Intro to Force Plate Gait Analysis

How can we tell if a dog is lame?


EXAM
15

Question

- How do we determine if a leg is lame?
  - 1 leg is easy
  - More than one….almost impossible

Correlation between visual gait evaluation and force plate gait analysis in naturally lame dogs

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Objectives: To determine the sensitivity and accuracy of visual gait exam by two board certified veterinary surgeons, using Force plate Gait Analysis (FPGA) as the gold standard. Sensitivity was defined identification of the presence of lameness and accuracy was defined as identification of the lamest leg.

Study Design: Prospective, blinded

Animals: Dogs were 37 healthy adult client ov
Thirteen were identified as lame by FPGA, eight
identified as lame by at least 1 observer. See Tabl

Table 1: Group A: Sound by FPGA; Group B: Lame

FPGA data	# dogs (f/s; m/c)	Age (yrs) Avg (range)	Bc Av
Normal	24 (11; 13)	3.92 (1-11)	27
Abnormal	13 (8; 5)	5.15 (1-11)	26.1 (20.6-38.8)
Total	37 (19; 18)	4.35 (1-11)	27.2 (19.7-38.8)

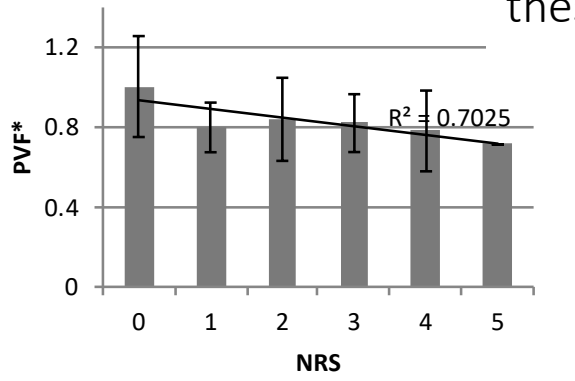
Subjective Methods: Both surgeons silently observed one dog at a time while the dog was trotted then walked across the force plate. Observers were blinded to the animal's history and were not informed of FPGA results. Two scales were used to record findings. The Visual Analog Scale (VAS) was 10 cm in length and marked "sound" on the left and "could not be more lame" on the right. Modified Sumner Smith Numerical Rating Scale (NRS) was as follows: 0) Sound; 1) Occasionally shifts weight; 2) Mild lameness in either walk or trot; 3) Mild lameness in both walk and trot; 4) Obvious but mild lameness, always weight bearing; 5) Mid-grade lameness with toe touching; 6) Severe lameness, foot is held up at some point; 7) Foot never touches ground during movement or standing.

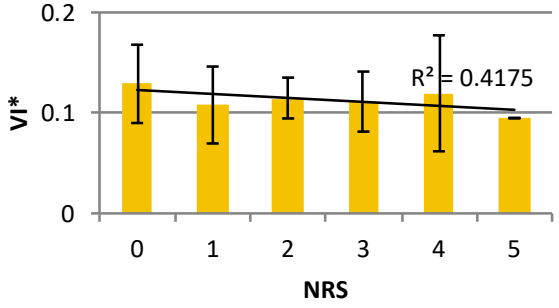
Objective Methods: Vertical ground reaction forces (GRFs) were measured using two serial force plates (Force plate model 9281B, Kistler Instrument Corporation, Amherst, NY). Data was collected at the trot, then at the walk. Velocity goals were 2 m/s for the trot and 1 m/s for the walk but these were customized to the natural pace of each dog. Five trials saved that were within +/- 0.1 m/s of the mean for that dog. A computer program (Bioware, Kistler Instrument Corporation) reported GRFs including peak vertical force (PVF), vertical impulse (VI), and contact time (CT) for each trial and calculated means for each. Symmetry indices were calculated for fore- and hind limbs separately (most lame / least lame) and considered asymmetric when this value was 10% different from that calculated from a population of 67 sound dogs using the same protocol described here.

Results: Pearson's correlation was used to
agreement between continuous variables (VAS, fo
measurements) and Spearman's rho was used to
agreement between the ordinal variable NRS a
variables. A moderate correlation was defined as ar
value of 0.6-0.79 and a strong correlation was defi
absolute value >0.8.

In cases where observers did n
lameness (NRS = 0), the
difference by FPGA was 12.5%.

separately with 1 value for each Observer.





Observer 1 identified the most lame forelimb in 4/4 (100% accuracy) and Observer 2 identified the most lame forelimb in 3/4 (75% accuracy). Both observers correctly identified the most lame hind limb in 3/6 dogs (50% accuracy) but only agreed with each other on 2 of these.

Clinically, the visual gait exam should always be coupled with the animal's history and full palpation exam, and radiographs or other imaging modalities to further hone diagnoses. FPGA is most indicated as an objective tool to aid in identifying mild unilateral lameness or to following progression in chronic or post-operative cases.

