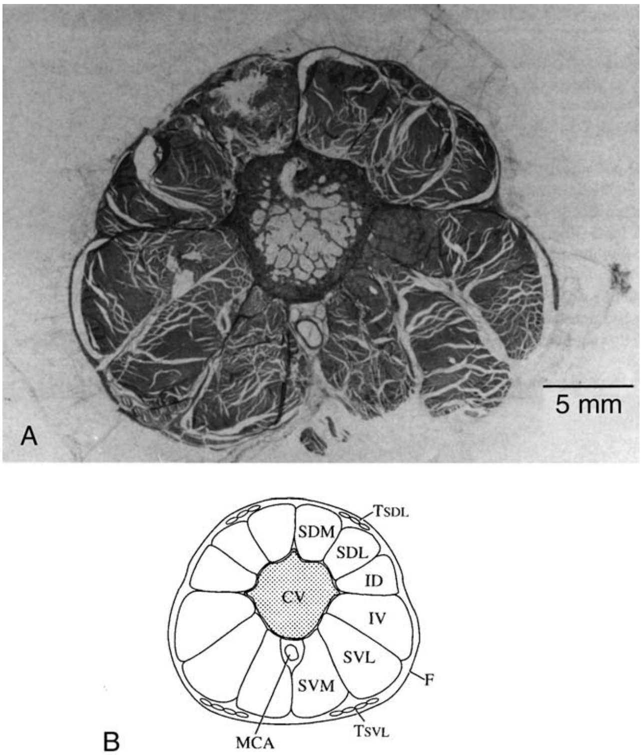


Figure 3. Histopathologic sections of intertransversarius ventralis muscle (approx 8 cm from tail base) from two English Pointers affected with coccygeal muscle injury *(limber tail)*. *A,* Moderate fiber size variation associated with multifocal fiber hypertrophy and scattered round/angular atrophic fibers *(arrowheads)* many of which are dark-staining (basophilic) as well as internal nuclei in several fibers *(arrows)* (hematoxylin-eosin; bar = 30 μm). *B,* Pronounced fiber size variation, diffuse fiber atrophy, scattered hypertrophic fibers, and fibers with internal nuclei (hematoxylin-eosin: bar = 25 μm). (*From* Steiss J, Braund K, Wright J, et al: Coccygeal muscle injury in English Pointers (limber tail). J Vet Intern Med 13:540–548, 1999; with permission.)



CV = coccygeal vertebra
F = fascia
ID = intertransversarius dorsalis coccygeus m.
IV = intertransversarius ventralis coccygeus m.
MCA = median coccygeal artery
SDL = sacrococcygeus dorsalis lateralis m.
SDM = sacrococcygeus dorsalis medialis m.
SVL = sacrococcygeus ventralis lateralis m.
SVM = sacrococcygeus ventralis medialis m.
TSDL = tendons of SDL
TSVL = tendons of SVL

Figure 4. Histologic section from a clinically normal English Pointer, demonstrating the cross-sectional anatomy of the tail approximately 8 cm from the tail base *(A)*. Muscle groups are shown in *B.* (*From* Steiss J, Braund K, Wright J, et al: Coccygeal muscle injury in English Pointers *(limber tail).* J Vet Intern Med 13:540–548, 1999; with permission.)

eccentric muscle contractions more readily results in muscle pathologic findings than exercise consisting of concentric muscle contractions.[24, 32] Damage associated with eccentric muscle contractions may be pertinent, based on observing the manner in which Pointers continuously whip their tail side to side, demonstrating an "active tail."

Recommendations

Prevention

Prevention is aimed at minimizing or avoiding the predisposing factors listed previously. This includes adopting a regular training program so as to avoid overexertion in unconditioned dogs. When traveling long distances, trainers have reported that stopping approximately every 4 hours to let their dogs out has cut down on the incidence of limber tail associated with transport.

Treatment

Treatment includes rest to allow for healing of the muscle damage within the tail and short-term administration of anti-inflammatory drugs during the acute phase.

