Evaluation of a pressure walkway system for measurement of vertical limb forces in clinically normal dogs

B. Duncan X. Lascelles, BVSc, PhD; Simon C. Roe, BVSc, PhD; Eric Smith; Lisa Reynolds, BS; Jacqueline Markham; Denis Marcellin-Little, DEDV; Mary Sarah Bergh, DVM; Steven C. Budsberg, DVM, MS

Objective—To compare ground reaction forces (GRFs) measured by use of a pressure-sensitive walkway (PSW) and a force plate (FP) and evaluate weekly variation in the GRFs and static vertical forces in dogs.

Animals—34 clinically normal dogs and 5 research dogs with lameness.

Procedure—GRF data were collected from 5 lame and 14 clinically normal dogs by use of an FP and a PSW. Peak vertical force (PVF), vertical impulse (VI), and velocity measurements (determined by use of photocells and PSW data) were compared between groups. Peak vertical force, VI, stride length, ground phase time (ie, contact time), and static body weight distribution data were collected on 2 occasions, 1 week apart, in 20 different clinically normal dogs by use of a PSW; week-to-week variation in values was evaluated.

Results—Measurements of velocity derived by use of the photocells were not different from those derived by use of the PSW. For any 1 limb, values derived by use of the PSW were significantly lower than values derived with the FP. For values obtained by use of either technique, there were no differences between left and right limbs except for values of PVF measured via PSW in forelimbs. Values of PVF, VI, contact time, stride length, and static weight distribution generated by the PSW did not vary from week to week.

Conclusions and Clinical Relevance—Values for GRFs varied between the FP and PSW. However, data derived by use of PSW were consistent and could be used to evaluate kinetic variables over time in the same dog. (*Am J Vet Res* 2006;67:277–282)

The use of force plates to measure GRFs in dogs is well established. The earliest force plates operated on a mechanical basis, by means of springs and levers.[1]

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From the Comparative Pain Research Laboratory, College of Veterinary Medicine, North Carolina State University, Raleigh, NC 27606 (Lascelles, Roe, Smith, Markham, Marcellin-Little); and the Department of Small Animal Medicine and Surgery, College of Veterinary Medicine, University of Georgia, Athens, GA 30602 (Reynolds, Bergh, Budsberg).
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Address correspondence to Dr. Lascelles.

Force plates used since the late 1970s operate on the basis of strain gauges and have been used to evaluate GRFs in dogs at the walk,[2,3] at the trot,[4–6] and during jumping.[7] The use of force plates has become a standard means of objectively evaluating the effectiveness of analgesics for managing perioperative limb pain.[8,9,a] and alleviating chronic pain associated with osteoarthritis.[10–12,b] However, there are several disadvantages to measurement of GRFs by use of a single force plate. First, use of a single force plate does not permit measurement of successive events during locomotion; to collect data for multiple footfalls on 1 foot, multiple passes are required to achieve appropriate placement of the foot on the plate the desired number of times. Attempting to obtain measurements from all 4 feet increases the necessary number of passes over the force plate and multiplies the problem.[13] Second, stride length constraints make it difficult to collect data in small dogs when standard force plates are used, and limb and foot velocity cannot be assessed in those instances. Force plates do not evaluate the distribution of force across the foot and cannot be used to evaluate static force distribution simultaneously across all 4 limbs. Another limitation of force plates is that at low to moderate speeds, dogs tend to keep 1 or more feet in contact with the ground, resulting in overlap of feet on the force plates.[14] Because of these limitations, other systems have been developed.

Pressure-sensing systems operating on the basis of resistive ink technology were initially developed for industrial applications. More recently, they have been used for medical applications, such as evaluation of pressure distribution in joints[15] and beneath the human foot during locomotion, by use of in-shoe[16,17] and floor-mat systems.[18] A pressure-sensing system was compared with a traditional force plate for measuring vertical forces in clinically normal Greyhounds at a walk[19] and for evaluating the distribution of forces over the pads of clinically normal Greyhounds and Labrador Retrievers during walking.[20] Although such pressure systems cannot measure the mediolateral and craniocaudal forces during locomotion, advantages associated with their use include the ability to record data for multiple foot strikes for all limbs during a single pass, data of actual limb or foot velocity (without the use of photoelectric cells), data from animals of a wide size

GRF	Ground reaction force
PSW	Pressure-sensitive walkway
PVF	Peak vertical force
VI	Vertical impulse

range, data from individual footfalls even if several feet are on the ground concurrently, and static weight distribution across all limbs in a standing animal. However, if pressure-sensing systems are to be used appropriately in veterinary medicine, information is needed on the data yielded under various testing conditions.

The objective of the study reported here was to test the hypotheses that there would be no difference between GRFs measured by use of a PSW and those measured by use of a force plate in clinically normal and lame mixed-breed dogs, and that there would be no significant variation from week to week in GRFs and static vertical forces measured by use of a PSW in clinically normal mixed-breed dogs. We aimed to compare measurements of PVF and VI obtained by use of a force plate and PSW in lame and clinically normal dogs. We also aimed to compare velocity as determined by photoelectric cells with velocity calculated from data obtained with the PSW. Finally, we aimed to compare values for PVF, VI, stride length, ground phase time (ie, contact time), and static body weight distribution that were obtained by use of the PSW and collected on 2 occasions, 1 week apart, in clinically normal dogs.

Materials and Methods

Animals—Healthy adult dogs that weighed 20 to 40 kg were used. For the first part of the experiment, 14 clinically normal (nonchondrodysplastic) client-owned dogs of various breeds were used. Five mixed-breed male hounds with lameness secondary to chronic femorotibial stifle joint osteoarthritis and that resided in a research colony were also used. In the second part of the experiment, 20 different clinically normal (nonchondrodysplastic) client-owned dogs of various breeds were used. To be considered clinically normal, dogs had to have no history of musculoskeletal abnormalities, to have undergone physical examination, and to have had radiographs of the pelvis acquired while sedated. The study was approved by the North Carolina State University Institutional Animal Care and Use Committee, and informed owner consent was obtained for each dog.

Experimental design—The first evaluations involved comparison of values for PVF and VI as measured in dogs with a force plate and with the PSW. The second part of the experiment involved evaluation of week-to-week variation in PVF, VI, stride length, ground phase time, and static body weight distribution by use of a PSW.

Equipment and data collection protocol—Two identical biomechanical force plates,[c] positioned in series, were mounted flush with the walking surface at the approximate midpoint of a 12-m long platform. Both plates interfaced with a dedicated computer where data were collected, processed, and stored with dedicated software[d] according to a described protocol.[5] The rate of data collection was 1,000 Hz/plate. Velocity and acceleration were measured by means of 5 photoelectric cells placed 0.5 m apart and coupled with a triggered timer system.[5] Video recordings were made of all trials and were used to confirm gait and foot contacts. A valid force plate trial consisted of a full forefoot strike on each force plate without another foot being on the plate at the same time, followed by an ipsilateral hind foot strike in the same fashion on each force plate. Thus, data from all 4 limbs were obtained in a single pass. A single trained observer (LR) evaluated each foot strike and subsequent force profile and determined whether or not the trial was valid. Velocity and acceleration were restricted to ranges of 1.7 to 2.1 m/s and –0.5 to 0.5 milliseconds^2, respectively. Ground reaction forces for the x-, y-, and z-axes were collected. For the purposes of this project, only those forces in the z-axis were analyzed, including maximal force exerted in the z-axis, the PVF, and the VI.

The PSW system[e] consisted of a custom-built combination of 4 high-resolution sensors connected together to create a single low-profile 2 × 0.5 × 0.005-m pressure platform that was connected to a dedicated laptop computer[f] via a 32-bit 2-slot card bus to a peripheral component interconnect expansion system.[g] The output data were analyzed with proprietary software.[h] Data were recorded as frames, in a movielike format. Each frame contained information about the pressure profile on the mat, and when the frames were combined, the information was given in relation to time. For comparison of force plate measurements with PSW measurements, the PSW was positioned in the center of the runway such that velocity and acceleration could be measured by the same photoelectric cells that recorded the data for the force plates. The mat was positioned so that velocity and acceleration were measured over the length of the PSW. A nonfunctional mat, constructed of the same materials and dimensions as the one containing the active PSW, was positioned directly in front of the active PSW with no gap, such that dogs trotted over that mat prior to contacting the active PSW.

Experimental conditions—At each testing time point, each dog was weighed on the same electronic scale and allowed to become familiar with the force plate or PSW and testing area. Dogs were walked across the force plate (or PSW) until they appeared to be comfortable and relaxed (generally 6 to 12 passes). The number of handlers used was kept to a minimum, but if the dogs were not relaxed, different handlers were used.

Data collection—Dogs were handled in the same manner for collection of force plate and PSW data. A valid run occurred when a dog moved in a straight line across the force plate or PSW without pulling to 1 side or turning its head. All runs were recorded by use of a digital video camera in the first part of the experiment, and the videotapes were reviewed at the time of data collection to ensure that the requirements for a valid run had been met. For trotting data collected on the PSW, a valid trial was one in which the dog trotted in a steady and straight line along the entire length of the PSW and in which each foot strike fell into the recording area of the mat. Velocity and acceleration were restricted to 1.7 to 2.1 m/s (1.7 to 2.0 m/s for the study of week-to-week variation) and –0.5 to 0.5 milliseconds^2, respectively. Those variables were measured from the photocells and from calculations performed on data from the mat. For static weight distribution data collected on the PSW, dogs were walked onto the PSW at a velocity of approximately 1 m/s and then abruptly stopped. This resulted in the dog assuming an approximately square stance with the head held directly in front. After the dog had maintained that position for 3 to 5 seconds, data collection began, and recordings continued for 13 seconds (ie, for 600 frames of data). Data were retained if the dogs stood still and relaxed without visibly shifting weight, lifting or off-loading a limb, turning, or lifting or dropping the head. The consistency of data over the 13 seconds was visually evaluated to ensure that there was a 5-second period of steady force recordings.

For the second part of the experiment (evaluating week-to-week variability in measurements derived by use of the PSW) the PSW was set up with a nonworking mat as described along 1 wall of a quiet 5 × 25-m hallway. The PSW was conditioned and equilibrated each day, as per manufacturer instructions, prior to calibration. The PSW was calibrated differently for collection of trotting and standing data. Calibration was performed by having a human weighing 65 kg step onto the mat with 1 foot, with a delay of 1 second from first step to calibration, for trotting data; for standing data, the human subject stepped onto the mat with 2 feet with a delay of 5 seconds from first step to calibration. The sampling rate was 47 frames/s, and the duration of data acquisition was 150 to 200 frames for trotting data and 600 frames for standing data.

Experimental protocol—Prior to the study, dogs were randomly allocated to be tested on either the force plates or the PSW first. For each dog, 5 valid data sets were collected on both systems. Kinetic variables (PVF and VI) were calculated for each limb and normalized for body weight. Multiple footfalls were recorded in each set of data (ie, each movie) on the PSW, but only 1 footfall for each limb from the midpoint of each movie was analyzed. Velocity was calculated from the photocells on every trial and from calculations from PSW data (measuring stride length and dividing this by the time between strikes) in trials when that system was being used. Acceleration was measured by the photocells and associated software and also from calculations on PSW data.

In the second part of the experiment, dogs were evaluated on 2 occasions 1 week apart. For the kinetic data, dogs were trotted across the mat until 5 valid trials had been collected. Likewise, 5 sets of data with the dogs standing on the mat were collected. For the trotting data, velocity, PVF and VI, stride length, and ground phase time of each limb were recorded. For standing data, the percentage of body weight distributed over each limb was calculated, including a mean value from a 5-second period of steady weight distribution. The 5-second period was chosen from the midpoint of the 13-second recording period.

Statistical analysis—A repeated-measures model was used to analyze differences in the velocity data collected by the photoelectric cell system and the PSW system. System and runs were fixed effects in the model. Differences in GRF measurements (PVF and VI) collected for each limb by the 2 methods were also analyzed by use of the repeated-measures model. Method, limb, and limb by method interaction were included as fixed effects in the model, and weight of the dog was included as a covariate in the model. All pairwise comparisons between limbs and method were adjusted for multiple comparisons by the Tukey-Kramer method. Similarly, differences between velocity, limb PVF, VI, stride length, and ground phase time collected with the PSW at different time points were analyzed by use of a repeated-measures model. Comparisons were made for these variables within and between paired limbs. Finally, differences in values for the percentage of body weight distribution while standing were compared within and between paired limbs at the different collection times. All statistical analyses were conducted with commercially available software.[i] A 2-sided value of $P \leq 0.05$ was considered significant.

Results

There was no significant difference in values for velocity as measured in the force plate trials versus the PSW trials and no difference between velocity measured by use of photocells and measured from the PSW. Mean ± SE velocity measured by the photocells during PSW trials was 1.91 ± 0.016 m/s, whereas the velocity measured from the PSW was 1.89 ± 0.016 m/s.

The clinically normal dogs (n = 14) had a mean weight of 27.4 ± 5.3 kg. In those dogs, there was a significant difference between data obtained by use of the force plate and data (PVF and VI) collected by use of the PSW for each limb. Values obtained by use of the PSW were consistently lower than those obtained by

Table 1—Mean (SD) values for PVF and VI recorded by means of a force plate and a PSW in 14 clinically normal dogs at the trot.

Variable	Limb	Force plate	PSW
PVF (% BW)	Right forelimb	116 (10.0)*	100 (13.6)†
	Left forelimb	115 (7.98)*	106 (16.3)
	Right hind limb	72.7 (8.22)*	63.5 (9.85)
	Left hind limb	71.0 (9.67)*	65.2 (12.9)
VI (% BW/s)	Right forelimb	16.7 (1.28)*	14.5 (1.96)
	Left forelimb	16.5 (0.97)*	14.9 (1.77)
	Right hind limb	9.12 (0.79)*	7.80 (1.29)
	Left hind limb	8.79 (0.89)*	7.75 (1.10)

*Significant ($P < 0.05$) difference between data generated by use of the force plate and data generated by use of a PSW. †Significant ($P < 0.05$) difference in data for left versus right limbs for a single measuringtechnique.
% BW = Percentage of body weight.

Table 2—Mean (SD) values for PVF and VI recorded by means of a force plate and a PSW in 5 dogs with lameness at the trot.

Variable	Limb	Force plate	PSW
PVF (% BW)	Right forelimb	108 (9.09)*	91.2 (9.5)
	Left forelimb	103 (13.5)*	90.2 (18.4)
	Right hind limb	63.8 (10.1)	54.2 (12.28)
	Left hind limb	59.0 (13.8)	54.3 (15.8)
VI (% BW/s)	Right forelimb	18.9 (2.48)*	15.6 (1.84)
	Left forelimb	17.9 (2.6)*	15.5 (2.62)
	Right hind limb	9.54 (1.38)	8.21 (2.0)
	Left hind limb	8.70 (2.19)	7.95 (2.46)

See Table 1 for key.

Table 3—Mean (SD) values for variables collected in 20 clinically normal dogs at the trot. Data were collected on 2 occasions in the same dogs at a 1-week interval. Notice that there were no week-to-week differences in any variables.

Variable	Limb	Week 1	Week 2
Velocity (m/s)		1.89 (0.09)	1.88 (0.09)
PVF (% BW)	Right forelimb	95.3 (12.8)	98.2 (11.5)
	Left forelimb	97.5 (14.3)	97.2 (10.6)
	Right hind limb	58.9 (9.14)	60.6 (9.54)
	Left hind limb	62.7 (11.7)	61.8 (9.9)
VI (% BW/s)	Right forelimb	14.5 (2.25)	14.8 (1.74)
	Left forelimb	14.5 (2.09)	14.6 (1.75)
	Right hind limb	8.02 (1.36)	8.24 (1.19)
	Left hind limb	8.56 (1.53)	8.45 (1.37)
Stride length (m)	Right forelimb	0.989 (0.070)	0.986 (0.069)
	Left forelimb	0.988 (0.065)	0.984 (0.070)
	Right hind limb	0.979 (0.069)	0.982 (0.069)
	Left hind limb	0.976 (0.061)	0.983 (0.068)
Contact time (s)	Right forelimb	0.25 (0.03)	0.25 (0.03)
	Left forelimb	0.25 (0.03)	0.25 (0.03)
	Right hind limb	0.22 (0.04)	0.22 (0.03)
	Left hind limb	0.22 (0.04)	0.22 (0.03)
BW-Distrib (%)	Right forelimb	31.3 (3.5)	31.4 (4.2)
	Left forelimb	30.5 (3.3)	30.8 (2.7)
	Right hind limb	19.0 (3.9)	18.7 (1.9)
	Left hind limb	19.2 (2.7)	19.1 (3.0)

BW-Distrib (%) = % BW distribution.
Body weight distribution data were collected in standing dogs at the same time as the measurements of the other variables.
See Table 1 for remainder of key.

use of the force plate (**Table 1**). Within a measuring technique, there was no difference between PVF or VI data for the left versus right forelimbs and left versus right hind limbs except for data obtained via the PSW for PVF; in those data, there was a significant difference between values for the right and left forelimbs.

The lame dogs (n = 5) had a mean weight of 30.8 ± 4.8 kg. Among lame dogs, there was a significant difference between data obtained by use of the force plate and data (PVF and VI) obtained by use of the PSW for the forelimbs, but not for the hind limbs. In forelimbs, values obtained by use of PSW were consistently lower than those obtained by use of the force plate for the forelimbs (**Table 2**). Within a measuring technique, there was no difference between the values of PVF or VI for the left versus right forelimb or the left versus right hind limb.

In the second part of the experiment, dogs' mean weight was 29.0 ± 6.22 kg. No significant differences were observed in dog velocity or values for individual limb PVF, VI, contact time, or stride length from week 1 to week 2. Significant differences were observed in forelimb and hind limb data values of PVF, VI, and contact time (**Table 3**). There were no significant differences in the percentage of body weight distribution from week 1 to week 2, but a significant difference between forelimbs and hind limbs was observed in values for the percentage of body weight distribution.

Discussion

In this study, there were no differences between the methods of measurement in values obtained for velocity. This is not surprising because the photocell system measures the velocity of the dog at the level of the thorax, whereas the PSW system measures foot velocity; it is intuitive to expect that the torso and feet travel at the same velocity. It is possible that different anatomic sites would trigger the photocells during a run (eg, the dog's muzzle on 1 cell vs the dog's thorax on the next) and that this would result in inaccurate measurements. However, we used 5 cells and calculated the mean of the values. Another possible drawback to the use of photocells is that there is a constant absolute distance between sensors, whereas the gait of each dog has a slightly different cycle that is dependent on speed. Because speed during the gait cycle changes continuously, the photocell method of measurement may record the position of the subject at different points in the gait, yielding estimates of speed across the distance that do not necessarily represent the mean speed between consistent points in the stride cycle. Despite these potential drawbacks, our results validate the ability of photocells to accurately determine values for velocity that are consistent when recorded from various points on the body and were in accordance with reported data from studies[21–22,j] in which velocity was monitored kinematically on a frame-by-frame basis. However, determination of velocity by use of the PSW does not take into account the fact that appendicular limb segment velocity (ie, limb velocity) may vary among dogs because of morphologic differences. Whether there are differences in limb velocity relative to foot or torso velocity among dogs with highly dissimilar limb segment lengths has not been reported. Simultaneous kinematic measurements of torso and foot velocity and limb segment velocity would be necessary to make that determination. Velocity and acceleration are known to affect GRFs in dogs; therefore, velocity and acceleration variables have been maintained within tight limits in most studies.[23–26] However, there are no data to support the notion that limb segment speed is another variable that should be controlled in studies in which investigators are attempting to quantify changes in gait within or between dogs. Limb segment velocity is not presently considered to be a confounding factor if the range of dogs' sizes is narrow. For this reason, in most studies, including ours, narrow limits for the weight of study dogs are established.[27,28] In our study, velocity was calculated from PSW measurements of time between foot strikes. For this, the time between initial contacts of the foot strikes was used. It is possible that measuring the time between points of maximal force would have been more reliable, but subsequent evaluation of the data did not indicate that there was any difference in velocity when those times were used in calculations.

In the present study, significant differences were detected in values of PVF and VI as determined by use of the force plate versus the PSW system. These findings were in contrast to those from a previous study,[19] in which no significant difference was detected between values of VI recorded by the force plate versus PSW (although values for PVF in the forelimb did differ significantly). A closer evaluation of those data reveals that there were significant differences in values of VI and PVF, for forelimbs and hind limbs, in the individual limbs of certain dogs. In our study, data were collected from trotting dogs, whereas in the previous study,[19] data were collected from walking Greyhounds, and this may explain the different results between the 2 studies.

Several possibilities exist to explain the differences in data between the 2 measuring systems. The construction of the mat is such that conditioning and the way in which calibration is performed may have an important influence on the readings obtained. The PSW should be calibrated with an object with similar surface characteristics as the subject and over a duration that is similar to the subject's stance time-foot contact time. However, it is also necessary that 25% of each section of the PSW be covered during the calibration process. Given these constraints, in the present study, the most practical and consistent way to calibrate the PSW was to use human subjects standing with bare feet on the mat with a delay of 1 second from first contact to calibration. The stance time of any given limb in trotting dogs is shorter than 0.5 seconds, but our attempts to calibrate the equipment with a 0.5-second delay resulted in more variation. However, when we used the different methods for calibration depending on whether walking or trotting data were being collected, we were able to calibrate in the region of the maximal pressures induced by standing or trotting dogs.

Differences in the way calibration was performed between the 2 studies may explain the different results, but the details of how calibration was performed were not provided in the previous study.[19] As postulated by those investigators, other explanations for the differences may be the slow dynamic response and lower sampling frequency of the PSW; both factors may partially explain the lower kinetic variable readings recorded by the PSW, compared with readings from the force plate. The sampling rate of 45 Hz of the PSW may not be sufficient to determine the maximum vertical force in trotting dogs, and further studies evaluating different sampling frequencies (ie, between 45 and 1,000 Hz) with a force plate and the effect on the results obtained are needed.

In our study, there was no significant difference between the systems in values for PVF and VI in the hind limbs of lame dogs. This was likely because of the greater variability in these data, compared with hind limb data from the clinically normal dogs.

Given that there was a significant difference between the data collected by the 2 systems for an individual dog, we wished to determine whether the data collected by the PSW were consistent. Results of the second part of our study revealed no significant differences in values for PVF (expressed as a percentage of body weight, PVF%BW), VI (expressed as percentage of body weight/unit second, VI%BW/s), stride length, and stance time in measurements made 1 week apart in clinically normal mixed-breed dogs. Similarly, there were no differences in body weight distribution from week to week. These findings indicated that the data generated by the PSW were consistent. Therefore, despite the fact that the data for GRF generated by use of a PSW appeared to be significantly different from data generated by use of a force plate in a given dog, data from a PSW could potentially be used to accurately evaluate changes over time.

The disadvantage of the PSW is that data cannot be collected regarding mediolateral and craniocaudal forces; however, those variables have only rarely been used or reported in the veterinary literature. Another disadvantage of the PSW is the time required for data acquisition. In our study, it took approximately the same time to acquire valid trials with either system, but data output (for velocity, PVF%BW, and VI%BW/s) was immediate with the force plate system, whereas approximately 30 to 60 minutes were required to obtain, edit, and evaluate data from the PSW movies for 5 runs of each dog. The time involved in data collection using the 2 systems may have been more similar if we had only used a single force plate as opposed to 2 force plates arranged in series.

An advantage of the PSW over the force plate is the ability to move the mat to different locations and to set up the PSW only when required for data collection. Although the 2 × 0.5-m mat cannot be rolled or folded, it is still relatively portable. We used a nonworking mat placed in front of the working PSW each time. This was because when the mat is placed on the ground, it represents a different surface from the surrounding ground, and as such, represents a change in surface for the trotting dog. Addition of the nonworking mat accustomed dogs to the surface texture before the initiation of data collection.

An important advantage of the PSW over the force plate is the ability to obtain full-stride data. Vertical forces are very sensitive to step-to-step changes in speed.[13,29] The PSW can overcome the limitations of force plate studies by providing full-stride data with a reliable measure of step-to-step speed changes (even without horizontal force being directly measured).

Body weight distribution is a novel and potentially useful variable to measure. In clinical orthopedic evaluations, it is known that many dogs off-load, or favor, 1 limb in the standing position, yet lameness may be difficult to detect during gait evaluation.[30] The potential uses of such weight distribution data in standing animals have yet to be defined. Body weight distribution data from a PSW were used in evaluation of a nonsteroidal anti-inflammatory drug for postoperative pain alleviation in 1 study,[31] but the investigators did not report on how the data were collected, and that type of data had not been previously evaluated for consistency. Our results reveal that such data can be consistent from 1 evaluation time point to another. However, we found that the way in which dogs are handled can substantially alter data. In our study, even slight movements of the head or tension in the dog's body caused dramatic changes in weight distribution values. For that reason, we only used data generated from dogs that were standing in a steady, relaxed position with the feet placed approximately squarely. Attempts by handlers to pick up the feet and place them in a more square position resulted in unusual body weight distributions because the dogs became tense. The best way to achieve our aims was to walk the dogs onto the mat and stop abruptly, with the handler then moving to a position directly in front of the dog. This usually resulted in the dog assuming a square stance while looking directly ahead.

Although the absolute values generated via PSW for PVF and VI were different from those generated for the same dog on a force plate, data obtained by use of the PSW were consistent and could be used to evaluate such variables over time. The PSW was more portable than a force plate system, and certain variables that cannot easily be obtained from a force plate system, including stride length and body weight distribution, can be easily measured with the PSW system. Furthermore, measurements from a wider range of dogs with regard to size, and even cats,[32] can be obtained, allowing for investigation of more diverse population groups in future kinetic studies.

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