Normal And Abnormal Gait

Chapter 91

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Methods of Gait Analysis

Normal locomotion of the dog involves proper functioning of every organ system in the body, up to 99% of the skeletal muscles, and most of the bony structures.(1-75) Coordination of these functioning parts represents the poorly understood phenomenon referred to as *gait*. The veterinary literature is interspersed with only a few reports addressing primarily this system. Although gait relates closely to orthopaedics, it is often not included in orthopaedic training programs or orthopaedic textbooks.

The current problem of gait analysis in humans and dogs is the inability of the study of gait to relate significantly to clinical situations. Hundreds of papers are included in the literature describing gait in humans, but up to this point there has been little success in organizing the reams of data into a useful diagnostic or therapeutic regime. Studies on human and animal locomotion commonly involve the measurement and analysis of the following:

Temporal characteristics

Electromyographic signals

Kinematics of limb segments

Kinetics of the foot-floor and joint resultants

The analyses of the latter two types of measurements require the collection and reduction of voluminous amounts of data, but the lack of a rapid method of processing this data in real time has precluded the use of gait analysis as a routine clinical tool, particularly in animals.

The scientific study of gait in the dog began in the latter part of the 19th century with the advent of photography. In 1888, Muybridge, through the use of stroboscopic photography, was able to show the stride of a racing greyhound. (50) His book also details hound dogs running at various speeds as well as gait portrayals of various domestic and wild animals. Prior to this time, the portrayal of gait was performed by artists generally depicting the dog and horse in strides that are unnatural to the species involved.

The tools described below are those used in the study of the locomotion or gait in the dog. Currently, the clinical cost-benefit ratio is very high. The sophistication and highly technical nature of the equipment and techniques have proven clinical gait analysis to be of limited value at this time. However, the study of gait and the elucidation of the phenomena that contribute to canine locomotion are valuable. This chapter will provide a basis for understanding current techniques of canine gait analysis and hopefully will serve as an impetus for further research into canine locomotion that may prove to be of value to the orthopaedic clinician.

TEMPORAL CHARACTERISTICS

Temporal analysis of gait in the dog has yielded some norms for the average velocity of walking as well as time durations for the two phases of gait: the stance phase and the swing phase. The symmetry and asymmetry of gait are easily observed and can be measured using systems ranging from a stopwatch and a dirt path to determine foot placement to electronic walkways and foot switches that signal the instant of floor contact. The temporal aspects of gait may also be observed in combination with high-speed motion pictures to determine the length of the stance and swing phases. When these pictures are combined and integrated with a force plate, additional data are obtained. In general most of the temporal methods of analyzing gait can be performed in natural settings without encumbering the animal being studied.

KINEMATIC ANALYSIS

Kinematics is the study of relative motion that exists between rigid bodies, known as "links." Kinematic analysis of gait investigates the displacement, velocity, and acceleration of various body segments. Stroboscopic photography, first used in the dog by Muybridge, was one of the earliest attempts to establish the norms for sagittal rotation of the extremities and excursions of the head and neck during various gaits in animals.(50) Currently, high-speed motion picture analysis is regarded as one of the best methods of kinematic analysis of gait in the dog. The development of electrogoniometry (electrical measurement of joint angles) has allowed simplification of the analysis of motion picture films, since the angles of various joints can be measured directly. Adrian has used this method in the dog to determine the normal standing angles of the hip, stifle and hock joints as well as the angles of these joints during gait.(1) One problem with electrogoniometry is proper positioning of the device to ensure that accurate measurement of the true angle is taken. The use of instrumented linkages by Kinzel represents a far more sophisticated method to determine motion of a joint with 6° of freedom.(40) Kinzel and coworkers, studying the shoulder joint of the German shepherd, were able to map the contact area of the scapulohumeral joint and show the relations of extension/flexion, abduction/adduction, and internal/external rotation during the gait cycle.(41) Arnoczky and co-workers have shown the usefulness of kinematics in the study of the normal relation between the tibia and femur to evaluate the cruciate ligament in the dog.(8)

ELECTROMYOGRAPHY

Electromyography, the study of electrical impulses generated in active muscle, is a useful method for determining the activity of muscles used in locomotion. Electromyographic signals may be unrelated to force, and electrical activity in the muscle can be generated by passive stretches as well as active contractions. Although knowledge of particular muscular activity during any phase of stride is important, it must also be determined whether these movements are shortening or lengthening ones. Tokuriki and Goslow and co-workers have studied the electromyographic patterns of the dog on a treadmill during walk, trot, and gallop. (70-72)

KINETICS OF FOOT-FLOOR AND JOINT RESULTANTS

The kinetic approach to gait evaluation assesses the forces generated during and resulting from the gait cycle. There are generally two types of forces that have attracted the interest of investigators: floor reaction force and joint reaction force. The most common method for studying floor reaction force is the force plate, a device that can be instrumented to measure vertical and horizontal forces and to predict, describe, and evaluate clinical disability.(13) The force plate is also used to test the results of various modes of treatment.(14) Joint reaction forces are usually derived mathematically, since direct implantation of the recording device is not feasible in a clinical Situations The data resulting from this mathematical derivation are helpful in predicting the forces that joints must sustain to remain healthy as well as in predicting the forces that must be withstood by prosthetic devices designed for total joint replacement. Knowledge of the forces across joints and the strains sustained by bones in vivo is important for reconstructive procedures such as internal fixation following fractures.

Another parameter used in kinetic studies is that of work or energy expenditure. This is measured by calculating forces and displacements or by using oxygen consumption techniques.(22,59)

The Normal Gaits of the Dog

The gaits of the dog are commonly used patterns of locomotion that can be divided into two main groups: symmetric and asymmetric. With symmetric gaits such as the walk, trot, and pace, the movement of the limbs on one side of the dog's body repeats the motion of the limbs on the opposite side with the intervals between foot falls being nearly evenly spaced. With asymmetric gaits such as the gallop, the limb movements of one side do not repeat those of the other and the intervals between foot falls are unevenly spaced. When considering gaits, one full cycle is referred to as a stride.

THE WALK

The walk has been described as the least tiring and most efficient form of locomotion of the dog.(35) When walking, the dog never has fewer than two feet on the ground (usually three feet), and occasionally all four feet may be on the ground. An illustration of the dog at a walk and the foot placement pattern is shown in Figure 91-1. The vertical force exerted by the front pads of the dog when walking is reported to be approximately 1.1 times body weight, and the corresponding figure for the back pads is 0.8 times body weight at a velocity of 3 ft to 5 ft/sec.(36) The forces recorded in the longitudinal plane show that the decelerating force is most prominent in the front feet and the accelerating force most prominent in the rear feet.(11,14,36,37) Therefore, in the walking dog, it appears that forward momentum is maintained by the rear legs, while weight bearing, although maintained by all four legs, is greater in the front legs. The front legs are also used for slowing the animal and absorbing shock. There is conflict in the literature regarding the pad contact time. Hutton and co-workers indicate that the contact time for the front feet may be 1.5 times greater than that for the corresponding back feet.(36) Hildebrand, however, states that the mean support time is equal for the front and rear legs at the walk.(33) The contact time between the pad and the ground is a function of leg length and is directly proportional, meaning that the long-legged dog has a longer contact time than does the short-legged dog. (34) Hildebrand states there is a predilection for short-legged dogs to use walking gaits that have a relatively long time interval between the foot fall of a given hindfoot and the foot fall of the forefoot on the same side of the body.(33) Therefore it would be unusual to see small dogs pace; rather, a trotting configuration would be the rule. In long-legged dogs, walking gaits approach those of a pace. There is a great deal of variation in the gaiting pattern according to size and among individual dogs. In general, small dogs show the greatest variation in their gait. (33)

FIG. 91-1 This series of drawings depicts a dog walking. The footprint pattern shown below the figures demonstrates which foot is on the ground during that cycle of gait.

The action of the front limb during support may be described as a strut, with the movement of the limb and body modeled as an inverted pendulum. (12,45,66,70) This model allows an increase in efficiency of locomotion during the walk. It has been estimated that only 30% to 40% of the energy required for movement is provided by muscular action. The remaining 60% to 70% is ascribed to the conservation of energy of the body pendulum.(66) During most of the support phase, less than 20° of movement occurs at the shoulder, elbow, carpal, and metacarpal joints.(42,70) Progression of the animal is achieved by rotation of the scapula on the body wall. During the swing phase of this gait, a small initial flexion of the shoulder joint allows the limb to be lifted from the ground, followed by gradually increasing extension concurrent with increasing flexion of the elbow, carpal, and metacarpophalangeal joints.(70) These movements act together with the forward movement of the scapula to raise the limb off the ground and accelerate it in a forward direction. In preparation for the next stance phase, all the joints of the front limb are extended during the latter part of the swing phase (Fig. 91-2). Flexion and extension of the joints of the hindlimb show approximately 25° of motion in the hip joint during walking and 30° in the stifle and hock joints (Fig. 91-3). (25,70) The action of the hindlimb, however, is different than that of the forelimb. During the stance phase, the hip, tarsal, and metatarsophalangeal joints undergo gradual extension, while the stifle joint remains relatively fixed.(42) During the latter part of the support phase, movement of the metatarsophalangeal joint changes from hyperextension to flexion as push-off proceeds.(1)

Downward movement of the head and neck is associated with impact of both front feet at the initiation of each support phase, while an upward movement is associated with recovery of each limb. The head and neck therefore exhibit two peaks of movement for each stride. The articulation of the pelvis to the sacrum provides a relatively rigid support of the hindlimb as compared with the forelimb. Horizontal movements of the hip joints in relationship to the body are provided for by lateral movements of the spinal column. Therefore, as the hindlimb is advanced, the tail is moved toward the hindlimb striking the ground. The spine is moved laterally away from the leg striking the ground, thereby allowing horizontal movement of the pelvis to occur. This slight lateral motion to the lumbar region of the spine occurs twice with each stride to aid in forward placement of the recovering limb and increases the swinging movement of the hips, thus lengthening the stride.(42)

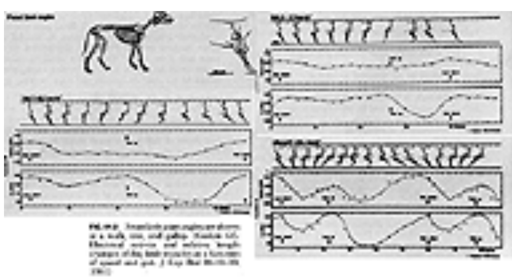
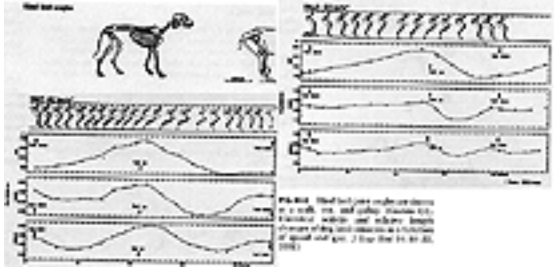


FIG. 91-2 Front limb joint angles are shown at a walk, trot, and gallop. (Goslow GE: Electrical activity and relative length changes of dog limb muscles as a function of speed and gait. J Exp Biol 94:19 33, 1981)

The various roles that the rear and front limbs play during locomotion have been indicated by force plate, electromyography, and other studies. The center of gravity of the dog lies close to the front limbs, probably near the base of the heart. In a normal stance, 60% of the dog's weight rests over the front legs: extension of the head and neck or lowering of the head can increase this forward weight bias by 10% to 15%.(35,57)