INFRASPINATUS OR SUPRASPINATUS MUSCLE CONTRACTURE

Case Study 1

An English Setter was transported on an 11-hour trip to an area for grouse hunting. The owner took the dog out three times for short walks during the journey and noticed nothing abnormal. The next day, however, the dog had difficulty in running through the brush. The left front leg tended to flail out at the shoulder in abduction. The abnormality was not as noticeable standing or walking. The dog did not seem to be in pain and did not resist bearing weight on the leg. A local veterinarian found no evidence of systemic illness or injury and administered a steroid injection. The owner stated that 4 weeks prior, he had hunted the dog briefly but was not aware of any injury. The abnormality persisted. One week later, the owner was referred to a veterinary orthopedic surgeon, who diagnosed contracture of the infraspinatus muscle. He explained that the shortening of the tendon produced external rotation of the shoulder. On testing passive ROM, the dog exhibited decreased elbow flexion with the shoulder placed in adduction and internal (medial) rotation. The veterinarian indicated an excellent prognosis for full recovery with surgical release.

Case Study 2

A 4-year-old male Rottweiler weighing 126 lb was trained for law enforcement. He was tracking a prison escapee over hilly terrain. He pulled up after running 2 miles, unable to continue, and the officer carried him back to the truck. He was referred to a veterinary neurologist. The shoulder muscles (infraspinatus and supraspinatus muscles) were swollen, hard, and painful bilaterally. CK was elevated to 10,000 IU on day 2. The clinician elected to perform a muscle biopsy of the supraspinatus muscle, which was interpreted as severe muscle necrosis. The biopsy site bled profusely, and the muscle tissue protruded through the incised fascial covering. The dog was cage-rested, and nonsteroidal anti-inflammatory drugs were administered. The dog improved slowly over the next week and was discharged without follow-up.

Overview

Infraspinatus muscle contracture has been reported in mature sporting and working dogs, including Pointers, Labrador Retrievers, Brittany Spaniels, and other breeds.[3, 10, 34, 36, 59] The condition may be observed in its acute stage during physical exertion, with dogs showing pain in the shoulder region and reluctance to bear weight. Dillon et al[10] reported on a Border Collie that became acutely lame while working sheep and would not bear weight on the affected limb. The infraspinatus and supraspinatus muscles were swollen and painful. Three months later, the Collie had severe atrophy of the supraspinatus and infraspinatus muscles. In many cases, no acute phase is observed. The chronic stage is characterized by forelimb abduction, external rotation, and extension. The involvement is unilateral in most cases, but both thoracic limbs can be involved.

Although the disease is called "infraspinatus contracture," the supraspinatus muscle can also undergo fibrosis and contracture.[35] Electrophysiologic studies have indicated that this is a disease of muscle and not of the suprascapular nerve.[36] Histologic studies have shown fibrous tissue replacement of the affected muscle, with few normal muscle fibers remaining.[3]

The cause of this myopathy is unknown. One hypothesis is that the infraspinatus muscle is traumatized[10]; however, trauma is rarely observed before the onset of clinical signs. Acute compartment syndrome warrants consideration as a cause of this disorder. Pressure measurements with an intracompartmental pressure monitor (Stryker Corporation, Kalamazoo, MI) are needed to confirm this hypothesis. The following features are suggestive of compartment syndrome:

1. Clinical signs appear while the dog is performing strenuous exercise.
2. There is sudden onset of the lameness when the acute phase is observed.
3. Dogs are reluctant to move, suggesting severe pain.
4. Swelling occurs over the shoulder muscles.
5. Swelling of the muscle through the incised fascia was noted in case 2 at the time of biopsy of the supraspinatus muscle.
6. Fibrosis affects the entire muscle(s).

A case of acute compartment syndrome of the supraspinatus muscle has been reported in an athlete.[52] These muscles could be especially susceptible to compartment syndrome because they are surrounded on their deep surface by the scapula and superficially by dense connective tissue. These surrounding structures could render the muscles unable to accommodate increased compartmental pressure such as could be generated with strenuous muscle exertion.

