Modification of the contact area of a standard force platform and runway for small breed dogs

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Force platform, kinetics, gait analysis, ground reaction forces, dogs

Summary

Objectives: To develop a platform that used standard size force plates for large breed dogs to capture ground reaction force data from any size dog.

Methods: A walkway platform was constructed to accommodate two force plates (60 cm x 40 cm) positioned in series to a variety of smaller sizes. It was constructed from a custom wood frame with thick aluminium sheet force plate covers that prevented transfer of load to the force plate, except for rectangular windows of three different dimensions. A friction study was performed to ensure plates did not translate relative to one another during gait trials. A prospective, observational, single crossover study design was used to compare the effect of force platform configuration (full plate size [original plate], half plate size [modified plate]) on ground reaction forces using eight adult healthy Labrador Retriever dogs.

Results: Slippage of the steel plate on the force plate did not occur. Peak propulsion force was the only kinetic variable statistically different between the full size and half sized platforms. There were no clinically significant differences between the full and half force platforms for the variables and dogs studied.

Discussion and conclusion: The modified force platform allows the original 60 x 40 cm force plate to be adjusted effectively to a 30 x 40 cm, 20 x 40 cm and 15 x 40 cm sized plate with no clinically significant change in kinetic variables. This modification that worked for large breed dogs will potentially allow kinetic analysis of a large variety of dogs with different stride lengths.

Introduction

Several tools exist for measuring orthopaedic disease in dogs and response to treatments. Subjective owner questionnaires can be used after validation and reliability testing to quantify improvement of orthopaedic disease in dogs (1–6). Pressure walkways indirectly measure peak vertical force between the limb and ground, and are useful for assessing changes in peak force over time (7–10). Kinematic measures describe joint motions throughout the gait cycle (7). Force platforms are commonly used to directly measure multiple components of the force between limbs and the ground. Measured kinetic variables provide insight into understanding gait alterations associated with orthopaedic disease, and into treatment efficacy (7).

One of the biggest limitations for force platforms has been the inability to easily collect data from small breed dogs (8–9). The size of the force plate must accommodate stride length to ensure single limb loading, ideally for ipsilateral thoracic and pelvic limbs during the same trial for ease of using standard quadruped software. For cost and efficiency, gait laboratories usually have only one size force plate. The standard force plates used for medium to giant breed dogs have a measurement range that can be used for small breed dogs but the actual plate length is not suitable for collecting data from dogs with smaller stride length (8–9).
Our goal was to develop a platform that used standard size force plates for large breed dogs to capture ground reaction force data from any size dog. Further, we demonstrate the collection of data from large breed dogs before and after platform contact area modification.

Materials and methods

Force platform modification

A new walkway platform was constructed to accommodate two force plates (60 x 40 cm) (60 cm x 40 cm x 3.5 cm; measurement range 0–10 kN, calibrated for 0–2 kN range) positioned in series along their long dimensions (Figure 1). The design is similar to the standard 5.3 m long modular walkway available commercially with a gradual elevation at both ends of the level force platform. Non-elevated flooring extended 5 m beyond the inclined walkway on both ends. The modules for the elevated platform were constructed from a 4.5 cm high custom wood frame with 6.35 mm thick aluminium sheet covers except for the intended contact areas of the force plates. The modules that housed the force plates used a custom wood frame with a cut-out for the full sized force plates (60 x 40 cm). The aluminium sheet had a cut-out that prevented transfer of load to the force plate, except for rectangular windows of three different dimensions: 30 cm x 40 cm (half plate size), 20 cm x 40 cm (third plate size), and 15 cm x 40 cm (quarter plate size). The dimensions were chosen to accommodate a variety of stride lengths. The force plates were isolated from the ramp, wood frame modules, and aluminium sheets by a 3 mm gap. Steel plates (1.27 cm thick) that corresponded in size to the windows in the platform were placed in contact with the force plate, level with, but not contacting, the surrounding platform. Only the steel plates allowed transfer of load from the limb to the force plates. Vinyl floor tile was applied to the surface of the aluminium covers and steel plates to provide adequate surface traction and prevent slippage between the limb and plate during gait. Separate modules were made for both the wood frame and the aluminium sheet cover for the different contact area dimensions. Modules were changed to accommodate different sized force platforms.

Clinical feasibility study

A prospective, observational, single crossover study design was used to compare the effect of force platform configuration (full plate size, half plate size) on ground reaction forces using eight adult healthy Labrador Retrievers (31.03 ± 3.88 kg; 2 female, 6 male; 5–6 out of 1–9 body condition score4). Data were collected during trot for each dog on two platforms, the full size and the half size, within the same day to avoid inter-day variation. The order of platform use was randomized with the criteria that half of the dogs were tested in each test sequence.

