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**Take Home Message**

Canine sagittal plane motion data acquisition with IMUs is feasible for the carpus, tarsus, stifle and hip joints. This technology allows data acquisition outside the gait laboratory and further investigation is indicated.

**Introduction**

Subjective clinical evaluation of lameness has been reported to poorly correlate with objective methods of assessment typically utilized in a research setting.2-4 Hence, camera based (optical) motion capture systems along with force platforms, allowing for objective quantification of joint kinematics and ground reaction forces, have been proposed as more accurate methods of lameness diagnosis.3,5-7

Limitations to conventional force platform and optical capture methods include poor transportability of the systems, capture volume limitations, the need for multiple trial acquisition, cost of equipment, facilities, time and expertise needed for data collection.3,48 Since data acquisition is limited to the location of the capture system, free movement of the animal in a natural environment is not possible.3 Because of these factors the use of kinetic and kinematic analysis is mostly limited to the research laboratory.

Inertial sensors or motion units are light-weight, portable motion tracking devices that measure angular velocity, orientation, and accelerations.9 These devices measure relative orientation of individual body segments rather than direct position.9,10 Consequently, attachment to individual limb segments proximal and distal to a joint is required to calculate joint angles.9-12 Data transmission is wireless and limited to the IMUs itself (i.e. no optical motion capture system requirement), permitting kinematic gait analysis at any location.12-15 Data acquisition is also continuous, eliminating the need for multiple attempts to acquire a successful trial within a short distance or specific foot strike pattern. IMUs have been extensively used in humans and few reports have been published in the equine literature.10,11,15-18 Despite their potential to reduce or eliminate many of the disadvantages of current gait analysis techniques and their prospective for use in clinical as well as research settings, IMUs have not been utilized for canine gait analysis.

The specific aim of this project was to evaluate the feasibility of an IMU-based system for kinematic gait analysis in dogs. We hypothesized that it is feasible to attach IMUs to the canine limbs and that IMU-based two-dimensional kinematic data would strongly correlate with optical kinematic analysis in clinically normal dogs.

**Methods**

Sixteen clinically healthy, medium-sized dogs were enrolled. Baseline kinematic data was acquired using an optical motion capture system. Following baseline data acquisition, a harness system was used for attachment of IMUs. Optical kinematic data with and without the harness were compared to evaluate the influence of the harness on gait parameters.
Sagittal plane joint kinematics acquired simultaneously with IMUs and the optical system were compared for the carpus, tarsus, stifle and hip joints. Comparisons of data were made using the concordance correlation coefficient (CCC) test and evaluation of root mean squared errors (RMSE).

For acquisition of IMU data, a specifically designed harness system was used to attach the IMUs to the study participants (Figure 1). Two IMUs were attached to the thoracic limb (laterally at the level of mid-metacarpus and mid-radius/ulna) and four IMUs were attached to the pelvic limb (laterally at the level of mid-metatarsus, mid-tibia, mid-femur and dorsally via a custom-molded pelvic plate). The metacarpal, radius/ulna, metatarsal, tibial and femoral IMUs were attached with the use of custom-designed, circumferential Velcro straps secured to the limb using double-sided tape to avoid rotation or slippage. To avoid detachment of the sensors and to provide additional stability, the Velcro straps were designed such that they wrapped around the sensor after fully wrapping around the limb. To store the wireless transmitter unit all animals were also fitted with a commercially available vest. The pelvic plate was made out of heat-moldable casting material and secured using elastic cords attached cranially to the vest and caudally around the tail of each dog.

Results

Data acquisition for IMUs was successful for every trial, however, only the data acquired during trials resulting in appropriate data for optical kinematics were used for data analysis. There were no significant differences between stance duration, swing duration, stride length or forward velocity (2.4±0.2 m/s and 2.5±0.2 m/s; p=0.203) between dogs with and without the harness. Significant differences between optical kinematic data for dogs with and without the harness were observed in multiple single time point (max/min) joint angle measurements, the joint motion range of the shoulder, carpal, hip, and stifle joints. When comparing optical and IMU kinematic data, strong correlations (0.948-0.984) were found for all 4 joints evaluated.

For the comparison of dogs with and without the harness using the conventional optical system, mean RMSE values ranged from 4.90° to 14.10° during swing. When compared to the range of motion (ROM) during swing phase, the mean RMSE values as a percentage of the ROM ranged from 12.32% to 22.72%, with the shoulder demonstrating a larger difference between the harness and no harness trials.

For the comparison of the IMU data to the conventional optical system, median RMSE values were similar across the four joints during the swing phase and ranged from 2.51° to 3.52°. When comparing the ROM during swing phase of a joint, the median RMSE values as a percentage of ROM for the carpus, hock, and stifle were very similar (< 5%, see Figure 2). The median RMSE as a percentage of the hip (8.10%) was larger than the other three joints.

Conclusions

We identified a strong correlation between optical sagittal plane kinematic and IMU data for the carpus, tarsus, stifle and hip joint in the study population. However, we also identified that the current attachment method interferes with several kinematic gait parameters. Based on the study findings it can be concluded that
IMUs provide an accurate alternative to optical kinematic gait analysis, however, further investigation into the impacts on canine gait and lameness and alternative attachment methods are indicated. The distinct advantages of IMU-based canine gait evaluation systems (e.g. lower cost, reduced time requirement for data acquisition, and use in a natural environment) warrant further research into this technology.

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References