REHABILITATION OF CANINE ATHLETES

The field of physical therapy and rehabilitation has much to offer veterinarians in terms of its potential application to sporting dogs as well as to orthopedic and neurologic patients. In 1978, canine physical therapy techniques were described by Downer.[11] In addition, a comprehensive text on canine rehabilitation is currently in press.[22] Some of the physical therapy methods that can be adapted to rehabilitation of the canine athlete include:

1. Thermal agents (ice, hot packs, diathermy, therapeutic ultrasound[43, 46])
2. Iontophoresis and phonophoresis for transcutaneous drug delivery
3. Therapeutic exercise
4. Electric stimulation
5. Manual therapy
6. Aquatic therapy
7. Orthotics (braces and splints)[19]

With regard to muscle disorders in canine athletes, emphasis should be placed on prevention, using appropriate progression of exercise during training and avoiding making the dog a "weekend warrior." Acute treatment is based on the principle of rest, ice, compression, and elevation. After recovery from the acute phase, treatment is based primarily on balancing a sufficient period of rest to allow for healing with reintroduction to low-intensity training activities. This reintroduction to training must be individualized for each dog. For injury prevention, one important area that can be adapted to canine athletes is the incorporation of warm-up and cool-down into the training program.[45]

Warm-up and Cool-down Before Training Sessions and Competition

Warm-up tends to be neglected in dogs in training. At competitive events, dogs frequently are taken directly from the truck or stake-out into their class. Even though much research remains to be done, warm-up is recognized as contributing to improving performance and protecting against injury.[2, 15] Recommendations have been published for human and equine athletes and for racing Greyhounds.[4]

The purpose of the warm-up is to produce a mild increase in body temperature of 1°F to 2°F. In human athletes, warming up can include walking, jogging, swimming, or mild- to moderate-resistance cycle ergometry.[15] Warm-up is classified as passive and active. In passive warm-up, an increase in body temperature is achieved by techniques such as massage, diathermy, ultrasound, and heat application.[27] This does not significantly increase the blood flow to the working muscles,[58] and passive warm-up is not used to a great extent. Active warm-up is the easiest way to increase muscle temperature. It is divided into two phases, general and specific.[21] General warm-up is a form of loosening up such as walking followed by jogging or trotting. The effect is to raise core temperature (which can be estimated from measuring rectal temperature), heart rate, and respiration rate.[21] For racing Greyhounds, 5 to 10 minutes of brisk walking or jogging before racing is recommended.[4] Treadmill exercise could also be incorporated into the warm-up (Fig. 5). Specific (neuromuscular) warm-up is a rehearsal for the activity. Specific warm-up is thought to improve skill and coordination. Sports that require accuracy, timing, and precise movements tend to benefit from some type of specific preliminary practice.[27] Dogs competing in agility would be candidates for including this phase of the warm-up.

The ideal warm-up prepares the athlete for subsequent activity

Figure 5. Treadmill exercise can be incorporated into training or rehabilitation programs. This dog is training for French Ring Sport and weight pull. Treadmills are convenient for warm up exercise, and the speed can be controlled for progressive exercise programs. However, the disadvantage is that the treadmill presents an artificial situation in which the ground moves beneath the dog's feet. Therefore, muscle groups may be activated differently on the treadmill compared with normal locomotion. (Courtesy of Patti Schaefer, DVM, Canisport Veterinary Therapeutic Services, Olympia, WA.)

without creating fatigue.[21, 58] Some trainers state that the ideal warm-up for any endurance activity is the same activity but at a lower intensity.[15] More precisely, the goal of warm-up is to exercise at a relatively low intensity that is less than 60% of maximum oxygen consumption or 70% of maximal heart rate for less than 15 minutes.[58]

The intensity and duration of the warm-up depend on factors such as the individual athlete, the event, the facilities, and the ambient temperature.[21, 58] If the warm-up exercise is too strenuous or the duration is too long, performance can be impaired by fatigue.[58] Excessive warm-up depletes energy stores, causes lactic acid build up, and raises body temperature too high.[21] After the warm-up is completed, the activity or event should begin within several minutes.[27] This allows recovery from temporary fatigue without losing the beneficial effects of the warm-up.

Numerous beneficial effects of warm-up have been documented for the musculoskeletal system. Greater forces are needed to injure a warm muscle than a cold muscle.[27, 50] With an increase in tissue temperature, collagen and the muscle-tendon junctions are more able to stretch, thereby minimizing trauma.[25] In addition, cold muscles have low blood saturation and tend to be more susceptible to tears than warm muscles.[18] Increased temperature within muscles promotes vasodilation. Vasodilation increases blood flow and increases the delivery of oxygen and nutrients to muscle and the removal of waste products.[15, 21] No one has conducted a study to measure the limb temperatures in dogs working in cold conditions such as subzero ambient temperatures or ponds covered with ice. The degree of thermal insulation provided by the hair coat is not known. If the intramuscular temperatures do decrease while dogs work in these cold environments, warm-up exercise might be important to minimize the tissue cooling of the limbs. Another important result of increased tissue temperature is increased oxygen delivery to muscles. As temperature increases, the oxy-hemoglobin dissociation curve is shifted to the right.[2] Other effects of warm-up on the musculoskeletal system include increased speed of muscle contraction and relaxation[27, 58] and increased muscle strength.[18]

Stretching exercises have been part of the traditional warm-up.[15, 21, 38] In a recent study, however, investigators found that muscle stretching performed during the pre-exercise warm-up in adult men did not significantly reduce the risk of exercise-related injury.[37] Instead, they concluded that fitness may be an important modifiable risk factor. For trainers, the warm-up for dogs would certainly be simplified if additional stretching procedures did not need to be incorporated.

Cool-down (Recovery Phase, Postevent Warm-down)

The athlete should be allowed a cool-down period consisting of low-intensity exercise such as walking. The intensity of the exercise would be 30% to 65% of maximum oxygen consumption.[20]

This low-intensity activity is used during the early recovery stage to ensure that blood continues to be circulated from the muscles to enhance the washout of the waste products of muscle metabolism such as lactic acid and to dissipate heat, thus shortening the recovery time.[14, 15] The postexercise cool-down could mirror the warm-up. The time until complete recovery depends on the type and intensity of the exercise. From 10 to 20 minutes is usually considered enough time for cool-down.[14]

SUMMARY

Muscle disorders associated with physical exertion in human athletes include delayed-onset muscle soreness, muscle strain, muscle tears, rhabdomyolysis, and acute and chronic compartment syndromes. Given that the structure of muscle is similar among different species, it is reasonable to expect that dogs experience the same phenomena. This article focuses on several of the muscle disorders of bird dogs, namely, coccygeal muscle injury and infraspinatus muscle contracture, and on those of dogs involved in tracking-obedience-protection training, namely, fibrotic myopathy, with an additional discussion of muscle strain. For injury prevention, one important area that can be adapted to canine athletes is the incorporation of warm-up and cool-down into the training program.

References

1. Adams OR: Fibrotic myopathy and ossifying myopathy in the hindlegs of horses. JAVMA 139:1089–1092, 1961
2. Bar-Or O: Pediatric Sports Medicine for the Practitioner. New York, Springer-Verlag, 1983, pp 34–38
3. Bennett RA: Contracture of the infraspinatus muscle in dogs: A review of 12 cases. J Am Anim Hosp Assoc 22:481–487, 1986
4. Blythe LL, Gannon JR, Craig AM: Care of the Racing Greyhound. American Greyhound Council, 1994
5. Bramlage LR, Reed SM, Embertson RM: Semitendinosus tenotomy for treatment of fibrotic myopathy in the horse. JAVMA 186:565–567, 1985
6. Braund KG: Clinical Syndromes in Veterinary Neurology, ed 2. St Louis, Mosby, 1994
7. Brown SG: Unique veterinary problems of coursing dogs. *In* Bloomberg MS, Dee JF, Taylor RA (eds): Canine Sports Medicine and Surgery. Philadelphia, WB Saunders, 1998, pp 426–433
8. Clanton TO, Coupe KJ: Hamstring strains in athletes: Diagnosis and treatment. J Am Acad Orthop Surg 6:237–248, 1998
9. Clarke RE: Fibrosis and contracture of the semitendinosus muscle in a dog. Aust Vet J 66:259–261, 1989
10. Dillon EA, Anderson LJ, Jones BR: Infraspinatus muscle contracture in a working dog. NZ Vet J 37:32–34, 1989
11. Downer AH: Physical Therapy for Animals. Springfield, Charles C Thomas, 1978
12. Eaton-Wells RD: Muscle injuries in the racing Greyhound. *In* Bloomberg MS, Dee JF, Taylor RA (eds): Canine Sports Medicine and Surgery. Philadelphia, WB Saunders, 1998, pp 84–91
13. Evans HE: Miller's Anatomy of the Dog, ed 3. Philadelphia, WB Saunders, 1993, p 314

14. Fisher AG, Jensen CR: Scientific Basis of Athletic Conditioning, ed 3. Philadelphia, Lea & Febiger, 1990, pp 177–178
15. Franklin BA, Buchal M, Hollingsworth V, et al: Exercise prescription. *In* RH Strauss (ed): Sports Medicine, ed 2. Philadelphia, WB Saunders, 1991, pp 48–51
16. Harries M, Williams C, Stannish WD, et al: Oxford Textbook of Sports Medicine. New York, Oxford University Press, 1994
17. Hewison C: Frozen tail or limber tail in working dogs. Vet Rec 140:536, 1997
18. Jensen CR, Fisher AG: Scientific Basis of Athletic Conditioning, ed 2. Philadelphia, Lea & Febiger, 1979, pp 267–271
19. Johnson R: The use of thermoplastic materials for orthotic design in veterinary practice. Proceedings of the Central Veterinary Conference, Kansas City, MO, August 2001, pp 1386–1388
20. Kujala UM, Orava S, Jarvinen M: Hamstring injuries: Current trends in treatment and prevention. Sports Med 23:397–404, 1997
21. Lawrence L: The benefits of warming up. World Equine Vet Review 4:6–11, 1999
22. Taylor R, Millis D, Levine D: Canine Physical Rehabilitation. Philadelphia, WB Saunders. In press
23. Lewis DD, Shelton GD, Piras A, et al: Gracilis or semitendinosus myopathy in 18 dogs. J Am Anim Hosp Assoc 33:177–188, 1997
24. Lieber RL, Woodburn TM, Friden J: Muscle damage induced by eccentric contractions of 25% strain. J Appl Physiol 70:2498-2507, 1991
25. Malone TR, Garrett WE, Zachazewski JE: Muscle: Deformation, injury and repair. *In* Zachazewski JE, Magee DJ, Quillen WS (eds): Athletic Injuries and Rehabilitation. Philadelphia, WB Saunders, 1996, pp 86–89
26. Matwichuk CL, Taylor S, Shmon CL, et al: Changes in rectal temperature and hematologic, biochemical, blood gas, and acid-base values in healthy Labrador Retrievers before and after strenuous exercise. Am J Vet Res 60:88–92, 1999
27. McArdle WD, Katch FI, Katch VL: Exercise Physiology, ed 3. Philadelphia, Lea & Febiger, 1991, pp 511–513
28. McKeag DB, Hough DO: Primary Care Sports Medicine. Dubuque, IA, Brown & Benchmark, 1993
29. McLatchie GR, Lennox CME: The Soft Tissues. Oxford, Butterworth-Heinemann, 1993
30. Michlovitz SL: Cryotherapy: The use of cold as a therapeutic agent. *In* Thermal Agents in Rehabilitation, ed 2. Philadelphia, FA Davis, 1990, pp 63–85
31. Moore RW, Rouse GP, Piermattei DL, et al: Fibrotic myopathy of the semitendinosus muscle in four dogs. Vet Surg 10:169–174, 1981
32. Nosaka K, Clarkson PM: Muscle damage following repeated bouts of high force eccentric exercise. Med Sci Sports Exerc 27:1263–1269, 1995
33. Orchard J, Marsden J, Lord S, et al: Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. Am J Sports Med 25:81–85, 1997
34. Pettit GD: Infraspinatus muscle contracture in dogs. Mod Vet Pract 61:451–452, 1980
35. Pettit GD, Slatter DH: Infraspinatus contracture associated with suprascapular paralysis in a dog. J Small Anim Pract 13:699–702, 1972
36. Pettit GD, Meyers KM: Studies on the pathophysiology of infraspinatus muscle contracture in the dog. Vet Surg 7:8–11, 1978
37. Pope RP, Herbert RD, Kirwan JD, et al: A randomized trial of pre-exercise stretching for prevention of lower-limb injury. Med Sci Sports Exerc 32:271–277, 2000
38. Ray S, Irvin R: The warm-up period. *In* Sports Medicine. Englewood Cliffs, NJ, Prentice-Hall, 1983, pp 39–44
39. Ricci MA, Corbisiero RM, Mohamed F, et al: Replication of the compartment syndrome in a canine model: Experimental evaluation of treatment. J Invest Surg 3:129–140, 1990
40. Sallis RE, Massimino F: American College of Sports Medicine's Essentials of Sports Medicine. Philadelphia, Harcourt Health Science Group, 1996
41. Shelton GD: Neuromuscular disorders. *In* Hoskins JD (ed): Geriatrics and Gerontology of the Dog and Cat. Philadelphia, WB Saunders, 1995, p 322
42. Stauber WT, Knack KK, Miller GR, et al: Fibrosis and intercellular collagen connections from four weeks of muscle strains. Muscle Nerve 19:423–430, 1996