The institutional animal care and use committee approved the study. Owner consent was obtained for all dogs enrolled in the study.

Data collection

The dogs had no history of lameness or prior orthopaedic surgery. General physical and orthopaedic physical examinations were deemed normal for all enrolled dogs by trained orthopaedic faculty or surgery residents. Dogs were trained to trot across the force platform walkway on a slack leash by an experienced handler, and were acclimated to the force plate before data collection.

Trials were recorded until a minimum of five valid trials was obtained on each platform. A trial was accepted as valid when all four limbs individually and fully contacted a force plate within one stride (ipsilateral thoracic and pelvic limbs on the

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a Kistler Force Platform, Model 9286AA: Kistler Instrument Corp., Amherst, NY, USA
b Body condition score system: Nestle Purina Pet Care Center, St. Louis, MO, USA
first force plate and the contralateral thoracic and pelvic limbs on the second force plate). Video data were used to determine position of each foot strike (collected using a 60 Hz digital video camera c and reviewed using gait analysis software d). Dog velocity and acceleration were measured using five photocells e mounted in series along the platform walkway. Dog velocity ranged from 1.6 to 2.5 m/s, and acceleration ranged from -0.45 to 0.55 m/s². Starting distance from the force plates was controlled for all dogs. Ground reaction forces were sampled at 200 Hz and recorded with software f that calculated gait variables for each foot strike for each trial. Gait variables used to compare the original and modified plate included peak vertical force (Fv), vertical impulse (Iv), braking peak force (Fbrake), braking impulse (Ibrake), peak propulsion force (Fpropel), and propulsion impulse (Ipropel). About 10–20 passes were required for each dog to obtain five valid trials on the standard and modified force platform. Data collection required about 20 minutes per dog.

**Static friction study design**

Friction between the steel plate and the underlying force plate was examined to ensure that the plates did not translate relative to one another during gait trials. A custom linear pneumatic actuator was used to induce movement of the steel plate relative to the fixed force plate, in the plane parallel to the interface between the plates and in the direction of dog movement (Figure 2). Actuator translation and velocity were determined by video capture (3 infrared optical video cameras f) at 200 Hz of a 16 mm spherical reflective marker on the actuator within a calibrated three-dimensional space, and gait analysis software g. The velocity of the actuator and the horizontal force was recorded from using the force plate while the actuator contacted and then pushed the modified steel plate. Five trials were recorded.

The horizontal static frictional force was determined as the maximum force recorded before actuator force quickly dropped to a low value when the steel plate slid over the force plate. The static coefficient of friction (μs) was calculated using the formula: \( \mu_s = \frac{f}{N} \) where \( f = \) static friction force and \( N = \) normal (perpendicular) force at the interface of the steel plate and force plate due to the mass of the steel plate and acceleration of gravity (11). The static coefficient of friction was averaged over five trials.

Two randomly selected trot trials (right and left limbs) from each of the eight dogs were used to investigate whether the steel plate had the potential to translate relative to the force plate during the dog trot trials. The horizontal force (Fslip) that would have to be overcome for the steel plate to translate (slip) for each limb for each dog trial was calculated as Fslip = Fv x μs. For all dogs, Fslip was compared to Fbrake and Fpropel over the entire stance period for the two randomly selected trials. ‘Slip potential’ was calculated as the ratio between the braking/propulsion force and the static friction force for every point during thoracic limb and pelvic limb contact on the steel plate and then expressed as a percentage (slip potential (%)) = [Fbrake, propell / Fslip] x 100). The larger the percentage means the closer the plate is to slipping during the trial. The highest percentage value for the two trials from each dog was reported to demonstrate the greatest slip potential.

**Statistical analysis**

The effect of force plate (full size, half size) on the dependent variables was assessed using a repeated measures analysis of variance that accounted for side (left, right) and trial (numbers 1–5) as fixed effects and dog as a random effect. Dog velocity and acceleration were included as covariates in the statistical model. Separate analyses were performed for forelimbs (thoracic) and hindlimbs (pelvic). Normality of the residuals was checked using the Shapiro-Wilk test. Effects were considered statistically significant when \( p < 0.05 \). Least square means are reported for force plate type, where mean values for levels of an effect were averaged over all other effects in the model (side, trial, velocity, acceleration). The difference associated with a change in each factor was expressed as a percentage of the mean value for side, trial and force plate (difference/mean). The percent difference/mean was considered clinically insignificant if the difference was less than 10% of the mean. All tests were conducted using commercial software h.

