

Canine Gait Analysis



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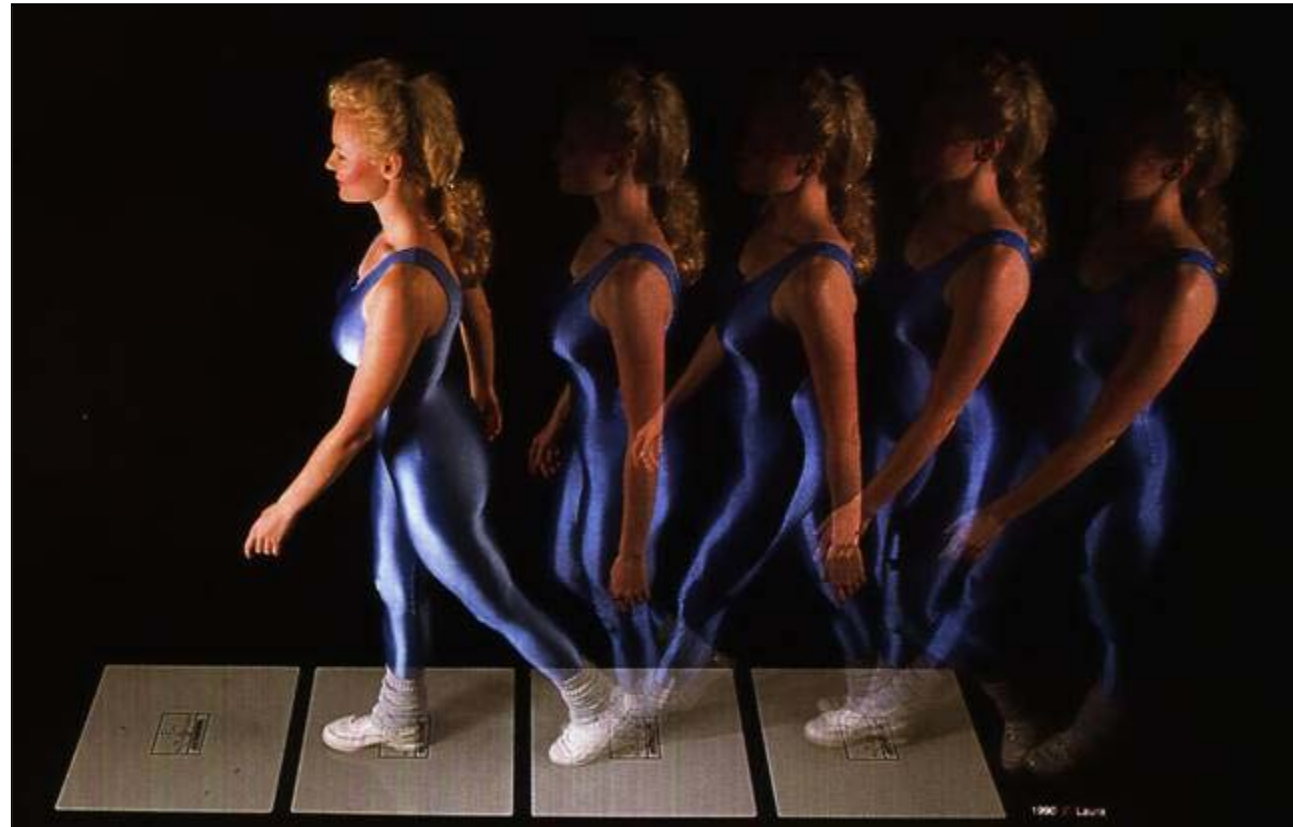
Gait