43. Steiss JE: Physical therapy modalities: Therapeutic ultrasound and phonophoresis. Compend Contin Educ Pract Vet 22:690–693, 2000
44. Steiss JE: What is limber tail syndrome? Canine Pract 22:1, 1997
45. Steiss JE: Warming up your dog before training sessions or competition. Retrievers Online 12(2):4–7, 2001; http://uab.edu/janetsteiss
46. Steiss JE, Adams CC: Effect of coat on rate of temperature increase in muscle during ultrasound treatment of dogs. Am J Vet Res 60:76–80, 1999
47. Steiss JE, Spano J: Roading versus running—what's the difference? American Field 246:17, 1996
48. Steiss JE, Braund K, Wright J, et al: Coccygeal muscle injury in English Pointers (limber tail). J Vet Intern Med 13:540–548, 1999
49. Steiss JE, Simpson S, Adams CC, et al: Is fibrotic (gracilis) myopathy due to muscle strain in physically active dogs? Located at: http://uab.edu/janetsteiss
50. Strickler T, Malone T, Garrett W: The effects of passive warming on muscle injury. Am J Sports Med 18:141–145, 1990
51. Swaim SF, Lee AH, Henderson RA: Mobility versus immobility in the healing of open wounds. J Am Anim Hosp Assoc 25:91–96, 1989
52. Takakuwa T, Takeda M, Tada H, et al: Acute compartment syndrome of the supraspinatus: A case report. J Shoulder Elbow Surg 9:152–156, 2000
53. Tory JS, Shephard RJ: Current Therapy in Sports Medicine, ed 3. St Louis, Mosby, 1995, pp 459–461
54. Turner AS, Trotter GW: Fibrotic myopathy in the horse. JAVMA 184:335–338, 1984
55. Vaughan LC: Muscle and tendon injuries in dogs. J Small Anim Pract 20:711–736, 1979
56. Wada N, Hori H, Tokuriki M: Electromyographic and kinematic studies of tail movements in dogs during treadmill locomotion. J Morphol 217:105–113, 1993
57. Watt PR: Posttraumatic myositis ossificans and fibrotic myopathy in the rectus femoris muscle in a dog: A case report and literature review. J Am Anim Hosp Assoc 28:560–564, 1992
58. Wenger HA, McFadyen PF, McFadyen RA: Physiological principles of conditioning. *In* Zachazewski JE, Magee DJ, Quillen WS (eds): Athletic Injuries and Rehabilitation. Philadelphia, WB Saunders, 1996, pp 202–204
59. Wright R, Windom A: Contracture of the infraspinatus muscle in a hunting dog. Vet Med Small Anim Clin 77:1501–1504, 1982
60. Zachazewski JE, Magee DJ, Quillen WS: Athletic Injuries and Rehabilitation. Philadelphia, WB Saunders, 1996

Address reprint requests to

Janet E. Steiss, DVM, PhD, PT
Department of Occupational Therapy
University of Alabama at Birmingham
900 South 19th Street
Birmingham Alabama 35294–2030

e-mail: steisje@hotmail.com