**Results**

The static coefficient of friction between the two plate surfaces was 0.52. The maximum slip potential for any trial from each dog ranged from 31.1% – 55.1%, with a
mean of 41.7% and median of 39.6%. Therefore, slippage of the steel plate on the force plate did not occur.

There was only one systematic difference for the kinetic variables between the full size and half size force platform for the dogs studied. In the pelvic limb, peak propulsion force was significantly different between the full and half size plate (p = 0.027). There were no clinically significant differences between the full and half force platforms for all the variables and dogs studied (Table 1).

Discussion

A force platform was modified to reduce the contact area on the force plate for potential use in small size dogs. Friction between components in the modified platform was examined to ensure that the platform was rigid under clinical and research study conditions. Kinetic data were collected using the full size (original) and half sized (modified) platforms from eight dogs to ensure feasibility. Results demonstrated that the steel plate was immobile relative to the vinyl tile surface. The modified platform can be adapted to above or below ground systems.

A steel plate was used to transfer dog limb loads to the force plate in the modified platform. Because the steel plate was not secured to the force plate with bolts for this study, the possibility of slippage between the steel plate and force plate had to be examined. Results demonstrated that the steel plate was immobile relative to the force plate for the limb loads observed during the trot for the Labrador Retrievers in the study. Because limb loads resulted in only approximately half of the force necessary for plate slippage, and the modified platform was similar to a commercially available raised platform. The platform is precisely cut out around the force plates so that there is minimal space, but no contact so no load is transferred between the platform and force plates. The inclined entrance and exit portions of the walkway are gradual and distant from the level section with force plates to allow dogs to reach gait equilibrium before travelling over the force plates. The dogs did not appear to be affected by, or react, to the vinyl tile surface. The modified platform can be adapted to above or below ground systems.

Table 1 Differences between the kinetic variable (least squares mean ± standard error) for the full and half size modified platforms.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Full size plate</th>
<th>Half size plate</th>
<th>Diff./Mean (%)</th>
<th>p-value</th>
<th>Velocity</th>
<th>Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LS mean SE</td>
<td>LS mean SE</td>
<td>LS mean SE</td>
<td>Plate</td>
<td>Velocity</td>
<td>Acceleration</td>
</tr>
<tr>
<td>Thoracic limb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Vertical Force %BW</td>
<td>117.2 3.3</td>
<td>116.1 3.2</td>
<td>0.9 0.194</td>
<td>&lt;0.001</td>
<td>0.115</td>
<td></td>
</tr>
<tr>
<td>Vertical Impulse %BW x s</td>
<td>16.46 0.42</td>
<td>16.65 0.42</td>
<td>1.2 0.176</td>
<td>&lt;0.001</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Peak Brake Force %BW</td>
<td>-16.17 0.75</td>
<td>-16.06 0.73</td>
<td>0.6 0.742</td>
<td>&lt;0.001</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Braking Impulse %BW x s</td>
<td>-1.39 0.07</td>
<td>-1.39 0.06</td>
<td>0.4 0.869</td>
<td>0.928</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Peak Propulsion Force %BW</td>
<td>8.11 0.51</td>
<td>8.06 0.50</td>
<td>0.7 0.756</td>
<td>0.011</td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>Propulsion Impulse %BW x s</td>
<td>0.59 0.03</td>
<td>0.59 0.03</td>
<td>0.5 0.830</td>
<td>0.094</td>
<td>0.078</td>
<td></td>
</tr>
<tr>
<td>Pelvic limb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Vertical Force %BW</td>
<td>74.1 2.5</td>
<td>73.8 2.5</td>
<td>0.5 0.427</td>
<td>&lt;0.001</td>
<td>0.018</td>
<td></td>
</tr>
<tr>
<td>Vertical Impulse %BW x s</td>
<td>9.21 0.30</td>
<td>9.20 0.30</td>
<td>0.1 0.854</td>
<td>&lt;0.001</td>
<td>0.228</td>
<td></td>
</tr>
<tr>
<td>Peak Brake Force %BW</td>
<td>-6.01 0.50</td>
<td>-5.96 0.49</td>
<td>0.9 0.778</td>
<td>0.001</td>
<td>0.219</td>
<td></td>
</tr>
<tr>
<td>Braking Impulse %BW x s</td>
<td>-0.29 0.04</td>
<td>-0.29 0.04</td>
<td>0.1 0.983</td>
<td>0.813</td>
<td>0.017</td>
<td></td>
</tr>
<tr>
<td>Peak Propulsion Force %BW</td>
<td>8.70 0.49</td>
<td>8.18 0.48</td>
<td>6.1 0.027</td>
<td>0.002</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Propulsion Impulse %BW x s</td>
<td>0.67 0.04</td>
<td>0.63 0.04</td>
<td>6.0 0.055</td>
<td>0.843</td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>

%BW = % body weight; % BW x s = % body weight multiplied by seconds; LS mean = least squares mean; SE = standard error. Values of p <0.05 are considered to be significant.

