Form Follows Function – A New Perspective on an Old Adage

M. Christine Zink DVM, PhD, DACVSMR

It is estimated that there are upwards of 75,000 police dogs in the United States in addition to unknown numbers of assistance dogs (dog guides for the blind, hearing dogs, physical assistance dogs, etc.) and other working dogs, all of which require specialized heath care and maintenance. To be able to provide appropriate veterinary care for these athletes in health and disease, it is critical to have a foundation knowledge of canine structure and locomotion.

A. Canine Structure

There is no species on earth that is more varied in structure than the dog. Dogs of a variety of breeds are used as working dogs, from the frequent use of German Shepherd Dogs and Malinois as police and military dogs that have a protection function, to the Labrador and Golden Retrievers that are commonly used as detection dogs and dog guides, to the wide variety of breeds that are trained as assistance dogs. Each breed of dogs has structural strengths and weaknesses and owners/handlers/veterinarians need to be familiar with these to maximize these dogs' functions throughout their lives.

Overall body size and shape are both significant factors in canine performance. For example, dogs with greater weight are slower to accelerate, turn and decelerate than lighter-bodied dogs. However, they also can have more power when their jobs require pulling, physically supporting a disabled individual or apprehending suspects. Overall size is a major factor in selection of specific breeds for specific jobs. However, within any given breed, individuals can vary significantly in structure, and this can be a significant factor in a dog's ability to function in their jobs.

a) Front Leg Structure

Much of a dog's athletic ability is a function of the structure of its front legs, which help the dog stride forward efficiently and effortlessly, yet turn quickly and accurately when necessary. The canine forelimb has all the same parts as the human arm: scapula (shoulder blade), humerus (upper arm), radius and ulna (lower arm), pastern (hand) and paw (fingers). Unlike the rear legs, which are attached to the body by the relatively unyielding hip joint, the front legs are attached to the dog's neck, spine and ribs only by muscles and tendons. These soft tissues give the dog the flexibility to take long strides with the front legs, to abduct the front legs to help the dog turn tightly, and to lay the front legs back against the sides of the body if necessary in jumping. The disadvantage of this flexible attachment is that the softer muscles and tendons can suffer strain under pressures that would have little effect on bones.

One way to assess a dog's front limb structure is to measure its angulation, which refers to the degree of bend at the shoulder joint (where the scapula and humerus meet) and at the elbow joint (where the humerus and the radius/ulna join). These angles provide levers upon which the muscles exert mechanical forces to drive the dog's body forward. Dogs with well-angulated front limbs can unfold those angles to reach far forward and push well back. Thus, the angulation of the front limb partially determines how much ground a dog can cover with each stride. This is important because the fewer the steps a dog takes, the less energy is required to get from A to B.

Well-angulated legs also provide more shock absorption for the dog's weight. Dogs with straight front legs tire more easily during exercise and are more susceptible to shoulder, elbow and carpal (wrist) injuries because of increased concussion on the joints of the leg.

You can evaluate a dog's shoulder angulation by standing the dog so that the lower leg from the elbow to the carpus is perpendicular to the ground and the dog's head is held up and looking straight ahead. This is how dogs are stood for evaluation in the conformation ring, because it gives the judge a consistent view of each dog's structure. If you draw a vertical line perpendicular to the ground just brushing the front of the shoulder joint, the top of the shoulder blade (scapula) should lie 30 degrees off that vertical line. Dogs with upright shoulder blades (angles of 20 degrees of less) are more susceptible to chronic shoulder problems such as arthritis and biceps tendonitis, a painful inflammation of the biceps tendon that can take months to heal.

The most important factor in evaluating elbow angulation is the length of the dog's humerus. To evaluate the length of humerus, just draw an imaginary line perpendicular to the ground through the center of the radius and ulna and upward. Ideally that imaginary line should cross the dog's back at approximately the area of the shoulder. If that imaginary line instead crosses somewhere along the dog's neck, it is likely that the dog has a shorter than ideal humerus. This will cause the angle at the elbow joint to be straighter, resulting in greater concussion to the elbow and increased risk of elbow arthritis.

The carpal joint, which is equivalent to our wrist, is made up of seven small, block-shaped bones that join the radius and ulna to the metacarpals – the bones of the pastern. The carpal bones fit together like a three-dimensional jigsaw and are joined to each other by a complex system of ligaments that allow enough movement between the bones to provide flexibility but not enough to permit friction, which would eventually result in arthritis.

The dog's pasterns and paws work together to absorb the shock of running and jumping, to provide traction and to provide added flexibility of movement. Many dog breeders and judges of conformation dogs believe that a standing dog's front legs, when viewed from the front should be straight from the elbow to the toes. Actually, having the toes point a little to the sides is a much more stable way to stand. When dogs step forward, the front legs rotate on their axes such that the feet point straight forward, allowing the toes to grip the ground most efficiently for moving. A dog whose feet point straight ahead when standing will toe in at the trot.

Dogs have five toes on their front feet. Four of the toes (equivalent to our fingers) are in contact with the ground when the dog is standing. When a dog runs, however, the entire foot from the carpus to the toes contacts the ground. If the dog then turns, it can dig the dewclaw (the equivalent of our thumb) into the ground to stabilize the leg and reduce torque on the rest of the leg.

There is a great deal of misconception about front dewclaws. The fact that they are not in contact with the ground when the dog is standing still has led people to mistakenly believe that they have no function in movement. As a result, the dewclaws are removed from many purebred puppies soon after birth. Many breeders feel this gives a cleaner, straighter look to the dog's front legs. Others believe that the dewclaws should be removed so that they will not get injured. But stop-action photographs clearly

demonstrate that they are in contact with the ground whenever the dog canters or gallops. Further proof of the front dewclaws' functionality comes from anatomical studies demonstrating that that there are several tendons that connect muscles of the lower limb to the dewclaw. Some veterinarians report a higher incidence of foot and carpus injuries and arthritis in dogs that lack dewclaws, likely because of additional torque on the leg. Thus, for working dogs it is best for the dewclaws not to be amputated. If the dewclaw does suffer a traumatic injury, the problem can be dealt with at that time, including amputation if needed.

b) Rear Leg Structure

The rear legs are attached to the backbone via the pelvis, an H-shaped bone that acts as a frame to support and separate the rear legs. The pelvis is analogous to the axle of a car, which supports the rear tires and connects them to the frame. The femurs (equivalent to our thigh bones), the uppermost bones in the rear legs, are the largest bones of the body. Each femur has a ball at one end that fits into a round cup on each side of the pelvis, forming the hip joints. The hip joints experience a great deal of wear and tear in a dog's lifetime and function best if the femur is tightly apposed to the pelvis.

The other end of the femur meets the tibia (the equivalent of our shin bone) at the stifle or knee joint. This is one of the most complex joints in the dog's body. The main function of the knee is to alternately straighten (a result of contraction of the quadriceps muscles along the front of the thigh) and flex (a result of contraction of the biceps muscles that run along the back of the thigh) the rear leg. Smooth flexion of the knee and resistance to torque is accomplished by the two lateral condyles of the femur acting like the rockers of a rocking chair as they slide in two troughs in the top of the tibia. Flexion and extension of the knee provide the majority of propulsion in canine rear leg movement so it needs to occur over a wide range of motion. Because no single tendon has the ability to stretch over the whole range of motion of the knee, there is an oval bone, the patella that floats in front of the knee and acts as a fulcrum to which the tendons of the thigh and lower leg attach.

Between each femoral condyle and the tibia sits a meniscus, a half moon-shaped disc of cartilage. The menisci compress with the weight of the body, helping to absorb shock. They also help the femur and tibia to fit together more closely, which is important to prevent spraining the ligaments of the knee. In fact, the knee joint fits so closely together that when the joint is opened surgically, there is a sucking noise as the two ends of the joint are pulled apart.

The femur and tibia are held together at the knee by two cruciate ligaments (cranial and caudal), so named because they cross over each other. The cranial cruciate ligament is particularly prone to tearing or even rupture when torque is applied to the leg. This is the most common injury of football players who are bearing weight on a leg when they are tackled at the knee. Dogs with straight rear legs are more likely to suffer rupture of the cranial cruciate ligament because it is easier to apply torque to a straight leg than to one that is angled.

How do you evaluate a dog's rear angulation? With the dog standing so that the rear pastern (the bones between the hock and foot) is perpendicular to the ground, draw an imaginary line along the back of the rear pastern and up to the level of the tail. The distance between that line and the bone at the back of the pelvis (ishium) gives you an idea of the dog's rear angulation – the greater that distance, the more the dog's rear angulation. This rule of thumb doesn't cover all aspects of rear

angulation, as the length of the tibia and rear pastern also modify rear angulation, but it does help with assessment of rear angulation at a glance.

Many people believe that more rear angulation is better. It is often said that a dog with abundant rear angulation has good angulation and a dog with a straighter rear has poor angulation. But there are advantages and disadvantages to both extremes. That is becaue angulation is inversely proportional to stability. The most stable rear is a straight rear. That is why many guarding breeds, such as the Chow Chow, the Mastiff and the Chinese Shar-Pei, are bred for straight rears. That stability helps them stand their ground. Stability can also help dogs with straighter rears turn more sharply than dogs with abundant rear angulation. On the other hand, an angulated rear means longer stride length and thus more efficiency in moving over long distances. In some breeds, such as the German Shepherd Dog, extreme rear angulation can result in a lack of stability that negatively affects a dog's performance. Moderate rear angulation provides the best of both worlds for working dogs.

The distal (closest to the foot) end of the tibia joins to the metatarsal bones (the equivalent of our foot bones) at the tarsal joint. The tarsal joint (which is the equivalent of our ankle) consists of a group of 7 bones that fit neatly together, held together by ligaments. Each bone is able to flex or extend against the adjacent bones to a small degree, but together the tarsal bones provide the hock with significant range of motion. The most important muscle of the lower leg is the gastrocnemius (calf) muscle which attached by a tendon (the equivalent of our Achilles tendon) to the largest bone of the tarsus, the talus (analogous to our heel bone). The gastrocnemius muscle extends the leg when your dog leaps up to try to catch the squirrel as it scurries up the trunk of a tree.

The dog has four metatarsal bones, each one of which runs from the tarsal joint to the bones of a toe. Each toe has three bones, just as our toes do. Occasional dogs of many breeds are born with a fifth toe on the insides of their legs, but these are usually removed at birth as, unlike the front dewclaws, they do not perform a function and can get caught and torn on vegetation. A few breeds, notably the Briard, the Great Pyrenees, the Beauceron, and the Anatolian Shepherd have a sixth toe, also present on the inside of the foot.

B. Canine Locomotion

Overview

In dogs there are four main gaits: the walk, trot, canter and gallop. Horses use these same four gaits, but, importantly, dogs have two different ways of cantering and two different ways of galloping, and the canter and gallop that dogs perform preferentially is different from those used by the horse. In addition, dogs have a transitional gait between the walk and the trot that is 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.

The Walk

When a dog walks, it first moves one rear leg forward, then the front foot on that same side. Then it moves the other rear foot forward and then the front foot on that side. So the pattern of footfall for the walk is RR, RF, LR, LF. When a dog is walking, there are either two or three feet on the ground at any given time. The walk is the only dog gait in which there are ever three feet on the ground.

The Amble

As a walking dog speeds up, each rear foot that steps forward is quickly followed by the front foot on the same side. Eventually it begins to look as if the two feet on the same side of the dog's body are moving forward together. However, if you look closely, or view a slow motion video, you will see that there still are moments when there are three feet on the ground, and thus this gait is still a form of the walk. It is essentially a fast walk.

Ambling dogs look very ungainly. The rear end sways from side to side and the dog doesn't lift the rear feet very high, often scuffling them along the ground. Not only that, but an ambling dog often moves at the same speed as a dog that is moving at an easy trot. This wasted horizontal energy is why the amble is not a preferred gait and really should be used only for short periods when transitioning from a walk to a trot or when a tired dog wants to rest its trotting muscles.

The Pace

Another reason why the amble is not a preferred gait is because it's just a short step away from the pace, which is an abnormal gait for all breeds of dogs. If an ambling dog continues to gradually speed up, eventually those two feet on the same side of the body that are moving forward together end up bearing all of the dog's weight. The two legs on the other side of the body then move forward and bear the dog's weight, with a moment of suspension in between. Now the dog is pacing. In a pace, there are only two feet on the ground at any given time, either both right or both left feet.

The pace is a very inefficient gait because the dog's center of gravity keeps shifting from side to side and the dog has to use energy to keep recentering its weight. That energy could be used to drive the dog's body forward instead. In addition, pacing dogs cannot respond quickly when a change in speed is required and they also do not have a wide range of speeds at which they can move without having to slow down to an amble or speed up to a trot.