The manner of walking on foot or a sequence of foot movements

Analysis

↑ Subjective

↑ Objective



Kinesiology



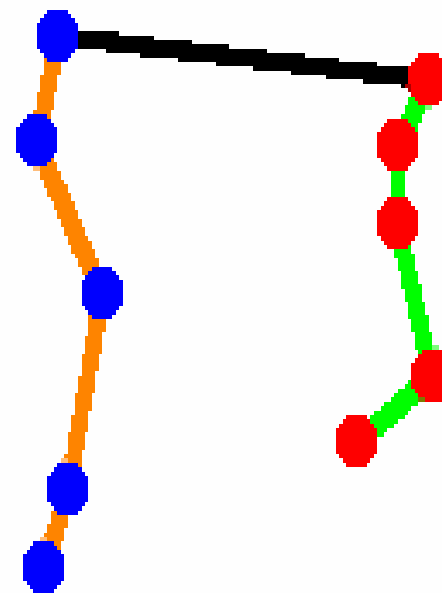
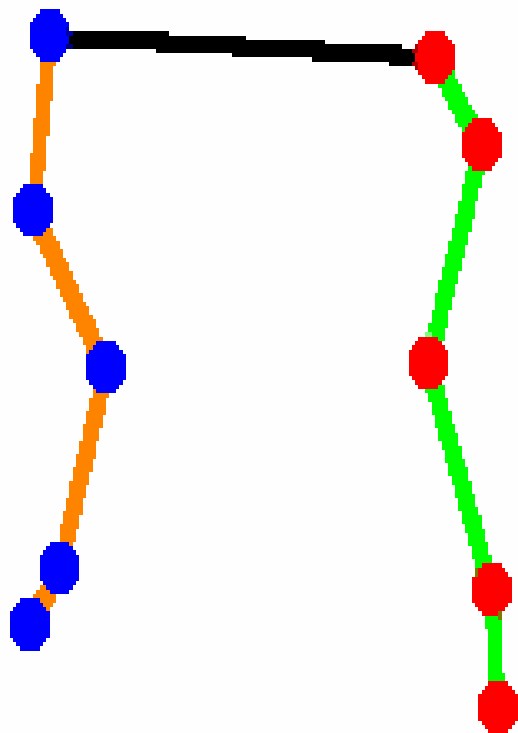
Kinematics

- ↑ Temporal and geometric characteristics of motion
- ↑ Cinematography, electrogoniometry and accelerometry

↑ Kinetics

- ↑ Forces that produce, stop or modify motion
- ↑ Force plate or force shoe

Wire Frame Walk and Swim



Force Sensors



- Piezoelectric

- generates an electric charge when subjected to mechanical strain, usually quartz
 - Kistler

- Strain Gauge

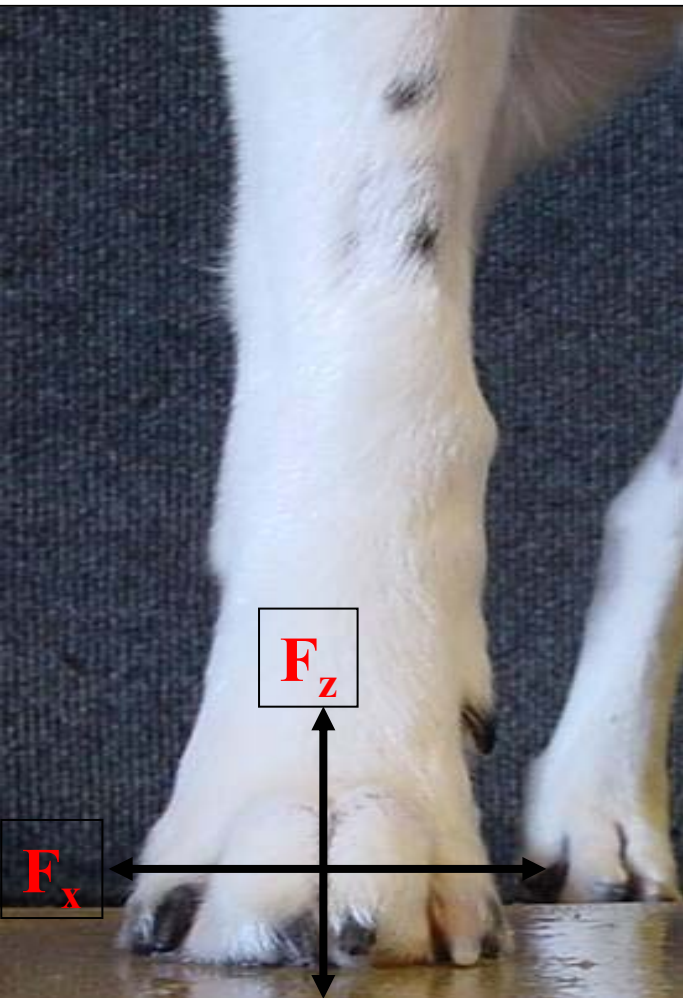
- Uses Ohms Law ($V=IR$) to calculate resistance in a material. Deformation in the material causes a change in the resistance and thus a change in voltage.
 - AMTI