FIG. 91-3 Hind limb joint angles are shown at a walk, trot



and gallop. (Goslow GE: Electrical activity and relative length changes of dog limb muscles as a function of speed and gait. J Exp Biol 94 19-33, 1981)

THE TROT

The trot is a symmetric gait produced when the diagonal pairs of legs move almost simultaneously, causing the duration of contact with the ground to be slightly longer for the hindlegs than the forelegs. The generalized picture of a trot is seen in Figure 91-4. The trot usually places two feet on the ground at all times; however, some dogs have a suspended phase that is termed a flying trot (Fig. 91-5). Dogs with short body length and long legs have difficulty trotting, since their hindlegs interfere with their front legs. Crabbing is a method of avoiding this type of interference by twisting the body to allow the hindfeet to pass to one side of the forefeet, so that the dog moves forward and laterally simultaneously.(15,44) The difference between the walk and trot involves the increase in the vertical movements of the body, especially the head and neck, as well as an increase in the movement of the joints, especially the shoulder, elbow, and carpus of the foreleg and stifle and tarsal joints of the hindleg.(1) Unlike the walk, flexion of the stifle joint may occur in midstance phase during the trot.(42) The amplitude of movement of the hindlimb joints shows that the hip joint undergoes 30° of angular change and the hock and stifle joints about 60°.(1,71)

Force-plate records of trotting dogs show higher vertical forces applied by the forelimbs than the hindlimbs, as in the walk; however, the magnitude of the vertical forces shows a twofold increase in the trot as compared with the walk, even though the trot may be accomplished at a slower speed.(37)

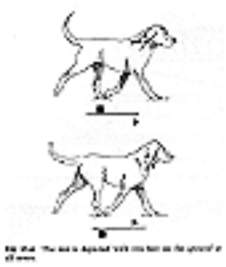


FIG. 91-4 The trot is depicted with two feet on the ground at all times.

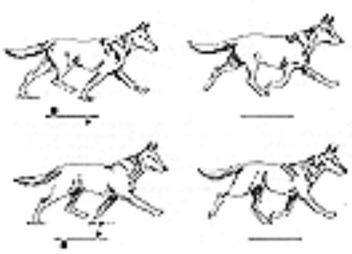


FIG. 91-5 The flying trot shows two suspended phases of this gait cycle.

THE PACE

The pace is a symmetric gait in which support is maintained by the animal with lateral pairs of legs (Fig. 91-6). The animal moves by swinging the forelimb and hindlimb on one side while bearing weight on the other side. It is a gait commonly used in long-legged dogs with close-coupled bodies and allows the animal to move in a straight, forward direction without the interference between front and hind legs that may occur at a trot. (33) The lateral oscillations of the body produced by the pace seem to be handled best by long-legged dogs.(42)

There is very little available data that describe the force parameters of the pace. The pace is also seen in dogs that are tired, out of condition, or have a diagnosable orthopaedic problem. This gait may allow the animal to change ground-reaction forces and maintain the same efficiency of motion but with a different type of effort, resulting in a more comfortable position for the dog.

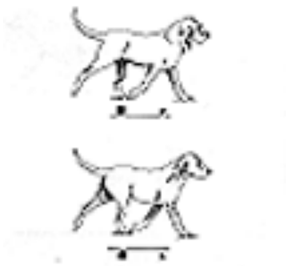


FIG. 91-6 The pace shows two feet to be on the ground at all times.

THE GALLOP

The gallop is an asymmetric gait used for high-speed locomotion. There are two patterns of gallop in the dog: the transverse gallop (Fig. 91-7) similar to the pattern used by the horse; and the rotary gallop (Fig. 91-8), which seems to be preferred by the dog and which in the horse is referred to as a crossed-lead gallop.(35,50) The dog can sustain the gallop at two speeds. The slow gallop, known as a canter or lope, represents a gait that can be sustained easily over a long period of time. It is a submaximal form of aerobic exercise in which aerobic glycolysis contributes to the total power of the dog while running. The fastest gallop can be maintained for short periods owing to the contribution of anaerobic glycolysis during exercise intensities that are greater than maximal aerobic exercise can sustain.(22) During the gallop in the dog, the duration of the stance phase decreases and the duration of the swing phase increases in comparison with the walk or trot. Usually periods of suspension occur following push-off of the leading front leg during the galloping stride. Some animals bred for speed, such as the greyhound, will show two suspended phases per stride, with the first phase occurring after hindfoot pushoff in a leaping portion of the stride and the second phase occurring following push-off of the leading forelimb (Fig. 91-9)(44)

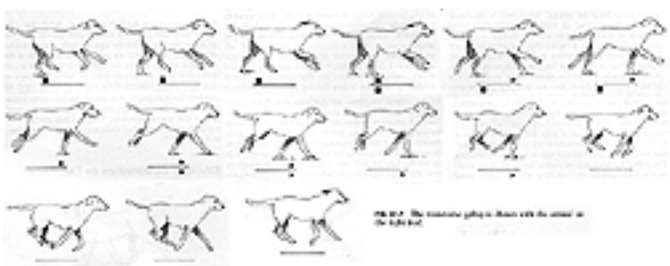


FIG. 91-7 The transverse gallop is shown with the animal on the right lead.

FIG. 91-8 The rotary gallop is depicted with the animal on the left lead.

The angular changes of the joints increase as the speed of the animal and its stride length increase. In one study, the elbow was shown to have an excursion of 80°, the shoulder 55°, the hip 50°, the knee 70°, and the hock 60° while the dog was traveling at a rate of 24.1 km/ hour.(25) Stride frequency increases linearly with speed during a walk and trot although at different rates. When an animal begins to gallop, the frequency of the stride remains almost constant while the animal increases its speed by increasing the stride length. The transition from one gait to another occurs at lower speeds and higher frequencies in small animals.(24) Hence, the Chihuahua may be galloping while the Great Dane is still walking. Movements of the head and neck exhibit a single peak per stride at the gallop, unlike the double peak shown at both the walk and trot.(50) Large increases in the magnitude of the movement of the head, neck, and back are one of the landmarks of locomotion of the gallop, providing one reason that more speed is obtainable than at any other gait.(35) The large downward swing of the head accompanies a long forward reach of the front limbs while the upward motion of the head is accompanied by arching of the back and movement of the hindlimbs under the body in preparation for foot placement. While the gaits of the walk and trot seem for the most part to use only muscles associated with the legs, the gallop uses muscles of the trunk also, hence the arching and extension of the back that occurs during the gallop.(25) it has been postulated that animals change gaits as speed increases so that additional elements of the body can be recruited for storage of elastic energy.(56) Therefore very little energy is being stored in elastic elements during walking, while during trotting energy is stored in elastic elements of the limb; finally the entire trunk of the body is involved in the elastic storage of energy during galloping. Large animals seem to have a maximum "whole animal" efficiency nearly three times greater than the maximum efficiency of their muscles,(31) and this seems to be due to elastic storage of energy-be that storage in muscle, tendon, or ligament. When the dog has accelerated to its constant average velocity, the mechanics of its locomotion are similar to those of a bouncing ball: the only energy necessary to keep the animal "bouncing" is the elastic energy not recovered at each step. Therefore small amounts of energy are put into the system to give an overall efficiency that is higher than would be obtainable by using muscle contraction alone. For muscle to use elastic energy, it must first lengthen to develop tension, then shorten to release the stored elastic energy. It can be seen from this theory that electromyographic studies of muscle must include relative positions of muscle to ascertain if these muscles are actively shortening or passively lengthening to store energy for the continuation of the gait cycle. Therefore, many more muscles are used as the gait speed increases. Tokuriki has studied and reported on the individual muscles used in the walk, trot, and gallop.(70-72)

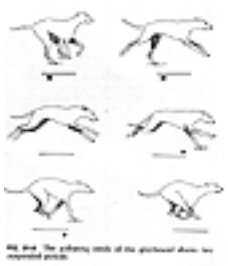


FIG. 91-9 The galloping stride of the greyhound shows two suspended periods.

