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Biomechanics

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Biomechanics is the application of mechanical principles to biological systems. This scientific field often uses traditional engineering methods to analyze the mechanics of living organisms.

Early in the 19th century researchers started to investigate the biomechanics of living organisms. Especially the gait analysis underwent a rapid evolution within the last decades and the technological advances in computer assisted gait analysis enable the researchers to perform sophisticated kinematic and kinematic research in animals. In canine gait analysis, researchers usually focus on the following types of analyses:

Kinematics is the science of describing the motion of objects. Kinematics therefore describe the movement of joints or segments in terms of the positions, accelerations, angles etc. in space. Therefore kinematical data can be used to evaluate the physiological and pathological gait, the function of the musculoskeletal systems or the effectiveness of medical or surgical treatments. Usually two- or three dimensional video assisted systems are used; obviously the three-dimensional kinematic analysis provides the most accurate information. On the other hand, these analyses systems are very expensive and only highly specialized institutions are able to perform these analyses. Nevertheless, during the last 20 decades numerous studies have been performed to describe the gait of dogs and horses.

Each of the joints describes a specially movement pattern during the gait cycle. The shoulder shows its highest extension at the transition between swing- and stance phase and its highest flexion in the middle of the swing phase. The elbow is in maximal extension at the transition between stance- and swing, maximal flexed during swing an again extended in the late swing and early stance. The carpal joint is like the other joints maximal flexed during swing. It starts the stance phase in extension and remains stable extended during the whole stance. The hip joint reaches its maximal flexion in swing and starts the stance phase in a flexed position. The maximal extension of the hip occurs at the end of the stance phase. The stifle joint is maximal extended at the end of the swing phase. This extension is slightly reduced during the stance phase, the maximal flexion occurs during swing. The hock shows its maximal extension at the transition of stance to swing and reaches a second extension maximum at the end of the swing phase.

In a kinematic study it was shown that in dogs with osteoarthritis of the hip the affected hip joint revealed an increase in extension and velocity at the end of the stance phase. The stifle showed an increased flexion throughout the stance phase and early parts of the swing phase; and the tarsal joint was more flexed during early stance as well as in early and middle parts of the swing phase1. In another study2 investigators found additional kinematic variables such as a greater joint adduction, range of abduction-adduction, and greater lateral pelvic movement, compared with controls. In dogs suffering from mild hip OA we found3 that the affect hip joint is earlier extended than in sound dogs, also the stifle joint shows an earlier extension. The hock shows a decreased and earlier extension of the hock in the late stance/early swing phase, an earlier flexion in the swing phase, an earlier extension at the end of the swing phase and a decreased flexion in stance phase.

KINETICS

Kinetic-analyses are used to describe the forces which act during stance phase. Usually, the measurements are performed with the use of force plates. Three orthogonal forces can be described: vertical, medio-lateral and cranio-caudal. Different force plate systems are used: single ground mounted force plates, serial systems and treadmills with integrated force plates. Each of these systems has it unique advantages and disadvantages. But in summary, ground reaction forces are objective and reproducible data which are the “Gold standard” in orthopedic research.

In dogs with OA of the elbow we could show that the load was reduced on the lame limb and increased on the contralateral hindlimb4. The naturally occurring osteoarthritis resulted in a compensatory gait pattern to reduce the stress on the affected limb. The load was reduced on the lame limb and increased on the contralateral hindlimb. The symmetry index indicated a weight-shift to the contralateral forelimb and diagonal hindlimb, which resulted in a more balanced weight distribution than in normal dogs. Dogs with induced lameness showed comparable but less pronounced alterations. These results suggested that forelimb lameness could lead to overload on non-affected extremities and the vertebral spine.
In contrast in dogs with hip OA the load was shifted to the contralateral hind leg. Using Fourier analysis an subtle effect on the force-time patterns of the front legs was detected.

ELECTROMYOGRAPHY

Electromyography (EMG) is a technique for evaluating and recording the electrical activity produced by skeletal muscles. For this purpose the use of e.g. needle or surface electrodes is possible. The use of needle EMG enables the exact measurement of the activity of a muscle but is an invasive method; in contrast the use of surface electrodes is non-invasive but can suffer from so called “cross-talks” which are generated by nearby muscles. Nevertheless it has been shown, that surface EMG is a sufficient method to describe the activity of muscles. Some studies have been performed using invasive needle EMG. Using surface EMG, only two papers have been published.

The quadriceps shows a 2-peak activity pattern. The 1st maximum can be seen in the early stance together with the lift-off of the contralateral pelvic limb. At this time the weight bearing pelvic limb accepts the weight of the hindquarter and brakes forward movement. The 2nd peak occurs together with the ground contact of the contralateral pelvic limb. The muscle contributes to stifle extension and prevents flexion, leading to stabilizing effect during the stance phase. The maximal activity of the biceps femoris is found at the transition of the swing in the stance phase, the lowest activity in the late stance. The maximal activity of the gluteus medius is found at the transition stance/swing phase together with the maximal extension of the hip. A second peak can be seen at the beginning of the stance phase together with the start of the hip extension.

KINEMATICS DURING SPECIAL MOVEMENTS

During stair up ambulation, dogs show an increased flexion of the stifle and the hock, the extension of the stifle is increased and occurs earlier than during normal walk. Walking stairs down results in an increased flexion of all joints of the hind legs and a decreased extension of the hip joint. During Cavaletti work, we found, compared to normal walk a higher flexion of the hock and stifle as well an increased extension of the stifle joint. During incline (11%) we found an increased flexion of the hip and decreased extension of the stifle, going decline (11%) the hock is less extended than during level walking and the hip is less flexed. In dogs suffering from hip OA it was shown in a doctoral thesis that the hip joint shows a 2-peak activity pattern. The 1st maximum can be seen in the early stance together with the start of the hip extension.

Bibliography


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