Selected References:

Evans R, Horstman C, Conzemius M: Accuracy and optimization of force platform gait analysis in Labradors with cranial cruciate disease evaluated at a walking gait. *Vet Surg* 34:445-449, 2005.

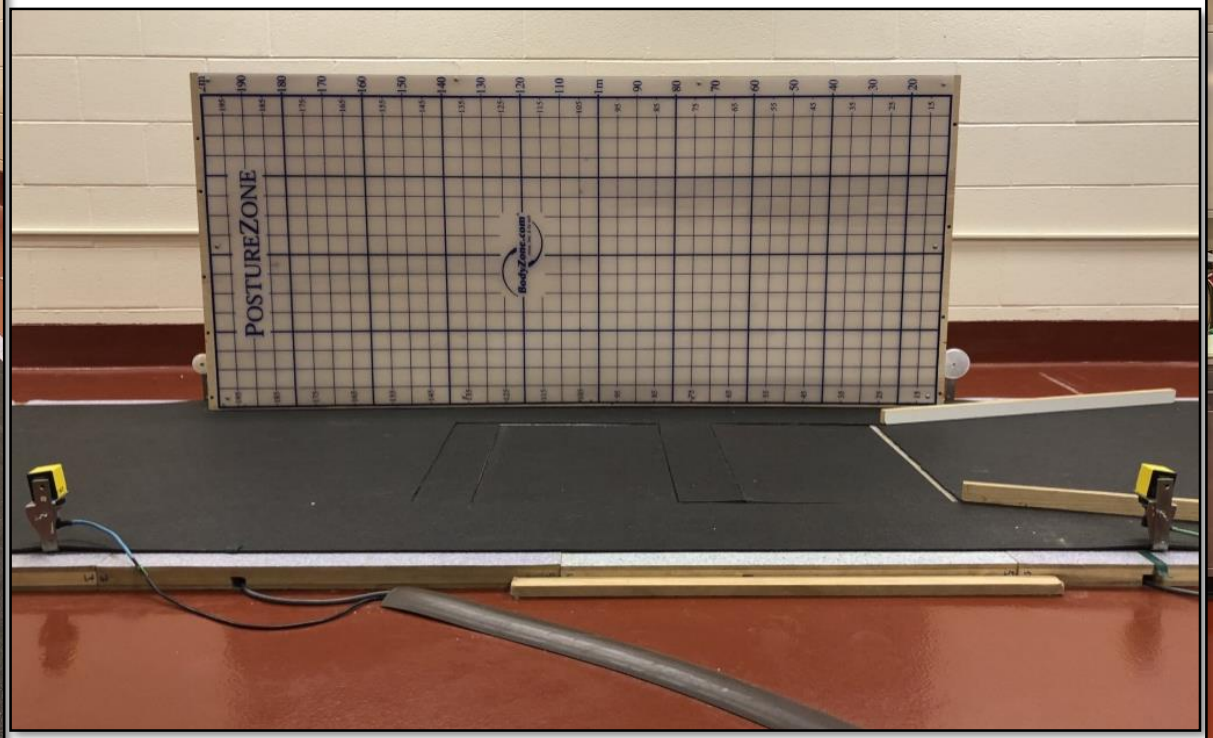
Quinn, MM, Keuler NS, Lu Y, Faria MLE, Muir P, Markel MD: Evaluation of agreement between numerical rating scales, visual analogue scales, and force plate gait analysis in dogs. *Vet Surg* 36: 360-367, 2007.

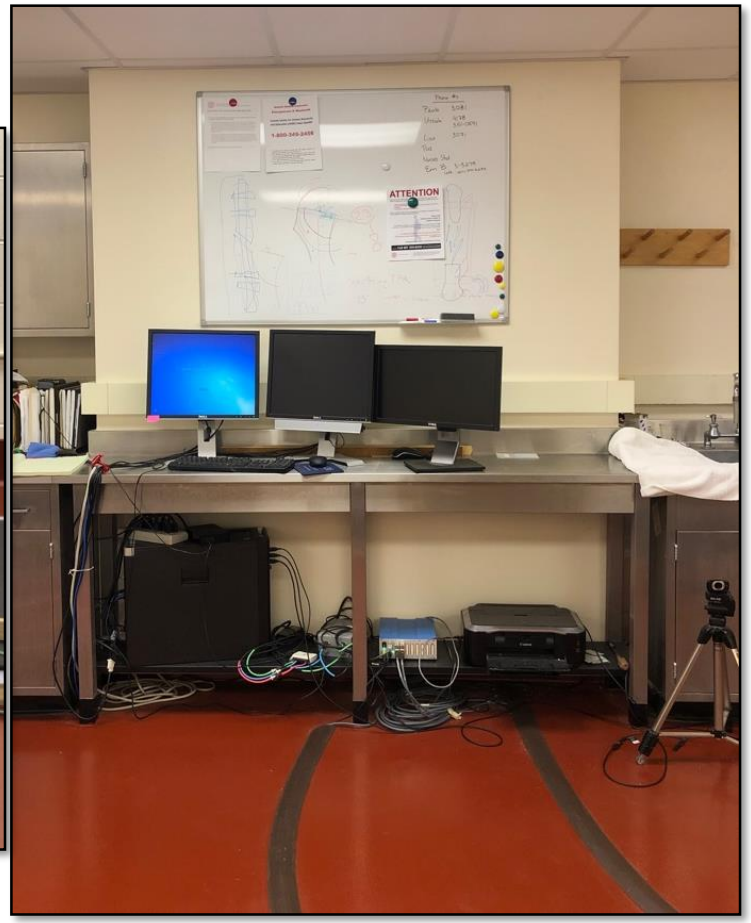
Voss K, Galeandro L, Wiestner T, Haessing M, Montavon PM: Relationships of body weight, body size, subject velocity, and vertical ground reaction forces in trotting dogs. *Vet Surg* 39: 863-869, 2010.

Voss K, Imhoff J, Kaestner S, Montavon PM: Force plate gait analysis at the walk and trot in dogs with low-grade hindlimb lameness. *Vet Comp Orthop Traumatol* 20: 299-304, 2007.

Waxman AS, Robinson DA, Evans RB, Hulse DA, Innes JF, Conzemius MG: Relationship between objective and subjective assessment of limb function in normal dogs with an experimentally induced lameness. *Vet Surg* 37: 241-246, 2008.

Force Plate Gait Analysis





[1]Portable Multi-component Force Plate Type 9286AA, Kistler Instrument Corp, Amherst, NY USA; [2]MATLAB, MathWorks, Inc., MA

Force Plate Gait Analysis

- Performed at walk and trot
  - Minimum of 5 acceptable trials
    - Good paw strikes, no distractions or pulling
  - Controlled velocity with dual-photocell system:
    - Walk (0.75 – 1.25 m/s)
    - Trot (1.75 – 2.25 m/s)
- Real-time processing with video and custom software[2]

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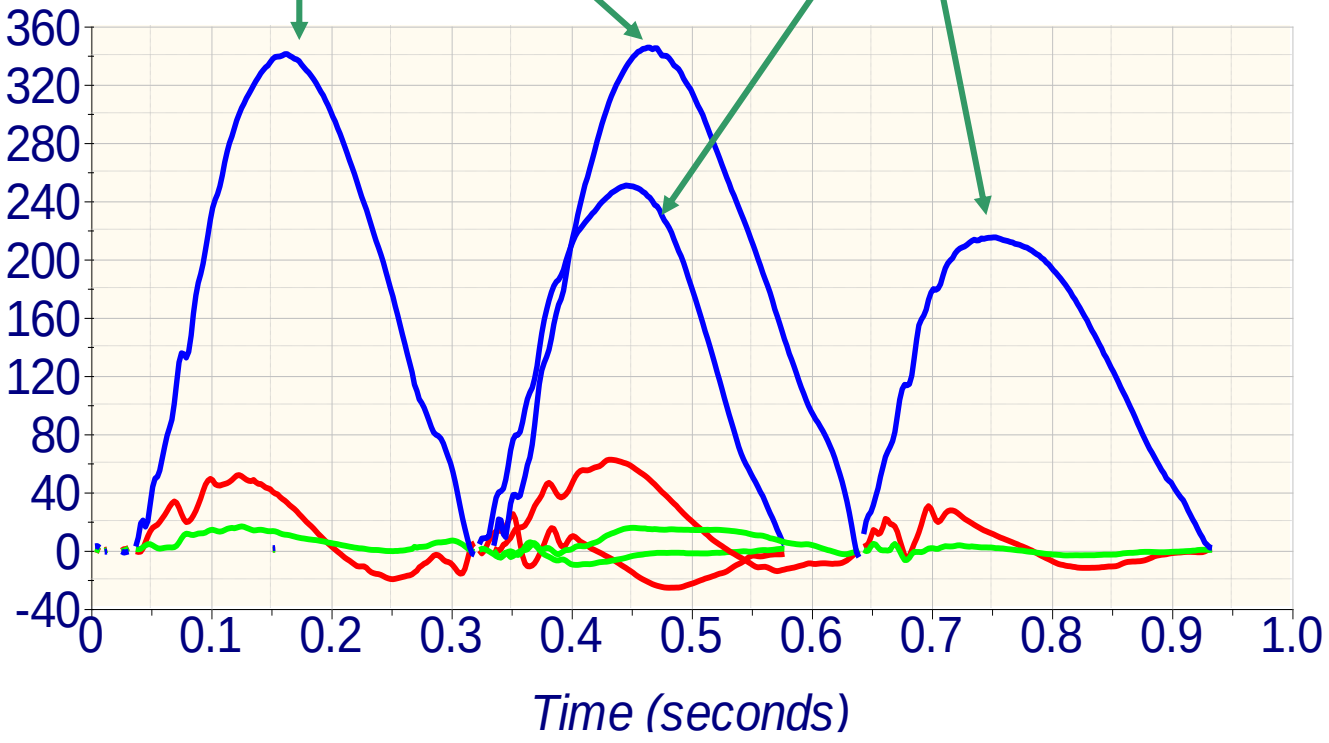
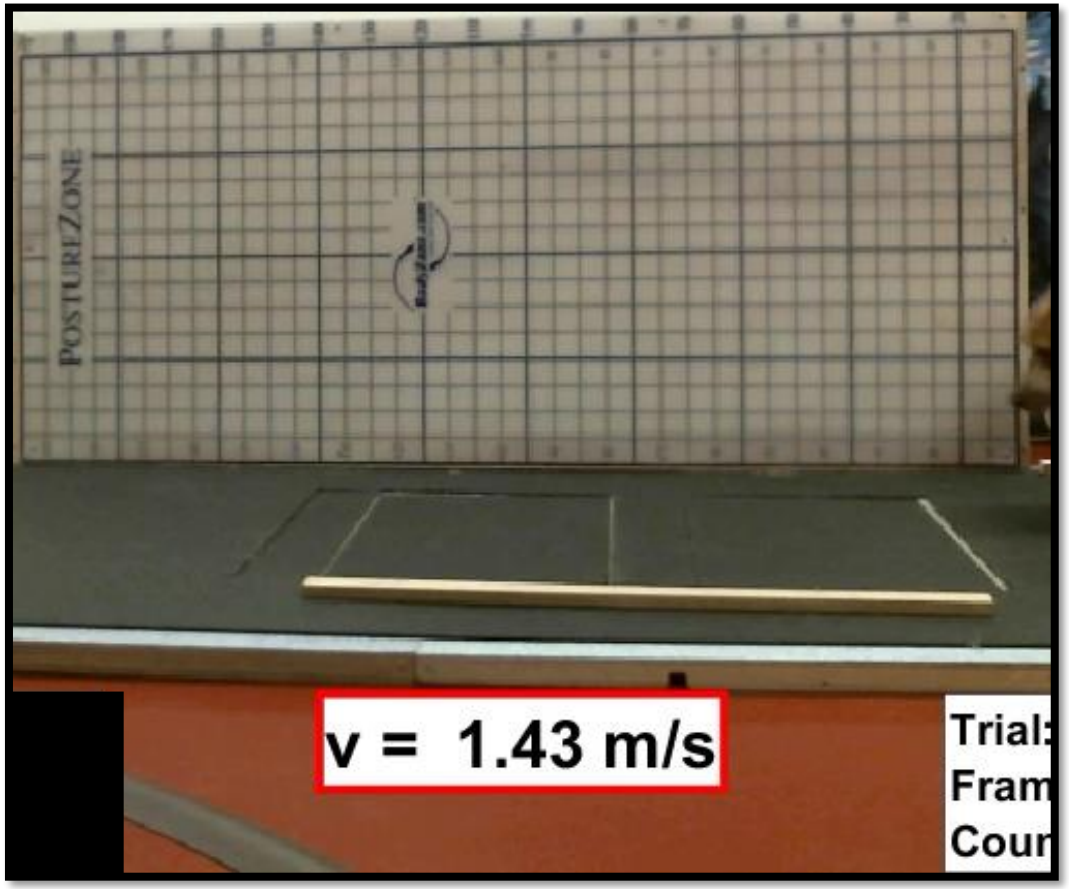
Forelimbs (Plate #1 then #2)

Hindlimbs (Plate #1 then #2)