Effects of Conformation on Locomotion

In the animal kingdom, the domestic dog displays the widest variety of size and shape within a single species. Two full orders of magnitude of weight differential exist between the Chihuahua and the Great Dane or English mastiff. Great differences in anatomical conformation can be seen when comparing the achondroplastic dwarf, such as the dachshund, with the Borzoi. These differences in size and shape significantly influence certain parameters of locomotion and add to the difficulty of characterizing the normal gait of the dog.(31-34) Very little comparative literature exists describing the differences in gaits between various breeds of dogs.(32) Although an extensive comparison among breeds of dogs will not be undertaken in this chapter, it is important to recognize that "normal" gait characteristics of one dog may not pertain to another. The stilted hackney gait of certain toy breed dogs would appear incongruous when dealing with the giant breed dogs. Furthermore, the broad chest of the bulldog suggests a wide stance in the front legs but not necessarily in the rear legs. Conformation requirements are given by the standard for the breed.

Most dogs stand squarely over their forelegs and hindlegs at rest; this is also true during walking, since the dog will support his body by three or more legs. However, as the animal increases its speed and changes gait, it has less support; therefore the legs move toward the center of mass, which is directly below the body. The gait pattern, called single tracking, is used to decrease the lateral oscillations of the body and provide continual support of the center of mass.(15) The degree of convergence of the limbs toward the center line under the middle of the body depends on both the speed of the animal and the conformation. Wide-set dogs with low centers of gravity, such as the bassett hound, do not single track. These dogs normally move with a pronounced lateral roll of the body that is considered abnormal in dogs with longer limbs. A guide to the conformation of the forelimbs and hindlimbs has been cited in the veterinary literature by Roy.(57)His ideal conformation of the front and rear limbs provides a general guideline for judging the effect of deviations from the norm. An angle greater than 45° for the layback of the scapula decreases the limb's extension while a smaller angle decreases efficiency of the movement. In the hindlimb, an angle of less than 45° from the pelvis affects movement of the hindlimbs and is observed in dogs with severe hip dysplasia. A slope of greater than 45° reduces the propulsive effect of the hindlimbs by decreasing the effectiveness of the spinal arching.(57)

Clinical Examination of the Locomotor System

As a quadruped, the dog has the ability to spare an injured joint or sore leg in such a way that the abnormality may be almost unnoticeable; the ability to shift the center of mass in an attempt to decrease weight bearing to any limb is remarkable. The use of the force plate has shown dramatically how easily the clinician can be misled regarding forelimb and hindlimb weight-bearing modes. (1,14) It is possible for a dog to move from a sitting to a standing position and begin walking without touching its hind limbs to the ground. Although this represents an extreme shift of weight, all the intermediate patterns can occur. Dogs with subtle gait changes or lameness may exhibit these signs only to their owners or handlers who notice the change in the dog's gait. The wide variation of breeds and gaits within the same breed may make it difficult for a clinician to diagnose an abnormality in any individual dog. Therefore when examining an animal's locomotive system, the anamnesis is very important. The owner or handler may be able to describe his impression of the dog's problem quite accurately. It is important to know the duration of the dog's problem, if the onset was acute or chronic, and if the condition is improving or deteriorating. Sometimes dogs with a disability will show discomfort only by shifting their gait from a trot to a pace. The owner may be unaware of the problem or fail to recognize that the dog is pacing; thus the owner's knowledge of the animal's normal gait is contrasted to the dog's signs at the time of examination. Examination of the dog's locomotive system includes observation before physical examination and manipulation, since this may change the gait pattern. The dog should be examined or observed from the front, back, both sides, and in at least two gaits. The walk may sometimes demonstrate the involved leg, but often the trot is necessary, since it increases the vertical force on the legs by about twofold.(37) Severe lameness is not difficult to diagnose. If the lameness is in the front leg, the dog will shorten the length of time that the sore leg is on the ground and at the same time remove the weight from this leg by raising its head and neck. The normal leg will have a protracted stance phase and may have a longer stride length than the injured leg. Instead of the head bobbing down with each stroke of the leg, it will rise during the stance phase of the sore limb and lower when the normal limb contacts the ground. This is an effort to shift the weight to the back legs and to relieve weight on the injured leg. The back legs may also be carried further under the body to receive weight that is shifted from the front. The limp will usually be more exaggerated at a trot than at a walk.

If the lameness is in the hindlimb, the dog will extend and lower the head to transfer weight to the forelimbs. (57) When the hindleg is placed on the ground, the dog may exaggerate the downward motion of the head and neck to lessen weight on the hindlimbs. The tail will also be an indication of lameness in the hindlimbs: rather than swinging from side to side as in the normal dog, it will move up and down with the up motion occurring when the injured extremity contacts the ground.(46) This again lessens the weight on the particular extremity. A dog with a hindleg lameness will carry the front legs further back under the center of mass, thus removing weight from the injured leg almost completely with little noticeable head bob.

When examining the dog, it is important that the dog is moved in a circle, both clockwise and counterclockwise, and walked backwards. Certain gait abnormalities are neurologic in nature and these exercises will assist in a diagnosis.

Following a thorough physical and neurologic examination, the dog should be observed again. At this point the clinician should reach a diagnosis and assess the function of the leg in light of the physical findings. In some cases, observation of the locomotive system in conjunction with the physical examination will not reveal the nature of the problem; therefore, radiographic examination is an option to be used when necessary. Joint flexion tests as well as nerve blocks may assist in both the dog and horse. Although not used often, nerve blocks may separate multiple pathologic conditions associated with lameness that occur in the same leg, thereby indicating the problem. Arching of the back, a common sign of weight transfer, can also be a sign of pain and disability of the back itself. Careful physical examination of a dog with arching of the back should include palpation of the area.

Neurologic Conditions Associated With Abnormal Gait

Almost every neurologic condition will be associated in some way with an abnormality of gait, such as an inability to gait, knuckling, lameness, unsteadiness, or development of a protective mode of walking evidencing severe pain. Arching of the back, lowering of the head and neck, and extension of the head are seen with intervertebral disk disease, especially cervical disease but also with thoracolumbar disease. The early signs of degenerative myelopathy are usually gait abnormalities of the hindleg. These abnormalities are especially evident when the dog is trotting or moving in a circular direction. The hindlimbs seem unstable, and the legs seem to lose their proprioceptive ability. Knuckling of the hindlimbs is also characteristic of the problem, and the hindfeet should be observed for evidence of scraping of the nails. In some dogs, the sound of toenails dragging on a hard floor is quite noticeable and should alert the clinician to the fact that a neurologic problem may exist, since lame dogs rarely knuckle or drag their feet when walking unless neurologic disease is present.

Cervical cord disease in giant breed dogs may present with only gait signs. These dogs seem uncoordinated in the forelimbs and hindlimbs although the hindlimbs may seem to be affected more severely than the front limbs.

Gait Abnormalities Associated With Joint Problems

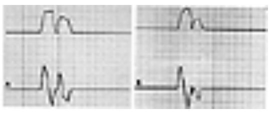
Most joint abnormalities are associated with gait abnormality. Obvious lameness and decreased weight bearing, as mentioned above, are characteristic of joint lameness.