The Trot

This is the dog's most efficient gait. Wolves have been known to cover 100 miles a day, mainly using the trot. When trotting, a dog moves diagonal front and rear feet forward together. First are two diagonal front and rear feet move forward (e.g., RF-LR) then there is a moment when the dog's whole body is suspended in the air, then the other diagonal front and rear feet move forward and bear the dog's weight (e.g., LF-RR).

The trot is the best gait to use for aerobic conditioning for canine athletes because it is the only efficient gait that requires each side of the dog's body to work equally hard during exercise. Each front and rear leg must support the dog's body without help from the opposite leg.

The Canter

There are two variations in the pattern of footfall for this gait, so most people find this gait a bit more complex to understand. In the *classical canter*, first one rear foot moves forward, then the other rear foot and the diagonal front foot move forward together, then finally that last front foot. So the order of footfall is RR, LR-RF, LF or LR, RR-LF, RF, depending on which lead the dog is using. Of the two rear or the two front feet, the second one to strike the ground is called the *lead leg*, because it is placed on the ground physically ahead of its partner. So in the first example above, the dog is using the left lead in

both the front and the rear. In the second example the dog is using the right lead in both the front and the rear.

The classical canter is how normal horses canter. Dogs use this form of the canter only about 10 percent of the time. The rest of the time they use the *rotary canter*. In the rotary canter, the dog uses different lead legs in the front and the rear. So the order of footfall is either RR, LR-LF, RF or LR, RR-RF, LF. The rotary canter allows dogs to turn very sharply and with greater drive from the rear. In horses, however, this gait is referred to as cross cantering and it is considered undesirable because it is uncomfortable for the rider (it's also not very good for the horse, I think—it doesn't look normal when you watch it).

The Gallop

The gallop starts with the dog's spine flexed and two rear feet on the ground, one foot (the lead foot) slightly ahead of the other. The dog then extends its spine, stretching its front feet forward, which hit the ground, one slightly ahead of the other. The dog then flexes the spine to bring the rear feet forward to start the cycle again. When the dog uses the same lead in the front and rear, the gait is called the *classical gallop* and is the same type of gallop used by horses. But when the front legs are on a different lead from the rear, it's called a *rotary gallop* and is used by dogs preferentially. In fact, it is very uncommon to see dogs use a classical gallop.

Gaits Used by Working Dogs

Tracking Dogs: trot > walk
Police Dogs: walk > canter > gallop > trot
Dog Guides: walk
Assistance Dogs: walk > trot

C. Conditioning and Retraining Working Dogs

Properly conditioned working dogs perform better and are less likely to suffer injuries. When injury does occur, they are less severe and recovery is faster. In addition, fit working dogs suffer less stress and this translates to greater stamina and longevity as working dogs. This creates a win-win situation for both dog and handler.

Evaluate Fitness

A good way to evaluate a dog's fitness is to feel the size and tone of the core (paraspinal and abdominal) and rear limb muscles. The core body muscles are important for coordination of spinal and limb movements and are critical when immediate responses of the limbs are necessary. Since the front legs bear two-thirds of the dog's weight and all the weight of the dog plus the effects of gravity when a dog is jumping, cantering or galloping, the front limbs get more exercise than the rear during regular activities. As a result, handlers must place special emphasis on exercises to keep the rear limb and core muscles toned.

Critically Assess Structure

Dogs are the most varied species on earth. As a result, it is important to understand each dog's structure to design a conditioning and retraining that will take advantage of the dog's strengths and account for its weaknesses. For example, German Shepherd Dogs generally have abundant rear

angulation. This gives them a very long stride, allowing them to jump high and long, which can be an advantage in protection and police work. On the other hand, the same flexibility that gives them their rear angulation also means that they frequently experience hyperextension of various joints, particularly the toes and the carpi (wrists). They also can experience trauma to their hocks as they can hit the ground when running and jumping. In contrast, Belgian Malinois tend to have straighter front and rear assemblies, i.e. reduced angles at the shoulder and elbow and at the knee and hock. This gives these dogs tremendous agility – they are known for their rapid acceleration and ability to turn sharply.

