Comparison of Over Ground and Treadmill Based Gait Data in Dogs

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ABSTRACT INTRODUCTION:
The dog is a common model for studying joint function and the progression of osteoarthritis (OA). Kinetic, or force platform data collection in dogs is well established. While kinematic data in dogs has been collected for years, the methods of collecting dynamic gait data and the subsequent analysis have varied. Both kinetic and kinematic gait evaluations have been performed using data collected by either over ground or treadmill based ambulation. Debate continues regarding the use of treadmills for the collection of gait data. Recently, a study compared a treadmill with imbedded force plates against a standard force plate and found that both provided similar peak vertical force results for the hind limbs and forelimbs of sound and lame dogs at a trot. Unfortunately, to the authors’ knowledge there are currently no studies that compare canine kinematic data during over ground and treadmill based dynamic gait.

In this study the hypothesis being tested was that dynamic gait data collected from dogs would be different when generated during over ground versus treadmill based ambulation. Additionally, we compared the sagittal waveforms produced during joint range-of-motion with a classic frequency spectrum reconstruction methodology (Fourier) and a newer method of waveform analysis known as Generalized Indicator Function Analysis (GIFA) that is a multivariate vector waveform analysis method.

METHODS:
Five adult dogs weighing 20 to 30 kgs were used in this study. Dogs had 35 retroreflective markers affixed to the skin on the right and left rear limbs and pelvis. Marker locations were captured at 200Hz by 8 infrared cameras (Vicon MX03, Vicon Motion Systems, Inc.) arranged around a gait platform. Data was recorded and analyzed by a motion analysis program (Peak Motus 8.5, Vicon Motion Systems, Inc.). Dogs were then recorded moving overground through the calibrated space 5 times during both a walk and trot, at velocities of 0.9-1.2 m/s and 1.7-2.1 m/s, respectively. Then, gait data collection was recorded with dogs moving on the treadmill at a walk and trot. All dogs were trained on the treadmill prior to study initiation. All dogs were recorded at a walk during a treadmill belt speed of 1.0 m/s and at a trot with the treadmill belt speed of 1.9 m/s. The first 5 complete gait cycles were utilized for analysis. While bilateral data collection was performed, unilateral data was utilized for comparison. For both the overground and treadmill based gait, local and global coordinate systems were established and a segmental rigid-body model of the canine right hindlimb was produced.

Dynamic three-dimensional joint kinematics were evaluated for the coxofemoral, stifle, and tarsal joints. Sagittal flexion/extension waveforms for all joints were then compared using two analysis methods. The data was analyzed independently for each method. First, a Fourier transformation was performed for each waveform. Eight paired Fourier coefficients were produced and compared with a paired-t test. All hypothesis tests were 2-sided and the significance was set at $p < 0.05$. The paired t-tests were implemented using a computer software program (SAS v9.2). Significance was set at $p < 0.05$. Then, the same data set was analyzed with GIFA, a multivariate vector waveform analysis method that maximizes signal power while maintaining a large signal-to-noise ratio, and provides the ability to assess differences at specific points along the waveforms. This statistical method is designed to determine the vector that best separates groups of vectors measured under different conditions.

RESULTS:
Sagittal (flexion (+)/extension), transverse (internal (+)/external rotation), and frontal (abduction (+)/adduction) plane kinematics during movement of the distal segment relative to the proximal segment for all three joints (coxofemoral, femorotibial, and tarsal) were generated and collected during each dynamic gait cycle for the walk and trot. Only the sagittal flexion/extension waveforms were utilized for comparative analysis in this study. The sagittal waveforms were compiled and are graphically represented with 95% confidence intervals (Figure 1). Fourier Analysis: No significant differences were found between the overground and treadmill collected data for all joints (coxofemoral, femorotibial, tarsal) at both a walk and trot. GIFA: Significant differences ($p<0.05$) were found between the overground and treadmill collected data for all joints (coxofemoral, femorotibial, tarsal) at both a walk and trot.

DISCUSSION:
In this study both over ground and treadmill based gait collection produced similar waveform shapes for the coxofemoral, femorotibial, and tarsal joints in dogs. However, comparison of these waveforms with two different methods of waveform analysis provided conflicting data. Fourier analysis was unable to determine any significant differences between the waveforms, suggesting that either method can be used for evaluation of canine gait. However, GIFA analysis revealed significant differences ($p<0.05$) between over ground and treadmill based gaits and perhaps they cannot be directly compared. It is likely that the fundamental differences in these two analysis methodologies provided the conflicting results. Fourier analysis only assesses whether the waveforms are similar or dissimilar; whereas GIFA gives rise to eigenvectors that are functions of time and may prove a more sensitive measure of variability between gait waveforms in which only fine timing differences occur. The clinical significance of this discrepancy has yet to be elucidated.

REFERENCES: