The Veterinary Journal 202 (2014) 498–502

Contents lists available at ScienceDirect

The Veterinary Journal

journal homepage: www.elsevier.com/locate/tvjl

Variance associated with subject velocity and trial repetition during force platform gait analysis in a heterogeneous population of clinically normal dogs

Eric C. Hans, Berdien Zwarthoed, Joseph Seliski, Brett Nemke, Peter Muir *

Comparative Orthopedic Research Laboratory, School of Veterinary Medicine, University of Wisconsin-Madison, 2015 Linden Drive, Madison, WI 53706, USA

ARTICLE INFO

Article history:
Accepted 9 September 2014

Keywords:
Gait analysis
Dog
Velocity range
Force platform
Clinical trial

ABSTRACT

Factors that contribute to variance in ground reaction forces (GRF) include dog morphology, velocity, and trial repetition. Narrow velocity ranges are recommended to minimize variance. In a heterogeneous population of clinically normal dogs, it was hypothesized that the dog subject effect would account for the majority of variance in peak vertical force (PVF) and vertical impulse (VI) at a trotting gait, and that narrow velocity ranges would be associated with less variance.

Data from 20 normal dogs were obtained. Each dog was trotted across a force platform at its habitual velocity, with controlled acceleration (±0.5 m/s^2). Variance effects from 12 trotting velocity ranges were examined using repeated-measures analysis-of-covariance. Significance was set at $P < 0.05$. Mean dog bodyweight was 28.4 ± 7.4 kg. Individual dog and velocity significantly affected PVF and VI for thoracic and pelvic limbs ($P < 0.001$). Trial number significantly affected thoracic limb PVF ($P < 0.001$). Limb (left or right) significantly affected thoracic limb VI ($P = 0.02$). The magnitude of variance effects from largest to smallest was dog, velocity, trial repetition, and limb. Velocity ranges of 1.5–2.0 m/s, 1.8–2.2 m/s, and 1.9–2.2 m/s were associated with low variance and no significant effects on thoracic or pelvic limb PVF and VI. A combination of these ranges, 1.5–2.2 m/s, captured a large percentage of trials per dog (84.2 ± 21.4%) with no significant effects on thoracic or pelvic limb PVF or VI. It was concluded that wider velocity ranges facilitate capture of valid trials with little to no effect on GRF in normal trotting dogs. This concept is important for clinical trial design.

Introduction

Ground reaction forces (GRF) obtained by canine force platform gait analysis represent an important outcome measure in clinical trials. Peak vertical force (PVF) and vertical impulse (VI) best correlate with limb function (Evans et al., 2005; Fanchon and Grandjean, 2007). PVF represents the maximal load exerted by the paw during the stance phase, while VI represents the area under the force time curve. During locomotion, if limb pain is present, the resulting lameness leads to decreased PVF and VI. Many clinical trials use PVF and VI to evaluate limb function before and after medical therapy or surgical treatment (Budsberg et al., 1988, 1999a; Voss et al., 2008; Malek et al., 2012).

Reference ranges for GRF of clinically normal dogs remain unclear. Factors that contribute to GRF variability include breed size and conformation, trial velocity, trial repetition, and day-to-day variation (Budsberg et al., 1987; Jevens et al., 1993; Riggs et al., 1993; McLaughlin and Roush, 1994; Nordquist et al., 2011). Current guidelines for minimizing variability are to normalize GRF to bodyweight, and to use a narrow velocity range (±0.3 m/s) with controlled acceleration (±0.5 m/s^2) (Riggs et al., 1993; Budsberg et al., 1999b; Bertram et al., 2000). A limitation with these ideas is that supporting experimental work used small, homogeneous populations of normal dogs. Consequently, these recommendations may not be applicable to the heterogeneous dog populations typically found in clinical trials.

Analysis of force platform data across a heterogeneous canine population presents a unique challenge. The standard process of GRF normalization with bodyweight alone appears insufficient to control for all size-dependent variability (Voss et al., 2010). When additional dog-specific morphometric measurements are used for data normalization, significant differences between breeds are still recognized (Voss et al., 2011; Krotscheck et al., 2014). It has been suggested to use breed-matched groups in clinical trials, but this would adversely affect trial recruitment.