Age-Appropriate Conditioning and Sports Training

Dogs less than 6 months of age can be provided with simple obedience training and non-impact skill training. Strength training exercises, those designed to build muscle, can begin at 6 months of age. Training that includes impact, particularly repetitive impact such as roadwork and jumping over elbow height should wait until at least 14 months of age, at which point the growth plates have closed. Because of the delayed closure of growth plates in dogs that have been spayed or neutered, high impact and endurance training should be delayed in these dogs until 20 months of age.

Balanced Exercise

1. Strength Training

Typical strength exercises in dogs include movements of the body over short distances. Some of the best strength exercises can be done in very small spaces. These exercises can be categorized as those that strengthen the front legs, rear legs and core body muscles. A great exercise for strengthening the front limbs is to teach the dog to wave each front paw (separately) higher than the head, holding it as long as possible. An excellent core muscle strengthening exercise involves having the dog beg or sit up on its haunches. To make this exercise more difficult, have the dog remain in this position while you lure him with food to lean to one side and then the other, or have the dog do this exercise on a soft surface such as an air mattress or cushion. A great exercise for strengthening the rear is to have the dog raise itself from the beg position to a stand and then back down to the beg position without letting the front legs touch the ground. Again, this exercise is made significantly more difficult by performing it on a soft surface. The dog should be able to hold each position (beg, stand, beg) for 10-15 seconds without moving. Other examples of strength training exercises include running off leash, tugging, jumping, and wrestling with other dogs.

2. Endurance (Aerobic) Training

A typical endurance exercise is roadwork, in which the dog trots for at least 20 minutes continuously. It is essential for the dog to be in the trot gait for these exercises as this is the only gait that exercises both sides of the dog's body equally. Swimming continuously for at least 10 minutes is another excellent endurance exercise. Treadmills can be used for endurance conditioning as long as the treadmill is at least 2 ½ times the length of the dog's body. This rules out the use of human treadmills for most larger dogs.

The amount of strength and endurance training should be in proportion to the amount of each type of activity the dog does in its sport(s) or job. For the vast majority of working dogs strength is more important than endurance. Note: Endurance should not be mistaken for stamina. Of course, all working dogs need stamina – the ability to keep working for long periods of time.

3. Proprioception

Proprioception is the ability to know the spatial orientation of various parts of the body, especially the head, legs and feet. There are special receptors in the skin and muscles and joints that send messages along nerves to the spinal cord and brain about the movements of the body. These messages are then read and interpreted by the brain, allowing the dog to make coordinated movements such as landing from a jump, climbing over debris or grasping an object. Just like all nerves, those that govern proprioception can be trained. For example, if you play a musical instrument, you know that when you first started to learn the instrument you had difficulty placing your fingers where they were supposed to be. But with practice your fingers became more accurate and your responses more rapid. Likewise, with practice, dogs can improve their proprioceptive abilities. In addition, a dog that has better awareness of its body will be less susceptible to injury, and able to work for longer periods of time without tiring.

One of the best and most deceptively simple body awareness exercises is to have the dog walk through a ladder laid on the ground – the slower the better. Once the dog can walk forward without touching the edges or the rungs, have him move backward. You also can put the ladder on an uneven or soft surface like an air mattress or place it on a hill. Another variation is to have the dog step sideways first with the front feet, then with the rear feet stepping between the rungs. Search and rescue dogs can benefit from practicing stepping on the rungs of a ladder that is elevated off the ground.

4. Preparation and Recovery

Humans that are properly warmed up before the 100-meter dash run 7% faster. Appropriate warm-ups before sports are also thought to reduce the incidence and severity of injuries. Warm-ups should include movements that recapitulate what the dog will do in its job, so warm-ups will be different for dogs with different jobs. For a search and rescue dog a good warm-up could include some trotting, some jumps, some tugging, etc. These exercises provide active stretches, in which the dog moves its own body through motions that are similar to those of the job it is about to undertake. It is best not to try to passively stretch a dog's limbs prior to exercise by lifting them and stretching them out. This can be uncomfortable and even can increase the risk of injury. A good cool-down consists of gradually reduced exercise, such as a little trotting followed by walking, then a brief whole-body rubdown and passive range of motion.

Some dogs with jobs, such as police dogs, frequently are not able to warm up before they engage in sudden activity. It this case it is important to provide the dog with a cool-down period and watch carefully for signs of injury such as stiffness during the cool-down or when moving again after a rest period.