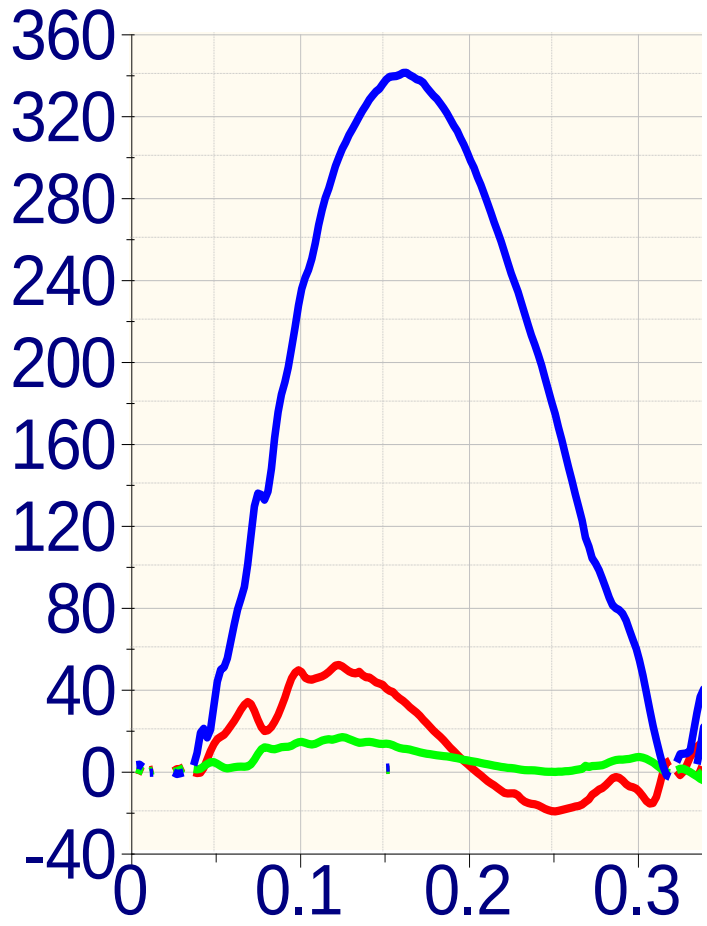




All data acquisition occurs during a single session for each dog

Ground Reaction Forces (GRFs)

- Peak vertical force (PVF_{BW})
  - normalized to weight (N/N)
- Vertical impulse (VI_{BW})
  - normalized to weight (N/N)
- Contact time (s)
- Rising slope (RS)
- Falling slope (FS)



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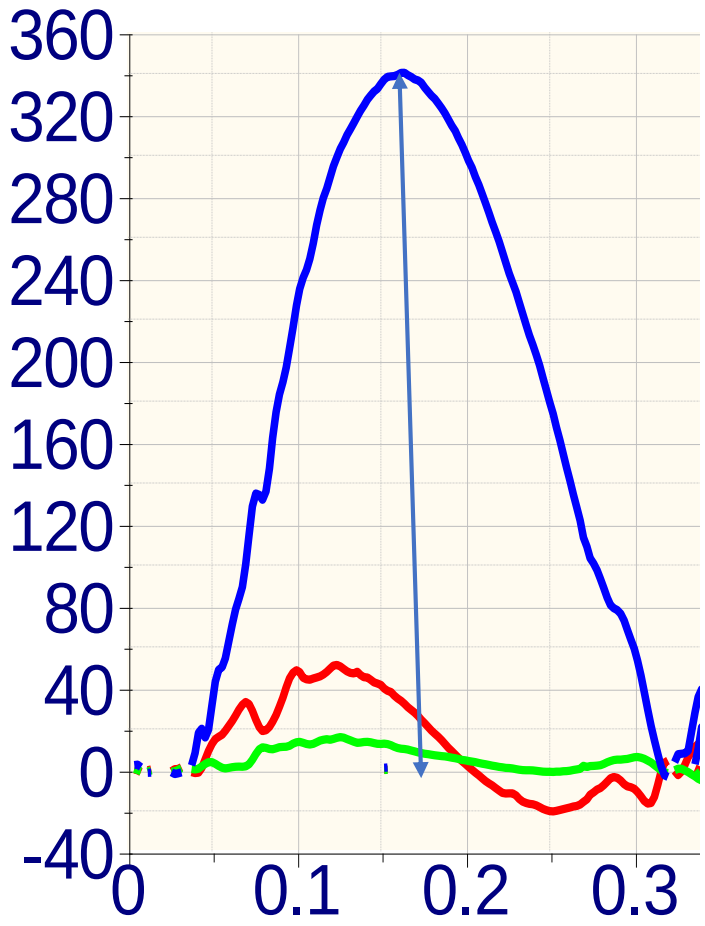

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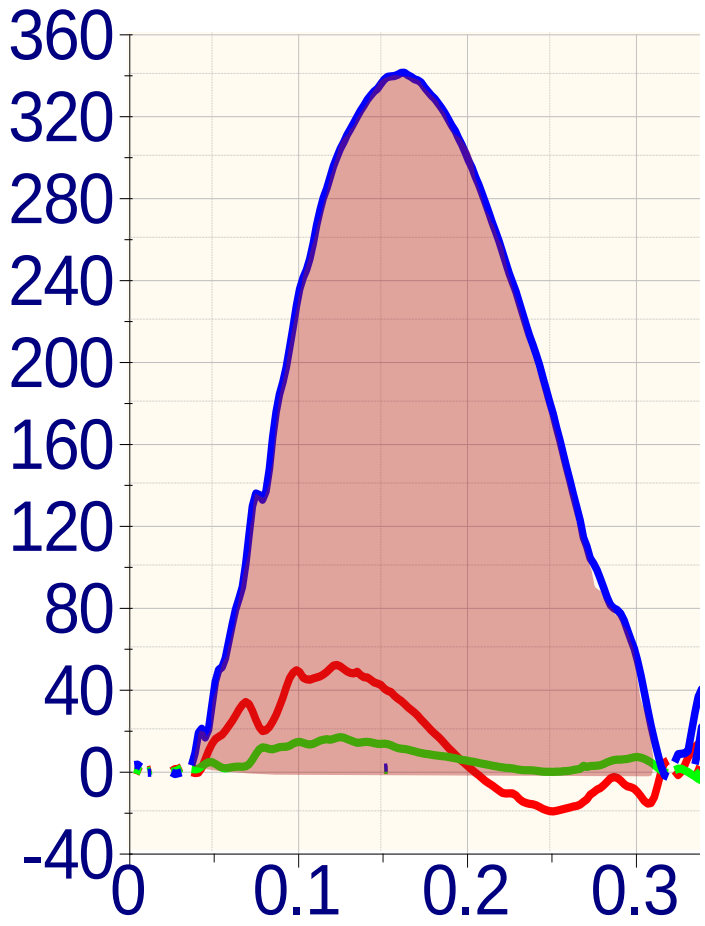