Studies investigating the effect of trial velocity have determined that trotting ranges are more sensitive than walking ranges for evaluating lameness (Voss et al., 2007). Currently, no standardized canine trotting velocity range is available. More than ten unique trotting velocity ranges, narrow and wide, have been used in

* Corresponding author. Tel.: +1 608 263 9819.
E-mail address: muirp@vetmed.wisc.edu (P. Muir).

http://dx.doi.org/10.1016/j.tvjl.2014.09.022
1090-0233/

veterinary trials to-date (Rumph et al., 1993; Borer et al., 2003; Ballagas et al., 2004; Lopez et al., 2006; Havig et al., 2007; Voss et al., 2008; Malek et al., 2012; Rialland et al., 2012; Brown et al., 2013; Fahie et al., 2013). The variance effects of these velocity ranges on GRF in a heterogeneous population have not been investigated. Velocity range selection has a potential relationship with trial repetition. Differences in size and body condition may affect an individual dog's ability to trot at a predetermined velocity. Such effects would be most evident with narrow velocity ranges. In lame dogs, these effects may be enhanced, as excessive trial repetition may exacerbate lameness during trial collection, perhaps to the point of limiting trial collection (Evans et al., 2003; Beraud et al., 2010).

The purpose of this study was to determine within a single statistical model the extent to which each model factor (dog subject, trial velocity, trial repetition, and limb [left or right]) contributes to variance in PVF and VI within a heterogeneous population of clinically normal dogs at a trotting gait. The variance effects from 11 unique velocity ranges were analyzed. We hypothesized that dog subject effect would account for the majority of variance in PVF and VI. We further hypothesized that narrow velocity ranges would be associated with less variance, but perform poorly at capturing valid trials.

Materials and methods

Clinical cohort

Force platform gait analysis was performed at the University of Wisconsin–Madison UW Veterinary Care Hospital with approval from the Institute for Animal Care and Use Committee. Medium to large breed client-owned dogs with no history of orthopedic disease were recruited. A veterinarian examined all dogs. Dogs were excluded if an orthopedic abnormality was identified. Gait analysis was performed in 26 dogs. After gait analysis, PVF of thoracic and pelvic limb pairs was examined for significant differences (see Statistical Analysis). If differences in PVF were identified, the dog was excluded. During recruitment, six dogs were excluded for significant differences in PVF. Data from 20 dogs were analyzed for variance effects.

Force platform gait analysis

All trials were collected using a single biomechanical platform that measured three-dimensional forces and impulses (OR6-6-1000 Biomechanics Platform with SGA6-4 Signal Conditioner/Amplifier, Advanced Mechanical Technologies). Velocity was measured by three photoelectric cells mounted 1 m apart. The force platform system was calibrated for measurement of GRF using weights. Photocells were calibrated for measurement of velocity using a pendulum. A handler guided dogs across the platform at their habitual trotting velocity. An observer evaluated each pass to confirm foot strikes and gait. A successful trial was defined by a thoracic limb hitting the platform followed by the ipsilateral pelvic limb with acceleration of ±0.5 m/s^2 at the trotting gait. If a dog was observed to walk across the platform during a trial, then that trial was excluded. If a dog could not perform a minimum of 20 valid trials in a single session the dog was excluded. For each dog, 20–30 trials were collected after habituation to trotting across the force-platform for a short period.

The force platform was connected to commercially available satellite data acquisition system to interface with the computer software used for gait analysis (Acquire v7.30, Sharon Software). Data were sampled at 1000 Hz without filtering. PVF and VI were measured and normalized to percent bodyweight (100 * N/N) by the data acquisition software. PVF was normalized to percent bodyweight with the following equation: $PVF_{\%BW} = PVF/(m * g)$, where m is body mass (kg) and g is gravitational acceleration (9.81 m/s^2). VI was normalized using a similar equation [$VI_{\%BW} = VI/(m * g)$].