RUPTURED CRUCIATE LIGAMENT

The force plate shows a characteristic signature of the forces in the horizontal direction in dogs that have ruptured the cranial cruciate ligament.* This force tracing shows the instability in the horizontal direction that is present when the dog is fully weight bearing on the plate. There is usually an initial retarding force on the plate followed by the acceleration force push-off. With cranial cruciate rupture, this retarding force may be decreased, and during midstance the normal transition to a forward push-off force is absent. In addition there is an oscillation, which is a sign of instability of the knee (Fig. 91-10) . Kinematics have also been used to study the ligaments of the knee in the dog. Arnoczky's determination of the instant center of motion for intra-articular and extra-articular repairs of the anterior cruciate ligaments is the first in the literature to document efficacy of repair by kinematic techniques There is no pathognomonic sign demonstrated on clinical evaluation of the gait of the dog with a ruptured cranial cruciate ligament. Signs associated with this disease include lameness in the hindleg. Because it is difficult to diagnose this problem by gait analysis, it is important to have the dog trot, since at this gait the knee joint angle changes, allowing significantly more joint loading than at a walk.(42)

* Newton CD: Unpublished data, 1980

FIG. 91-10 (A) The normal tracing from a force plate showing vertical



(above) and horizontal forces (below). Note the first large vertical peak represents forelimb contact while the smaller one represents hind limb contact. (B) The tracing or the dog with cruciate rupture shows a lower vertical component of the vertical force on the hind limb but a marked change in the deceleration force of the hind leg in the horizontal direction. This oscillation seems characteristic of cruciate rupture in the dog.

HIP DYSPLASIA

Hip dysplasia is a common entity that is discussed in the context of gait abnormalities. Radiographic and clinical problems of hip dysplasia vary widely. Radiographic evidence of hip dysplasia does not imply clinical evidence of the disease in the gait. In general, dogs with severe hip dysplasia who show gait abnormalities attempt to lessen the weight on the hindlegs by the weight-forward mechanisms described above. Some animals have such intense pain or weakness that the hindlimbs are unable to provide normal propulsive movement, causing the animal to sway and stagger as it walks. In addition, when viewed from the rear, the hindlimbs may spread excessively far apart in such a way that the animal stands in a base-wide conformation that provides greater stability.(57)

Good physical and neurologic evaluation of the older patient will help distinguish hip dysplasia from a neurologic problem such as degenerative myelopathy, which may be superimposed on hip dysplasia.

PATELLAR LUXATION

Medial patellar luxation is typically seen as a squat gait and toed-in appearance related to the severity of the condition. The patella may pass over the midline axis of the stifle joint in the lateral projection such that the quadriceps becomes a flexor rather than an extensor of the limb; these dogs are unable to extend their legs while walking. The crouched gait of the severely affected animal is almost pathognomonic. Occasionally, in animals not affected severely, little is seen on gaiting the animal. Occasional hopping or skipping of a beat of a stride is an indication to check the stifle joints. Lateral patellar luxation usually results in a very straight-legged appearance, since the dog uses a shuffling gait with a shorter stride behind. Both conditions may be associated with cruciate rupture and may then present with only an indication of a lame leg. Hyperextension of the hock Joints is sometimes seen in these straight-legged dogs and is evidenced in standing and walking.

OSTEOCHONDRITIS DISSECANS

Osteochondritis dissecans of the shoulder, knee, and hock joints is seen frequently. The most common lesion in the dog appears to be in the shoulder; these dogs usually gait with a shortened stride of one or both front legs and attempt to lessen the weight on the foreleg. The shortened stride may not be indicative of osteochondritis dissecans, but the disease should be included in the differential diagnosis when shortened stride is seen.

ELBOW DISEASE

A multitude of problems occur in the elbow joint that often cannot be diagnosed by gait analysis alone. Since there is very little motion in the elbow joint during walking and trotting, it may be difficult to make a diagnosis of elbow problems unless pain is significant.(70,71) Because the gallop causes a change of the angulation of the elbow during the stance and swing phase, it may be used for examination of the dog when practical.(72)

CHRONIC MUSCULAR INJURY

Chronic muscular injuries are often diagnosed most easily by examination of the canine locomotive system. Chronic muscle contractures of the shoulder show the usual external rotation and flexion evident through the entire gait cycle. Chronic contractures of the semitendinosus muscle of the hindlimb will result in a characteristic goose-stepping gait with internal rotation of the tibia before the stance phase. These gait abnormalities can be corrected by surgical section or resection of the involved muscle.

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