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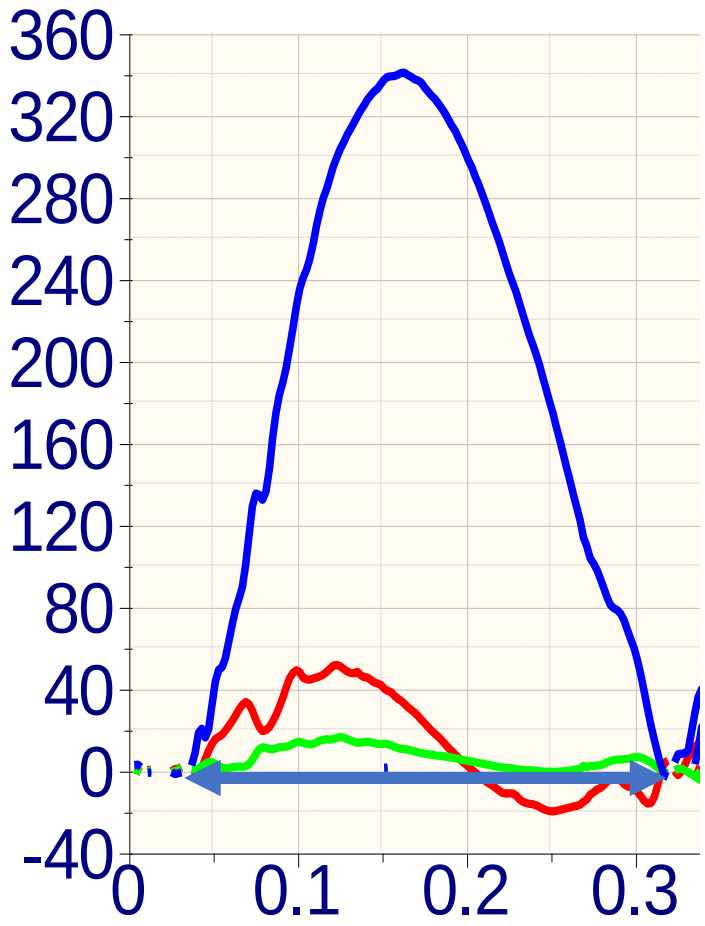

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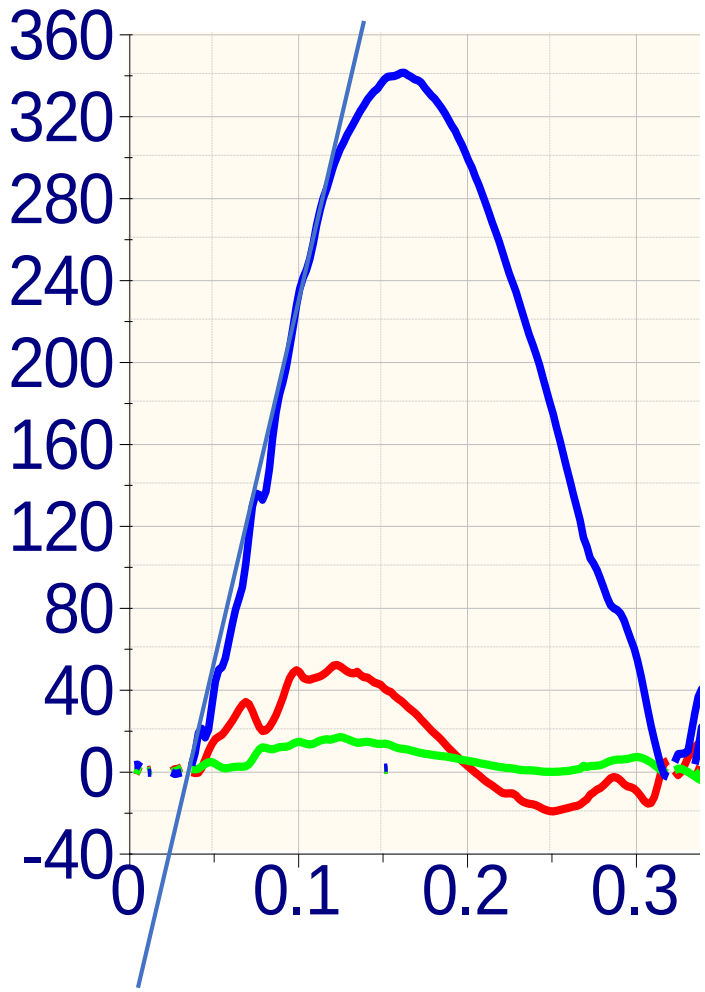