%BW = % body weight; % BW x s = % body weight multiplied by seconds; LS mean = least squares mean; SE = standard error. Values of p <0.05 are considered to be significant.

Figure 3 Addition of bolts to attach the steel top to the force platform section that will record ground reaction forces. This was added to ensure no slippage. An engineer placed the bolts in accordance to the plate specifications to avoid damage to the force plates.
platform was designed for smaller dogs, the design is sufficient for use with trot trials. Alternatively, the steel plate could be secured to the force platform with bolts, and this was done after completion of the study (►Figure 3).

One statistical difference was apparent in the pelvic limb gait parameters between the original and modified force platforms. The repeated measures study design optimized the ability to detect small differences associated with the force platforms by accounting for variability between dogs, trials, velocity, acceleration, and left and right limbs. The magnitude of this difference is well within normal variation between individuals, between trials within individuals, and across longitudinal studies within normal individuals; and less than the magnitude of meaningful treatment differences in clinical orthopaedic studies (13-16). Clinical trial studies look for at least a 10% change to indicate meaningful clinical improvements or declines after treatments (14-16).

The difference between the original and modified platforms was for peak propulsion force in the pelvic limb. Another study found that trial variance was more pronounced in the cranio-caudal forces than in the vertical forces (12). Variation is expected to be higher for cranio-caudal forces than vertical forces because speed and acceleration within trials will inevitably vary, even with strict speed and acceleration criteria used to determine valid trials. The differences observed for pelvic limb propulsion peak force are still well below the 10% change used to determine meaningful significant improvements or declines after treatments in clinical studies (14-16).

Velocity was between 1.6 to 2.5 m/s and acceleration was between −0.45 to 0.55 m/s². Studies show that keeping velocity within 0.3 to 0.4 m/s variability and acceleration no more than ±0.5 m/s² enhances consistency of trial data (17-19). Because these data had a wider range of velocity between the different dogs and had a significant influence on most variables, we elected to control for velocity and acceleration among the range of velocities and accelerations observed in trials, and to include the velocity and acceleration factors as covariates in the statistical model. By not rejecting valid trials that were not within the narrow velocity range, data acquisition was fast and it eliminated the concern of the dog getting tired and having increased variability of their trials. Further comparisons of this approach for velocity need to be studied.

Normal large breed dogs were studied to demonstrate that there were no clinically significant differences in gait parameters between the original and modified platforms. In order for Labrador Retrievers to contact ipsilateral thoracic limb and pelvic limbs on each force platform, only the half size modified platform was compared to the full size original platform. Ideally, small dogs with different stride lengths could have been used to test all of the different sizes. However, the focus of this study was to test the design of the platform modification and demonstrate it could be used to acquire consistent data. The third size and quarter size force platforms allow for kinetic data collection from dogs of a wide variety of sizes and body geometries. The modified force platform of all sizes is currently being used in our laboratory for small breed dogs.

The piezoelectric force platform used in our study had a large measurement range capability but was calibrated for a 0–2 kN range to optimize measurement resolution for canine use. Force plate load ranges and resolutions must be appropriate for different patient weights. Module dimensions would have to be modified for different size force plates. The aluminium covering must be stiff enough to prevent contact with the non-contact area portion of the plate. Only 10 minutes were required to change the platform to accommodate different size dogs although the components are heavy and require lifting. It would be advantageous to have a chart for selection of platform size and force plate spacing with knowledge of dog weight, distance between thoracic and pelvic limbs and limb length.

In conclusion, the modified force platform allowed the original 60 x 40 cm force plate to be effectively adjusted to a 30 x 40 cm, 20 x 40 cm, and a 15 x 40 cm sized plate. This modification that worked for large breed dogs will potentially allow kinetic analysis of a large variety of dogs with different stride lengths, specifically small breed dogs without having to purchase different sized force plates. This will hopefully allow investigators to use kinetics as an outcome measurement in clinical trials for all breeds of dog after complete validation in small breed dogs.

Conflict of interest
None declared.

References

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