Velocity range selection

A PubMed search performed in October 2013 using the following search phrase *'gait analysis + dog'* identified a total of 279 peer-reviewed publications. Articles were reviewed for veterinary studies in which force platform gait analysis was an outcome measure. All velocity ranges were recorded. In total, 15 distinct trotting velocity ranges were identified. Ten described velocity ranges were selected for use in this study based on their overlap with one another (Table 1). A velocity range in use in a clinical trial at the University of Wisconsin–Madison Veterinary Care Hospital was also included. Variance effects associated with the 11 trotting velocity ranges were initially considered. After data acquisition, trials were reviewed and data from valid trials were coded with one or more of the 11 velocity ranges of interest. During statistical analysis, an additional unique velocity range was created based on the initial results and was also analyzed in the statistical model (Table 1).

Table 1
Twelve velocity ranges used for analysis.

Velocity range (m/s)	Source
1.3–1.9	Malek et al., 2012.
1.3–2.1	Fahie et al., 2013
1.5–2.0	Rumph et al., 1993
1.5–2.2	Created after statistical analysis
1.5–2.5	Borer et al. 2003
1.6–1.9	Brown et al., 2013
1.7–2.1	Havig et al., 2007
1.8–2.2	UW-Madison clinical trial in progress
1.8–2.8	Lopez et al., 2006
1.85–2.15	Voss et al., 2008
1.9–2.2	Rialland et al., 2012
2.0–2.5	Ballagas et al. 2004

Statistical analysis

During initial screening of dogs, PVF for five trials from left and right limb pairs obtained at velocities that most closely approximated the mean for each dog were analyzed using Student's t test for paired data. Repeated-measures analysis-of-covariance was then used to analyze force platform data. Initially, dog, trial number, limb (left or right), and velocity were analyzed for significant contribution to data variance. Subsequently, the variance effects of the 12 velocity ranges of interest were examined in the statistical model. The effect size of each factor in the model was calculated. Post-hoc analysis was performed using Tukey's test. All analyses were performed using computer software (STATA v13.1, College Station, TX). Data were reported as means ± standard deviation (SD). Results were considered significant at $P < 0.05$.

Results

Clinical cohort

Data from 20 dogs were studied. All dogs were >1 year of age. Mean bodyweight was 28.4 ± 7.4 kg (range 18.5–46.2 kg). Breeds included were Labrador Retriever ($n = 3$), Springer Spaniel ($n = 2$), Siberian Husky ($n = 2$), and one each of Alaskan Malamute, Australian Shepherd, Samoyed, Belgian Malinois, Chesapeake Bay Retriever, Golden Retriever, Doberman, Border Collie, and German Pointer. Remaining dogs were mixed breeds ($n = 4$). Eight dogs were neutered males, three dogs were male, eight dogs were spayed females, and one dog was female.

Effect of velocity range on trial capture

A total of 586 trials were obtained. The mean number of trials collected per dog was 29.3 ± 2.3. The mean habitual trotting velocity of each dog ranged from 1.67 ± 0.12 m/s to 2.44 ± 0.22 m/s. The mean velocity for all trials was 1.95 ± 0.24 m/s. In general, narrow velocity ranges captured a smaller proportion of trials per dog compared to wider velocity ranges (Table 2). The velocity range that captured the greatest number of trials was 1.5–2.5 m/s, with 558 of 586 (95.2%) total trials. The mean proportion of trials captured per dog for this velocity range was 94.5 ± 10.7%. The velocity range that captured the least number of trials was 2.0–2.5 m/s, with 195 of 586 (33.3%) total trials. The mean proportion of trials per dog for this velocity range was 33.8 ± 27.9%. In total, six velocity ranges captured greater than 50% of trials per dog: 1.5–2.0 m/s, 1.7–2.1 m/s, 1.5–2.5 m/s, 1.8–2.8 m/s, 1.3–2.1 m/s, and 1.8–2.2 m/s. A novel range created during statistical analysis, 1.5–2.2 m/s, also captured greater than 50% of trials per dog. Mean PVF and VI varied across all velocity ranges (Table 2).