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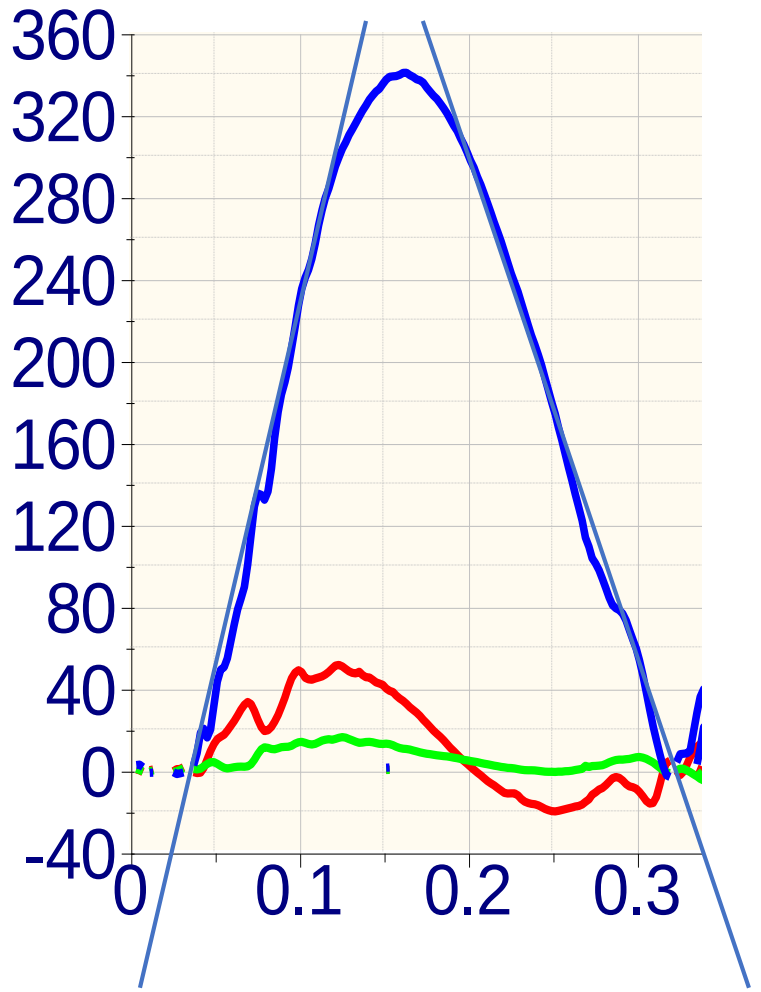
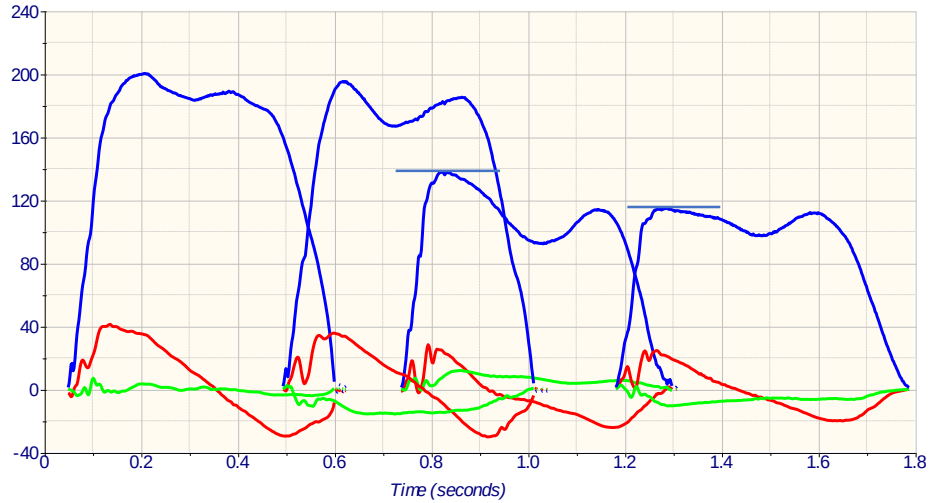


Force Plate Gait Analysis

- Symmetry Index
  - Appropriate ONLY IF if ALL other limbs normal



$$SI = \frac{1}{n}\sum_{k=1}^{n} R_k / L_k w_k$$

SI = symmetry index

n = number of trials

R_k = mean of the right (or operated) limb measurement

L_k = mean of the left (or unoperated) limb measurement

w_k = weighing factor (=1 in normal level locomotion)

Budsberg SC et al. Am J Vet Res 1993;54:1569-1574.

Symmetry Index Validation

- Normal dogs (n=69) and dogs with unilateral CCL (n=40)
- Methods
  - Pelvic limb GRFs of orthopedically normal dogs and those with unilateral ruptured CCL were collected
  - Normalization methods included:
    - None
    - Body weight (BW), Withers height (WH), WH and relative velocity (WH*F)
    - Principal component 1 (PC1)
  - Binary logistic regression was performed for all normalization methods
    - Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) calculated
  - Stepwise backward logistic regression was used; significant values were retained in the final model. $P < .05$ was significant.
- Results
  - Normalization of contact time (CT) by BW uniformly increased sensitivity, specificity, PPV, NPV, and accuracy
  - **SI was the most accurate at both the walk and trot (accuracy 80–96%)**
  - Normalization by BW, WH, and WH*F all achieved similar results

Krotscheck U, Collins S, Sutter N, Mohammed H, Todhunter R. Precision and accuracy of ground reaction force normalization in a heterogeneous population of dogs. Vet Surg 2014; 43: 437-445.

Can Machine Learning be used?

- Is a leg normal?
  - Binary outcome: Yes/No
- Degree of abnormality?
  - Goal: can we see progression over time?

Groups

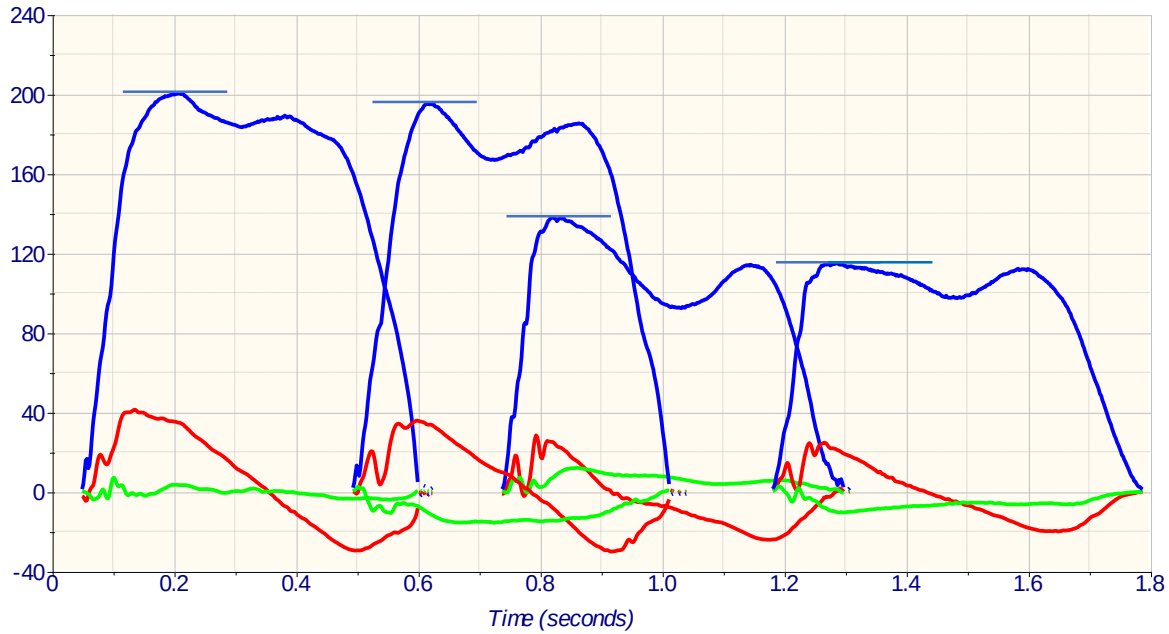
- Normal Control: (n=~80)
- Affected: 117 affected dogs
    - 1-4 limbs affected
- Normal Control: 71 dogs
    - 4 normal limbs
- Gait analysis at walk and trot (for most)

Force Plate Gait Analysis

- Proportional GRF calculated for PVF and VI

$$pGRF = \left(\frac{GRF\ affected\ limb}{GRF_{RF}+GRF_{LF}+GRF_{RR}+GRF_{LR}}\right) * 100$$

RF_{GRF} = Mean GRF of right front
LF_{GRF} = Mean GRF of left front
RH_{GRF} = Mean GRF of right hind
LH_{GRF} = Mean GRF of left hind



Steiss AJVR 1982, Abdelhadi AJVR 2013, Galindo-Zamora Vet Surg 2014