Force Platforms



- Ground Reaction Force (GFR)-force that the ground pushes on the body during contact
- Force Vector-has a magnitude and direction
 - F_x -medial-lateral shear
 - F_y -anterior-posterior braking or acceleration
 - F_z -force that pushes the body vertically
- Normalized-GFR are often divided by the patients body weight for easier comparison

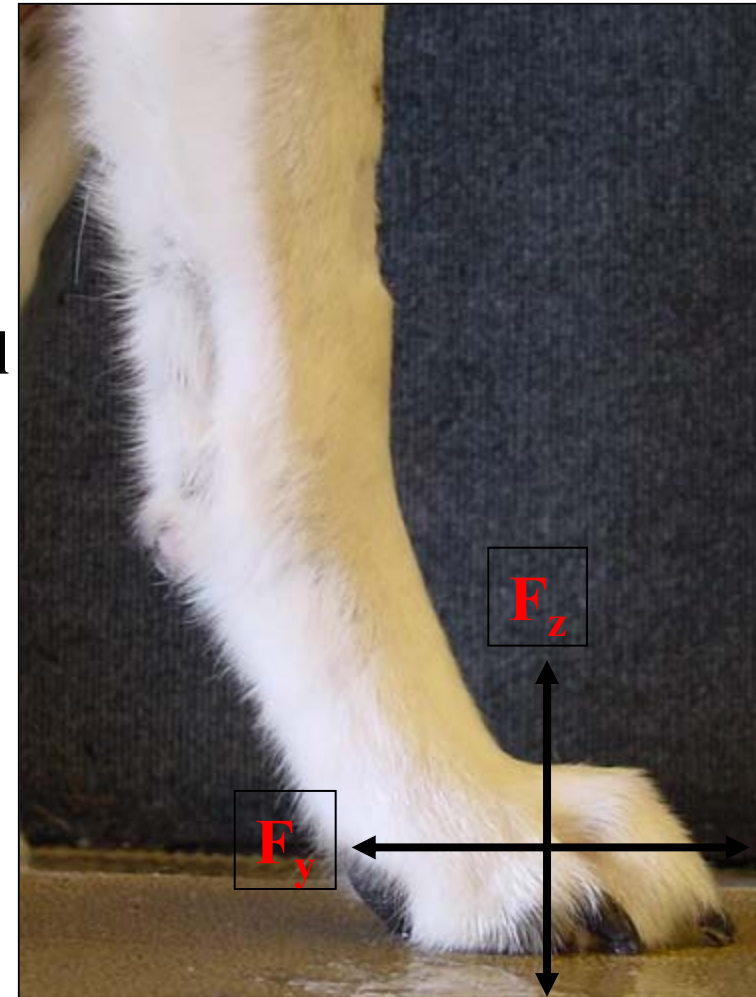
Ground Reaction Forces



F_x -Mediolateral

F_y -Craniocaudal

F_z -Vertical



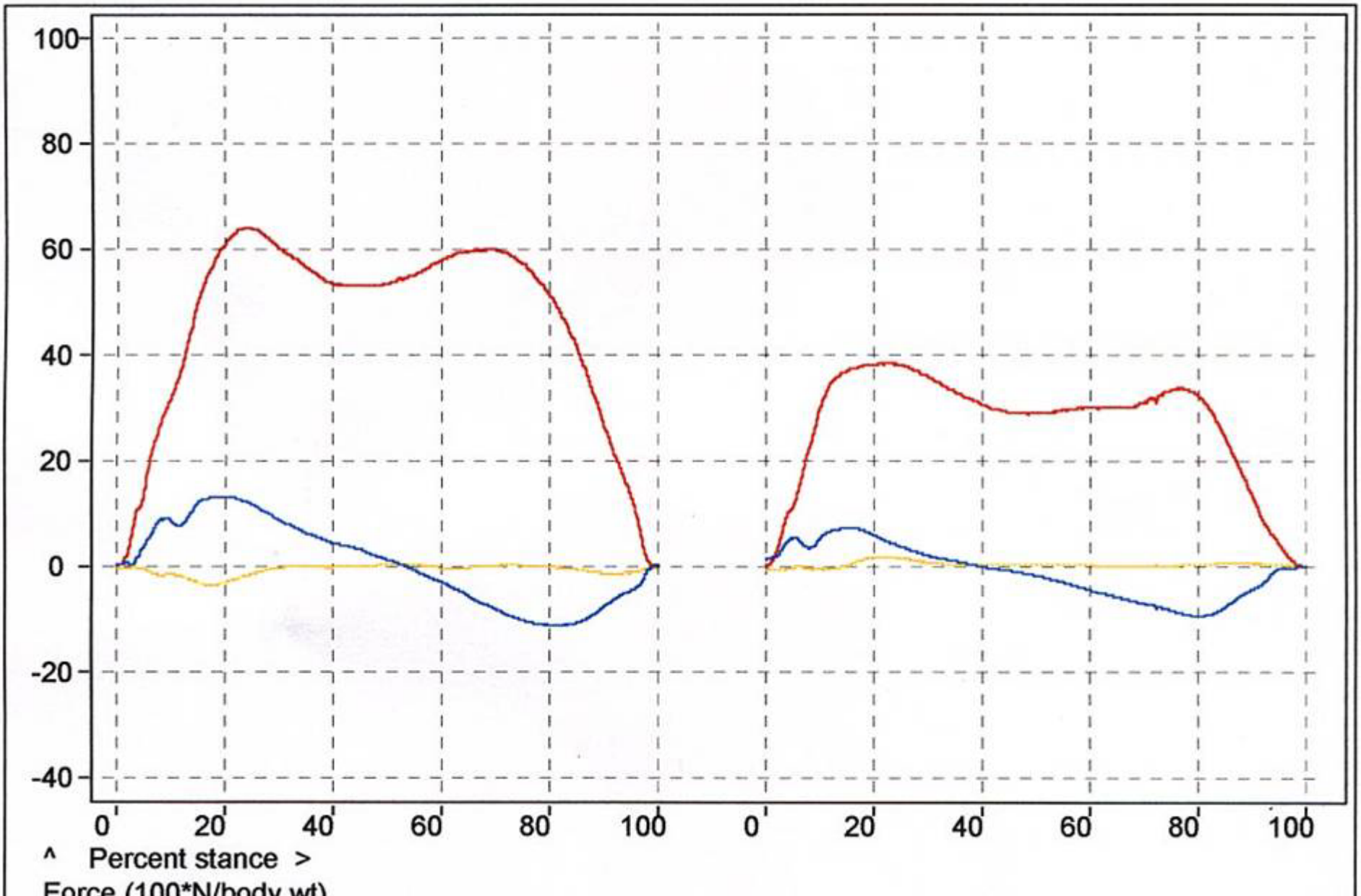


Valid Trial



- AMTI force platform with Sharon software.
- Velocity range: 1.0 to 2.5 m/s (range <0.3 m/s)
- Acceleration range: -0.5 to 0.5 m/s²
 - ⌘ (recorded using 3 photoelectric cells connected to computer & software)
- PVF and VI are collected for all limbs
 - ⌘ data represented as mean of first 5 valid trials
 - ⌘ a valid trial consists of a forelimb strike with the complete foot striking the pad and no other foot being on the pad at the same time followed by an ipsilateral hind foot strike in the same fashion.

z-force
x-force
y-force



Traditional Numbers Used

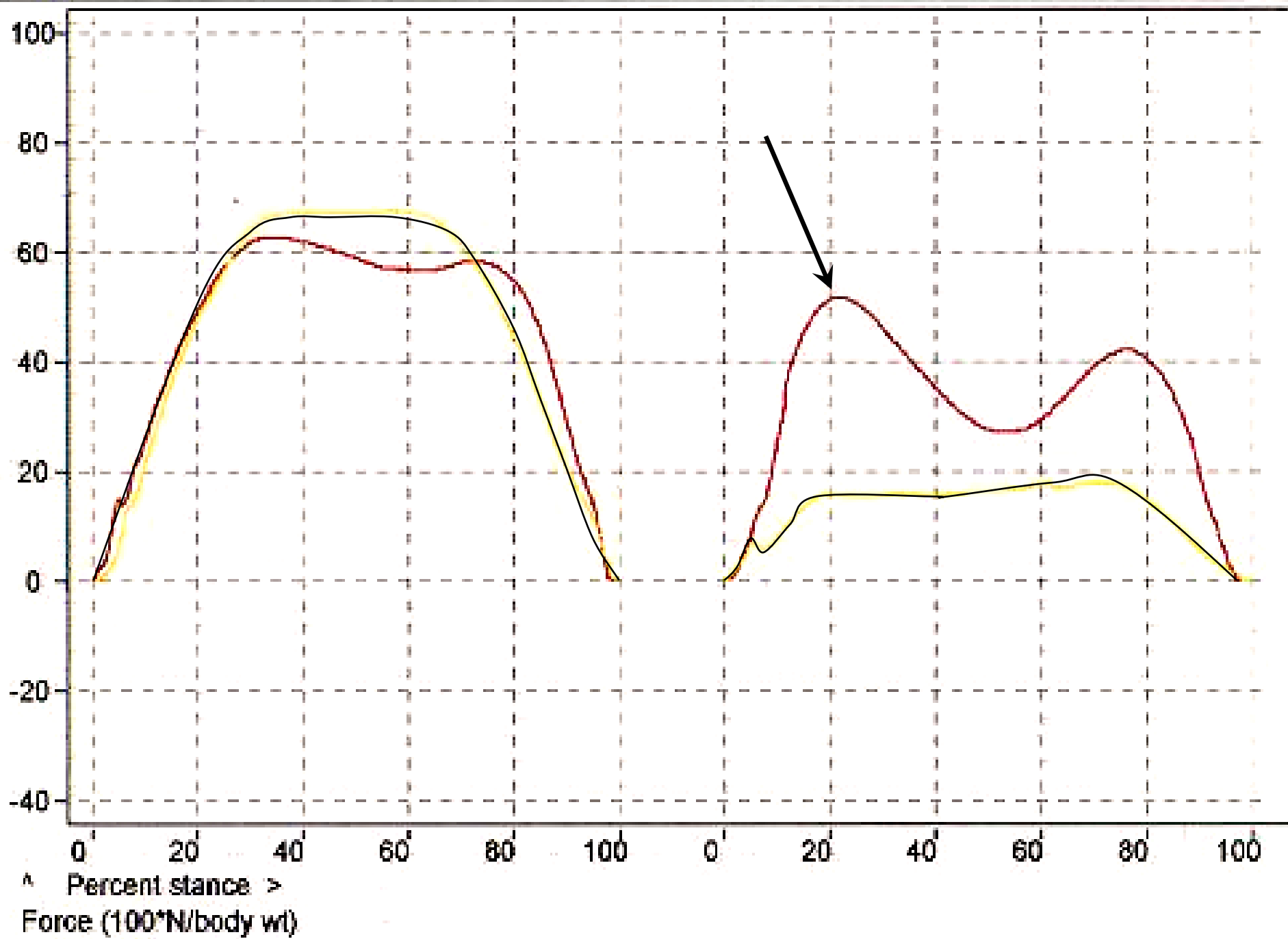


- Peak Vertical Force (PVF)
 - $f = 1200$ Hz
 - PVF (Z-peak) is the single largest force
- Vertical Impulse (VI)
 - area under a force by time curve
 - Z-Impulse is single most reliable description of limb function
 - Y-Impulse can be integrated to determine subject acceleration

Numbers that aren't used



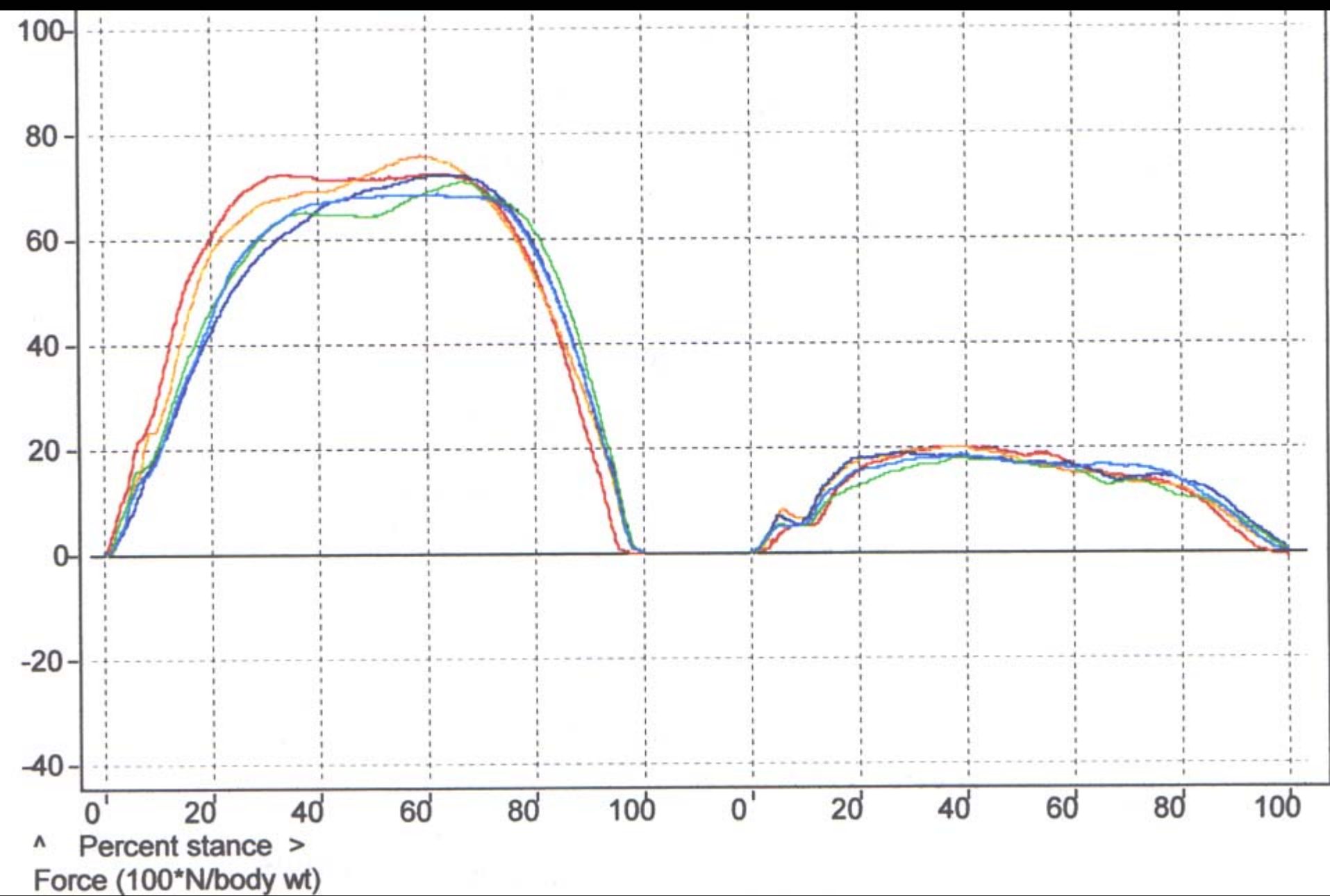
- Rate of Loading
 - slope of force curve; related to injury predisposition
- Free moment
 - torque that resists foot twisting about a vertical axis
- Coefficient of Friction
 - resultant shear force/normal force
- Center of Pressure
 - projection on the platform of the center of the vertical force distribution, used to calculate **joint moments**

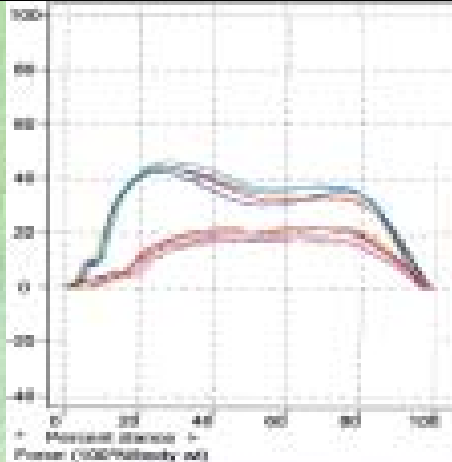


Points of Concern



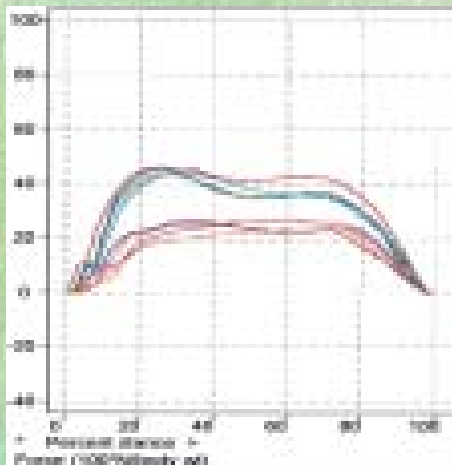
- Number of trials
- Confirmation of footfalls
- Gait velocity and trial variation
- Torso velocity vs. limb velocity
- Statistically, what is a trial?





