Understanding canine locomotion and gait is imperative to diagnosing numerous musculoskeletal and neurologic conditions. Prior to any orthopedic or neurologic examination, a gait evaluation should be performed.

Gait evaluation typically includes visual and/or subjective observation of the dog from a number of angles at both the walk and trot on a flat surface. To the trained eye, lameness can often be detected upon gait evaluation. However, a more subtle lameness may not be apparent on subjective gait evaluation and can be difficult to detect.

Recently, new validated objective gait analysis technologies have become available to help veterinarians quantitate characteristics of gait, which can greatly assist in the detection of a subtle lameness as well as response to various treatments.

NORMAL CANINE GAIT
Prior to detecting abnormalities in gait, one must understand normal canine locomotion. In dogs, there are 4 main gaits: walk, trot, canter, and gallop (Table 1, page 94).

Horses use these same 4 gaits; however, dogs have 2 different ways of cantering and 2 different ways of galloping. Therefore, the canter and gallop that dogs perform preferentially are different from those used by horses.1

In addition, dogs have a transitional gait between the walk and the trot called the amble. There also is a relatively common, but abnormal, gait in dogs called the pace, which is a normal gait for some breeds of horses.1

OBSERVING CANINE GAIT
Key considerations when evaluating gait include:
• Choosing a surface for observation that is even and flat
• Observing both the walk and trot
• Watching the animal from multiple vantage points, including going away, coming toward, from both sides, and while circling
• If the patient is a performance or working dog, evaluating the animal perform its specific tasks, such as jumping over obstacles or running
• Noting any signs of neurologic abnormalities, such as ataxia, paw scuffing, or stumbling.

While the walk is often the easiest gait in which to observe abnormalities because it is the slowest gait, a mild lameness may not be detectable. The trot is the best gait to use for detecting lameness as it is the only gait in which the forelimbs and hindlimbs never receive assistance from the contralateral limb in bearing weight.

Forelimb Lameness
Generally, with forelimb lameness, weight is shifted caudally, and the head goes “down on the sound” limb or, conversely, the head goes up when the lame limb is on the ground (although this observation has not been verified in dogs). In forelimb lameness, the hindlimbs may also appear tucked under and the back appear arched, and affected dogs may take short strides with the hindlimbs.

Dogs with a shoulder lameness tend to appear short strided, while dogs with an elbow lameness (eg, medial compartment disease) appear to circumduct the limb to ease pressure on the medial aspect of the elbow.

Hindlimb Lameness
On the contrary, with hindlimb lameness, weight is shifted cranially. The forelimbs may be placed more caudally, with the head and neck extended and lowered to help offset weight from the hind end. A “hip hike”—in which the hip on the lame side has increased vertical motion, making the hip on the unaffected side appear lower when observing the gait from behind—is often noted on the same side as the lameness. The tail may also rise as the lame leg contacts the ground.

METHODS OF GAIT ANALYSIS
It is imperative to have a means for objective gait analysis because gait is difficult to consistently and
## Summary of Canine Gaits

