Measurement of velocity with a kinematic system versus a photocell system in the collection of canine ground reaction forces

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Introduction

Collection of ground reaction forces (GRF) has become a very useful tool in the analysis of normal and abnormal gaits in dogs. It has the distinct advantage of quantitatively and consistently evaluating the severity of lameness over traditional subjective lameness examinations (1). It has also been demonstrated that careful collection techniques must be employed in order to ensure valid, reproducible, and reliable data (2, 3). Therefore, acceptable limits of velocity and acceleration for a given gait have been suggested in order to obtain consistent data which can compare values between collection sites, time periods, and animals (2, 3). To the author’s knowledge, all veterinary kinetic laboratories utilize multiple photocells (usually three or five) which are spaced a specified distance apart (0.5 to 3 m) in order to measure the velocity and acceleration of the subject passing across the force plates. The subject’s velocity is calculated by dividing the known distance between photocells by the time between triggering consecutive photocells. The value calculated by this methodology is considered to be the cranio-caudal velocity due to the very small contributions that the mediolateral and dorsosventral vectors contribute to the resultant velocity. Indeed, the values should be considered a scalar value of speed. However, convention in the current literature refers to this value as a velocity vector in the cranio-caudal direction.

Ideally, the same anatomical point on the subject will trigger consecutive photocells in order to give an accurate representation of the velocity of the entire subject. Theoretically, erroneous velocities could be reported if photocells are triggered by different parts of the subject’s anatomy. For example, if a dog’s nose triggers the first photocell and its chest the second, the velocity calculated by the computer will be artificially low due to the additional time the dog’s chest travels to reach the second photocell compared to the nose. Conversely, if the chest triggers the first photocell, and the nose the second, the reported velocity value will be artificially high. Or, if the photocells are positioned low enough for a dog’s forepaw to trigger two consecutive photocells in one stride length, then the velocity reported over that span could be as much as double the animal’s trunk velocity. Dog handlers also move through the same test space with the animals. It is possible that a handler’s leg instead of the dog may trigger a photocell which could result in an inaccurate velocity measurement.

Alternatively, kinematic analysis lends itself to highly accurate velocity measurement of anatomical locations due to its ability to measure the location of multiple markers many times a minute in three dimensional space (4). Kinematic systems measure these locations by calculating the position of a reflective marker from data obtained by two or more infrared cameras that are positioned at different angles to the subject.

By comparing the measured kinematic velocities of the dog and handler’s anatomical points with the measurements taken over the same time by the photocell system, inaccuracies within the photocell system’s measurements of velocity can be identified. Thus, our objective was to compare the instantaneous velocity readings from a photocell system with velocities from four different anatomical points on the handler and five
on the dog as measured by a kinematic system over the same space.

Methods, results and discussion

Ten healthy, non-chondrodysplastic, mixed breed dogs weighing 19.9 to 34.3 kg were included in this study; seven were obtained from an existing research colony at the institution; the others were client-owned. All of the dogs were found to be normal on physical examination, complete blood counts, serum chemistry, urinalysis, and radiographs of the hips and stifles.

For each day’s session, reflective markers were adhered to the handler’s sacrum and uni- laterally to the right greater trochanter, lateral femoral condyle, and lateral malleolus. Additionally, markers were adhered to the dog’s occipital protuberance, interscapular region, left acromion, lateral epicondyle, and styloid process.

The patients were familiarized with the force plate system prior to each session. All of the dogs were trotted on a raised gait platform, while both kinetic and kinematic data were simultaneously collected for at least five valid trials on Day 0, and then again seven days later. Care was taken not to alter the placement of the photocells in any way between trials or subjects. The kinetic and the kinematic systems were calibrated prior to each session.

The kinetic system consisted of two force plates in series and mounted flush with a gait platform, and was paired with a series of five photocells placed 0.5 m apart and 0.5 m above the gait platform (5). The trials were conducted and included or excluded in the same fashion as if the ground force reaction data was going to be evaluated. The inclusion parameters consisted of an average trial velocity between 1.70 to 2.10 m/s with an average acceleration between −0.50 m/s² and 0.50 m/s² as reported by the kinetic software, and footfalls with contralateral limbs falling on the same plate without any pulling on the lead or extraneous movement of the head. Four instantaneous velocities and three accelerations were collected by the software using the standard program for five photocells. Low intensity lasers in the red optical wavelength were securely clamped to each photocell for the entire duration of the study. Each laser’s beam was directed across the gait platform in such a way that it simulated the beam of the photocell. These lasers permitted an observer to visually estimate the triggering of the first and last photocells to specific video frames in order to set the first and last frames to include for kinematic analysis.

Kinematic data was collected concurrently by a kinematic system of three 200 Hz infrared cameras on either side of the walkway. A video camera synchronized with the kinematic system allowed for simultaneous video recording of each trial. The first five trials for each dog that had complete and valid kinetic and kinematic data sets for each day were processed so that each of the 10 dogs had five trials on Day 0 and on Day 7.

The kinematic system reports 200 velocity values per minute for each of the nine points. The testing span was defined as the frames between the appearance of the laser corresponding to the first photocell on either the dog or the handler to the first appearance of the laser corresponding to the fifth photocell. This span is theoretically the same as the time between triggering of the first and fifth photocells. The frames in which an anatomical marker was not seen by the kinematic system were excluded from the calculation of the velocity for that marker. The velocities in the cranio-caudal direction of each of the nine markers were averaged over the distance of the five photocells in order to calculate the average of velocities for that anatomical structure. Due to the fact that the velocity of the dogs and handler was overwhelmingly in the cranio-caudal direction, the velocity reported by the photocell system was assumed to represent the magnitude of the velocity in only the cranio-caudal direction.

The average of velocities of each anatomical point were compared with the velocity of the subject as reported by the photocell system via a Student t-test. Significance was set at p<0.05.

As seen in Table 1, the occipital protuberance and interscapular markers on the dogs were found to not have any statistically significant differences in velocity, (1.899 ± 0.105 and 1.906 ± 0.114 m/s, respectively), (mean ± std. var.) as that reported by the kinetic system (1.896 ± 0.093 m/s). P-values were 0.62 for the occipital protuberance comparison and 0.17 for the interscapular

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Average Velocity (+/- SD)</th>
<th>P-value (comparison with photocell value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photocell System</td>
<td>1.896 (+/- 0.093)</td>
<td>Not applicable</td>
</tr>
<tr>
<td><strong>Dog Markers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral styloid</td>
<td>1.940 (+/- 0.215)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Lateral epicondyle</td>
<td>1.935 (+/- 0.162)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Acromion</td>
<td>1.925 (+/- 0.128)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Interscapular region</td>
<td>1.906 (+/- 0.114) *</td>
<td>0.17</td>
</tr>
<tr>
<td>Occipital protuberance</td>
<td>1.899 (+/- 0.105) *</td>
<td>0.62</td>
</tr>
<tr>
<td><strong>Handler Markers</strong></td>
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<tr>
<td>Lateral malleolus</td>
<td>1.595 (+/- 0.264)</td>
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<tr>
<td>Lateral condyle</td>
<td>1.758 (+/- 0.137)</td>
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<td>Greater trochanter</td>
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<td>&lt;0.05</td>
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<tr>
<td>Sacrum</td>
<td>1.788 (+/- 0.099)</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

*Values that were not significantly different than the average velocity of the photocell system (p>0.05).
marker. When comparing the anatomic velocities of the handler to the average of velocities reported by the photocell system for each trial, all of the handler velocities were significantly different than those reported by the photocell system ($p<0.05$). Similarly, the forelimb markers of the dog (acromion, lateral epicondyle, and lateral styloid) also had significantly different velocities, $1.925 \pm 0.128$, $1.935 \pm 0.162$, and $1.940 \pm 0.215$, respectively) than those reported by the kinetic system ($p<0.05$). A significant difference was not found within any of the dogs between the trials on Day 0 compared with Day 7 ($p<0.05$), which suggests that the experimental protocol was repeatable.

This study was conducted in an attempt to validate the measurement of a canine subject’s velocity using a photocell system during the collection of ground reaction forces. Our data suggest that the velocity reported by our photocell system as the subject’s velocity is not statistically different to that of kinematic markers placed in the interscapular region and on the occipital protuberance. However, though statistically different, the velocities reported by the kinematic system for the canine forelimb markers would not have been conceivably different enough to biologically alter the kinetic data gathered during the trial. These results are in good agreement with the theory that the photocell system with photocells placed 0.5 m above the gait platform accurately measures the velocity of the trunk of a canine subject. The interscapular and occipital protuberance markers are the only referenced points on the canine subject that are likely to maintain a constant velocity during a trot. The lateral styloid, lateral epicondyle, and acromion will accelerate and decelerate during locomotion. Likewise, the handler’s lateral malleolus, lateral condyle, and greater trochanter markers are also expected to accelerate and decelerate and, thus, could not represent an accurate velocity for the dog or handler over a set period of time. The handler’s sacral marker, which is meant to represent the handler’s trunk velocity, was also significantly different from the average trial velocity reported by the photocell system. Therefore, the photocell system does not give an accurate measurement of the handler’s velocity over that time span. In conclusion, our photocell system, with five photocells spaced 0.5 m apart and 0.5 m above the gait platform, accurately reported the trial velocity of 10 canine subjects as the same velocity of markers placed on the subjects’ occipital protuberance and interscapular region. This study supports the use of photocells during the collection of ground reaction forces in order to acquire accurate velocity data that represents the trunk velocity of canine subjects.

References


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