<table>
<thead>
<tr>
<th>GAIT</th>
<th>FORWARD MOVEMENT</th>
<th>EXAMPLE</th>
<th>COMMENTS</th>
</tr>
</thead>
</table>
| **Walk**    | 1. One rear foot  
2. Ipsilateral front foot  
3. Other rear foot  
4. Front foot on that side | 1. RR  
2. RF  
3. LR  
4. LF | 2 or 3 feet on the ground at any given time  
Only canine gait in which there are ever 3 feet on the ground |
| **Amble**   | 1. One rear foot  
2. Quickly followed by ipsilateral front foot  
3. Other rear foot  
4. Quickly followed by front foot on that side  
Begins to appear as if ipsilateral feet are moving forward together | 1. RR  
2. RF  
3. LR  
4. LF | A faster form of the walk but not preferred gait  
Moments when 3 feet are on the ground observed on close inspection or slow motion video  
Very inefficient gait: Rear end sways from side to side; rear feet are not lifted very high, often scuffling along the ground; wasted horizontal energy and less pleasing to the eye  
Should only be used for short periods: transitioning from walk to trot or resting trotting muscles |
| **Pace**    | 1. Ipsilateral legs move forward together while other 2 legs bear weight  
2. Moment when body is suspended in the air  
3. Other 2 legs move forward together  
Only 2 feet on ground at any given time | 1. RF–RR  
2. No ground contact  
3. LF–LR | Abnormal gait for all dog breeds  
Very inefficient gait: Center of gravity keeps shifting from side to side; energy expended to keep recentering weight  
Cannot respond quickly when a change in speed is required  
Wide range of speeds for movement unavailable unless dog slows to amble or speeds up to trot |
| **Trot**    | 1. Two diagonal front and rear feet  
2. Moment when body is suspended in the air  
3. Other diagonal front and rear feet | 1. RF–LR  
2. No ground contact  
3. LF–RR | Most efficient gait  
Often gait of choice for gait evaluation: The front and rear leg must support the body without help from opposite leg |
| **Rotary Canter** | 1. One rear leg  
2. Both legs on other side of body together  
3. Other front leg  
Different lead legs in front and rear | 1. RR  
2. LR–LF  
3. RF | Predominant canter in dogs (90%)  
Allows very sharp turns with greater drive from the rear  
Referred to as cross cantering in horses |
| **Transverse Canter** | 1. One rear foot  
2. Other rear foot and diagonal front foot together  
3. Other front foot  
Same side leads in the front and rear | 1. RR  
2. LR–RF  
3. LF | Less efficient for dogs; only used in about 10% of cantering  
Used predominantly by horses |
| **Rotary Gallop** | 1. Spine flexes, with both rear feet on ground; lead foot slightly ahead of the other  
2. Spine extends, stretching front feet forward, which hit ground at same time, one slightly ahead of the other, with lead front on opposite side of lead rear  
3. Spine flexes to bring rear feet forward  
Different lead legs in front and rear | 1. RR–LR  
2. LF–RF  
3. RR–LR | Used by dogs preferentially |
| **Transverse Gallop** | 1. Spine flexes, with both rear feet on ground; lead foot slightly ahead of the other  
2. Spine extends, stretching front feet forward, which hit ground at same time, one slightly ahead of the other, with lead front on same side as lead rear  
3. Spine flexes to bring rear feet forward  
Same side leads in the front and rear | 1. RR–LR  
2. RF–LF  
3. RR–LR | Very uncommon dog gait  
Gallop used by horses |

LF = left front; LR = left rear; RF = right front; RR = right rear
reliably assess subjectively. Objective analysis is especially important when developing treatment plans and monitoring patient progress. Numerous methods for gait analysis have been developed (Table 2).

Visual Observation of Gait
A systematic and disciplined approach must be used to clinically evaluate a patient’s gait. To document this clinical evaluation in the medical record, findings are often semiquantified using a numerical rating scale (Table 3) or visual analog scale (Figure 1).

Both types of scales were developed to provide a systematic approach to visual observation of gait. However, it is important to realize that, while visual or subjective gait analysis is often helpful in identifying lameness, the gold standard for quantifying lameness is quantification of gait characteristics with a form of objective gait analysis, such as force plate analysis.

Evans and colleagues compared visual observation of gait to force plate analysis.2 This study evaluated 148 Labrador retrievers—131 that were 6 months post surgery for unilateral cranial cruciate ligament injury and 17 that were free of orthopedic disease.

The observer only identified 11% of the 131 dogs that were 6 months post surgery as being abnormal compared with force plate analysis, which revealed that 75% of the 131 dogs failed to achieve ground reaction forces consistent with sound Labrador retrievers.

While force plate analysis has been shown to be superior to visual observation, visual observation is still a practical tool in clinical practice, and its importance should not be discounted.

Kinematic Gait Analysis
Kinematic gait analysis quantifies the positions, velocities, acceleration/deceleration, and angles

*TABLE 2.
Methods for Canine Gait Analysis*

<table>
<thead>
<tr>
<th>Subjective:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Visual observation of gait (eg, numerical rating scale, visual analog scale)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Kinematic gait analysis</td>
</tr>
<tr>
<td>• Kinetic gait analysis (force plate analysis)</td>
</tr>
<tr>
<td>• Temporospatial gait analysis (pressure sensing walkways)</td>
</tr>
</tbody>
</table>

*TABLE 3.
Example of a Numerical Rating Scale for Visual Assessment of Gait*

<table>
<thead>
<tr>
<th>LAMENESS GRADE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 1</td>
<td>Sound at the walk, but weight shifting and mild lameness noted at trot</td>
</tr>
<tr>
<td>Grade 2</td>
<td>Mild weight-bearing lameness noted with the trained eye</td>
</tr>
<tr>
<td>Grade 3</td>
<td>Weight-bearing lameness, typically with distinct “head bob”</td>
</tr>
<tr>
<td>Grade 4</td>
<td>Significant weight-bearing lameness</td>
</tr>
<tr>
<td>Grade 5</td>
<td>Toe-touching lameness</td>
</tr>
<tr>
<td>Grade 6</td>
<td>Non-weight-bearing lameness</td>
</tr>
</tbody>
</table>

*Note*: Grades 2 through 6 lameness can be observed at the walk or trot.

For more information, visit tvpjournal.com and select Clinical Resources to download the numerical rating scale and visual analog scale described in this article. The scales have been kindly provided by Veterinary Orthopedic & Sports Medicine Group.
of various anatomic structures in space. Most kinematic gait analysis systems use colored, retroreflective, or light-emitting diode (LED) markers that identify specific anatomic landmarks (Figure 2).

A few of the most common locations for markers include the dorsal scapular spine, acromion/greater tubercle, lateral humeral epicondyle, ulnar styloid process, iliac crest, femoral greater trochanter, femorotibial joint, lateral malleolus of the distal tibia, and spinous process at T13. Typically, markers are attached by shaving and cleaning the skin with alcohol; then pressing the marker’s adhesive back directly to the skin. The marker can be further secured with tape, if needed.

When the dog is in gait, the movement of the markers is tracked by a series of cameras. The locations of the markers over time are then used to create a 2- or 3-D model of the dog’s gait with calculations of bone and joint excursions.

Kinematic parameters include displacements, angular velocities, and range of motion:

- **Displacement** is the distance recorded when a marker changes position.
- **Angular velocity** is the speed at which this change occurs.
- **Range of motion** is calculated from the displacement at a specific joint.

While a multitude of information can be gathered from this form of gait analysis, one major limitation is the variation of structures between breeds, as well as within breeds. Further limitations include the potential for skin variation of structures between breeds, as well as within breeds. Further limitations include the potential for skin
movement, and accuracy and repeatability of marker placement.

**Kinetic Gait Analysis**

Kinetic gait analysis measures the ground reaction forces that are the result of an individual’s step.

The most commonly used method for kinetic gait analysis is force plate analysis, in which metal plates are mounted on the floor or walkway (Figure 3) to measure ground reaction forces (Table 4 and Figure 4). The forces are measured in 3 dimensions: vertical, craniocaudal, and mediolateral.

These forces are often presented graphically, with the peak forces as the maximum forces generated in the described phase of gait, represented by the force–time curve. The impulse is then represented as the area under the force–time curve.

- **Peak vertical force** (PVF) is the single largest force during the stance phase and represents only a single data point on the force–time curve.
- **Vertical impulse** (VI) can be derived by calculating the area under the vertical force curve using time.
- PVF and VI are the two most commonly used indices to detect lameness3-5 and, in general, a dog with lameness has a lower PVF and VI in that limb.

While braking, propulsion, and mediolateral forces may be useful in evaluating mechanisms of locomotion, they are not commonly used for diagnostic purposes or to assess outcome.4

Force plate measurements have been the most widely used and validated quantitative gait application in veterinary medicine to date.3 Thus, force plate analysis is considered the optimum approach to quantification of gait characteristics by objective gait analysis.

However, there are disadvantages to force plate analysis. Limitations include:

- Inability to measure stride or step length
- Need for consistent velocity, long dedicated walkway, and multiple trials
- Difficulty in setting up, breaking down, and moving
- Complexity of software and data analysis
- Cost and impracticality for clinical practice.

**Temporospatial Gait Analysis with Pressure Sensing Walkways**

Pressure sensing walkways have been validated to analyze normal and abnormal gaits in dogs.6-13 Having this information aids in diagnosing orthopedic, muscular, and neurologic disorders.

### Tips for Obtaining an Acceptable Recording on a Pressure Sensing Walkway

- Walk or trot the dog down the mat at a consistent velocity or steady state gait.
- Keep dogs on a loose leash, their heads looking forward in the direction of travel, and moving down the center of the mat.
- One recent study has shown that the side the handler is on may affect gait analysis, particularly when evaluating the forelimbs; thus, it is recommended to perform multiple passes with the handler switching sides between passes.12
- Place the mat in a quiet location where dogs won’t become easily distracted.
- Start the pass 2 meters before the mat to encourage the dog to be straight and maintain a steady gait prior to stepping on the mat.
- If the dog has been trained for competitions, such as agility or obedience, it is most helpful to have the owner run the dog on the mat; otherwise, have the owner leave the room and have technical staff run the dog over the mat.
- Practice with the dog before recording to acclimate the dog to the mat and surroundings.
- Do not look at the dog while it is gaiting; this almost invariably makes the dog look at the owner or handler, although it might take three to four passes for this to work.
- If there is uncertainty regarding whether or not the pass down the mat was acceptable, it is often possible to review the video footage captured by the software’s camera.

### TABLE 5.

**Description of Measurements Calculated in Temporospatial Gait Analysis**

<table>
<thead>
<tr>
<th>TERM</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stance time</td>
<td>Stance phase of gait cycle and time paw is in contact with ground</td>
</tr>
<tr>
<td>Swing time</td>
<td>Swing phase of gait cycle and time paw is in air</td>
</tr>
<tr>
<td>Stride length</td>
<td>Distance from one footfall to the next footfall of same limb</td>
</tr>
<tr>
<td>Step length</td>
<td>Distance between heel point of one foot to heel point of contralateral foot</td>
</tr>
<tr>
<td>Total pressure index</td>
<td>Sum of peak pressure values recorded from each activated sensor by a paw during mat contact; related but not equal to peak vertical force</td>
</tr>
</tbody>
</table>
that affect gait. These measures provide novel information about temporal and spatial gait characteristics (Figure 5).

The portable pressure walkway system was originally developed for use in the human medical field\(^ {9,14,15}\) and has since been adapted and validated for use in veterinary medicine. Previous studies have established a protocol for temporal–spatial analysis and determined reference values and symmetry ratios for various breeds.\(^ {6-11}\)

Temporospatial gait analysis uses a pressure sensing mat (Figure 6, page 100) and computer software system to calculate velocity, stance time, swing time, stride length, step length, and total pressure index (Table 5, page 97).

Forces exerted to change speed, change direction, or maintain balance can interfere and complicate measurement interpretation.\(^ {12,16}\) The pressure sensing walkway does not measure force directly but does measure the influence of these forces. Therefore, by limiting excess external influences, the measurements may be more representative of the dog’s true gait.

As with any other gait analysis system, there are advantages and disadvantages to using a pressure sensing walkway. Advantages include:

- No size restrictions
- Multiple readings from a single pass
- Determination of stride and step length
- Information on limb placement
- User-friendly software
- Portability.

However, just as with every other system, there are disadvantages, including:

- Ability to only measure total ground reaction forces
- Inability to separate the 3 dimensions as with force plate analysis
- Cost.

**IN SUMMARY**

With more dogs participating in activities with their owners, canine sports, or a working role, it is essential for owners and veterinarians to...
understand canine gait. Early signs of lameness may be as subtle as a shortened stride or shorter stance time on the injured leg. Both subjective and objective gait analyses are important to not only establish a diagnosis but also monitor progression of treatment.

LED = light-emitting diode; PVF = peak vertical force; VAS = visual analog scale; VI = vertical impulse

References