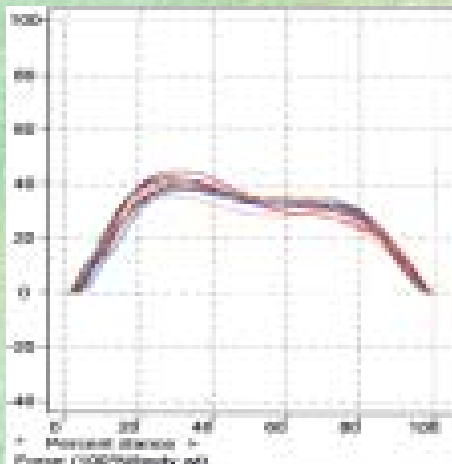
↑ Pre-Surgical

↑ Left	PVF = 19.47	VI = 6.19
↑ Right	PVF = 46.14	VI = 16.32



↑ 6 week Post-Surgery

↑ Left	PVF = 26.09	VI = 7.76
↑ Right	PVF = 39.71	VI = 13.19



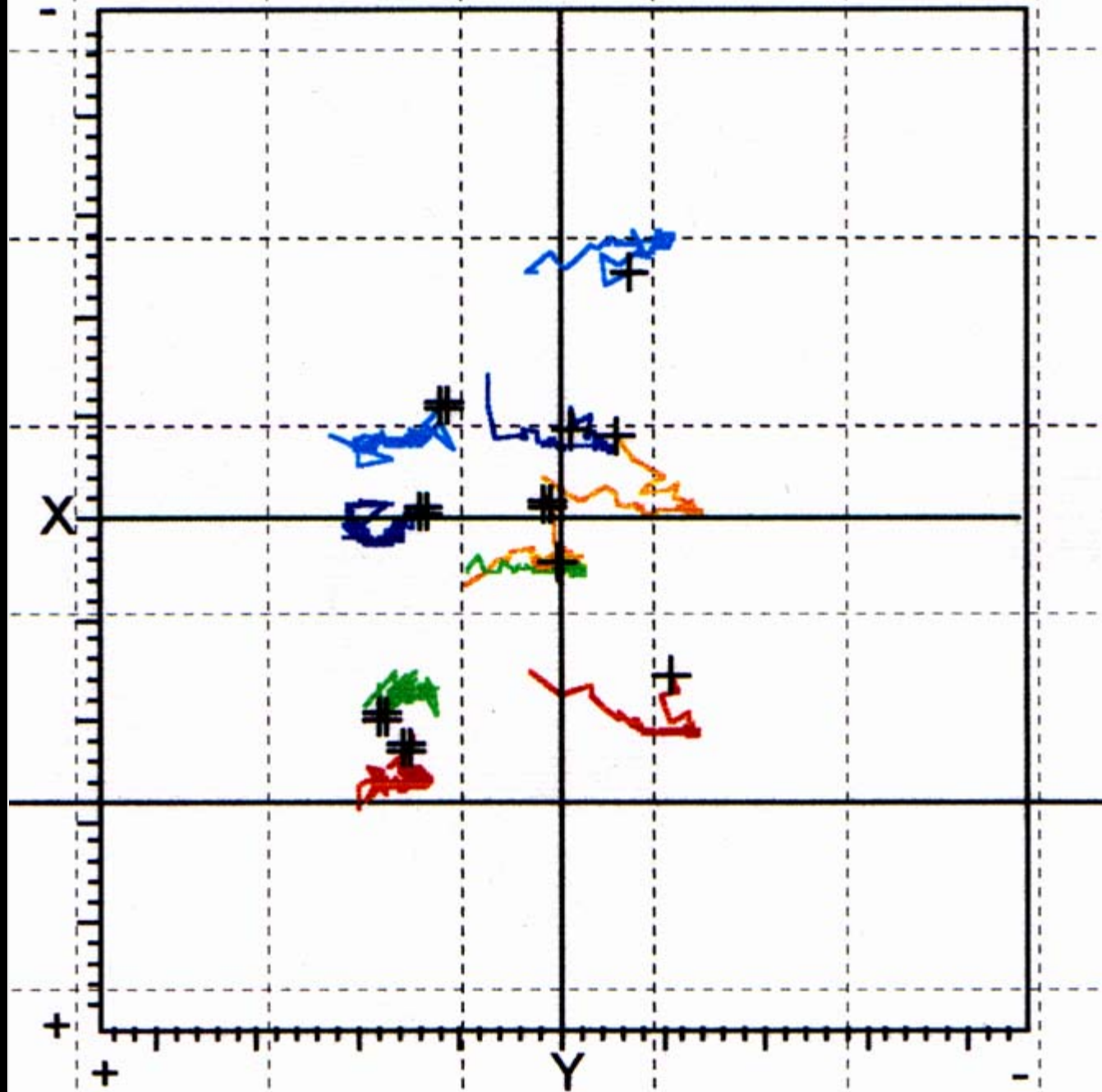
↑ 6 Month Post-Surgery

↑ Left	PVF = 40.80	VI = 12.24
↑ Right	PVF = 39.55	VI = 11.15

Confirmation of Footfalls



- Videotape of all attempts
 - time consuming to perform and review
- x vs. y graph
 - simple, fast, reliable



Walk vs. Trot



- What is the ideal velocity for clinical gait analysis
 - minimize trial variation
 - includes as many cases as possible
 - challenges the affected limb (trot is more “vigorous”)
- Budsberg et al. Force plate analysis before and after stabilization of canine stifles for cruciate injury, AJVR 1988.
 - Perform analysis, “during a walking gait”

Walk vs. Trot



- Budsberg et al. Evaluation of limb symmetry indices, using ground reaction forces in healthy dogs, AJVR 1993.
 - Two velocities: 1.25-1.55 and 1.85-2.05
 - "symmetry data in dogs at both velocities revealed no significant differences for a given velocity"
 - >97% of variance due to trial variation
- McLaughlin et al. Effects of increasing velocity on braking and propulsion times during force plate gait analysis in Greyhounds, AJVR 1995
 - Five velocities evaluated
 - "..no significant differences in the percentage of contact time spent in braking and propulsion between the walk and the trot gaits.."

Walk vs. Trot



- Gordon et al. "Effect of gait velocity on trial variation in dogs with naturally-occurring lameness."
 - Trial variation significantly increases as velocity increases
 - As severity of lameness increases trial variation increases
 - Number of trials at a trot was twice as great as a walk
 - 25% of dogs couldn't achieve 5 valid trials w/ 140 trial cut-off
- Ideal gait analysis in clinical studies
 - perform both walk and trot although ideal is too time consuming

Torso vs. Limb Velocity



- As limb velocity \downarrow stance time \uparrow
- This will proportionally \uparrow vertical impulse
a measure of (force x stance time)
- Velocity options
 - “gated” area measured with timing sensors
 - speedometer
 - calculation from continuous footfalls



-Even with similar torso velocity as body size \uparrow limb velocity \downarrow .

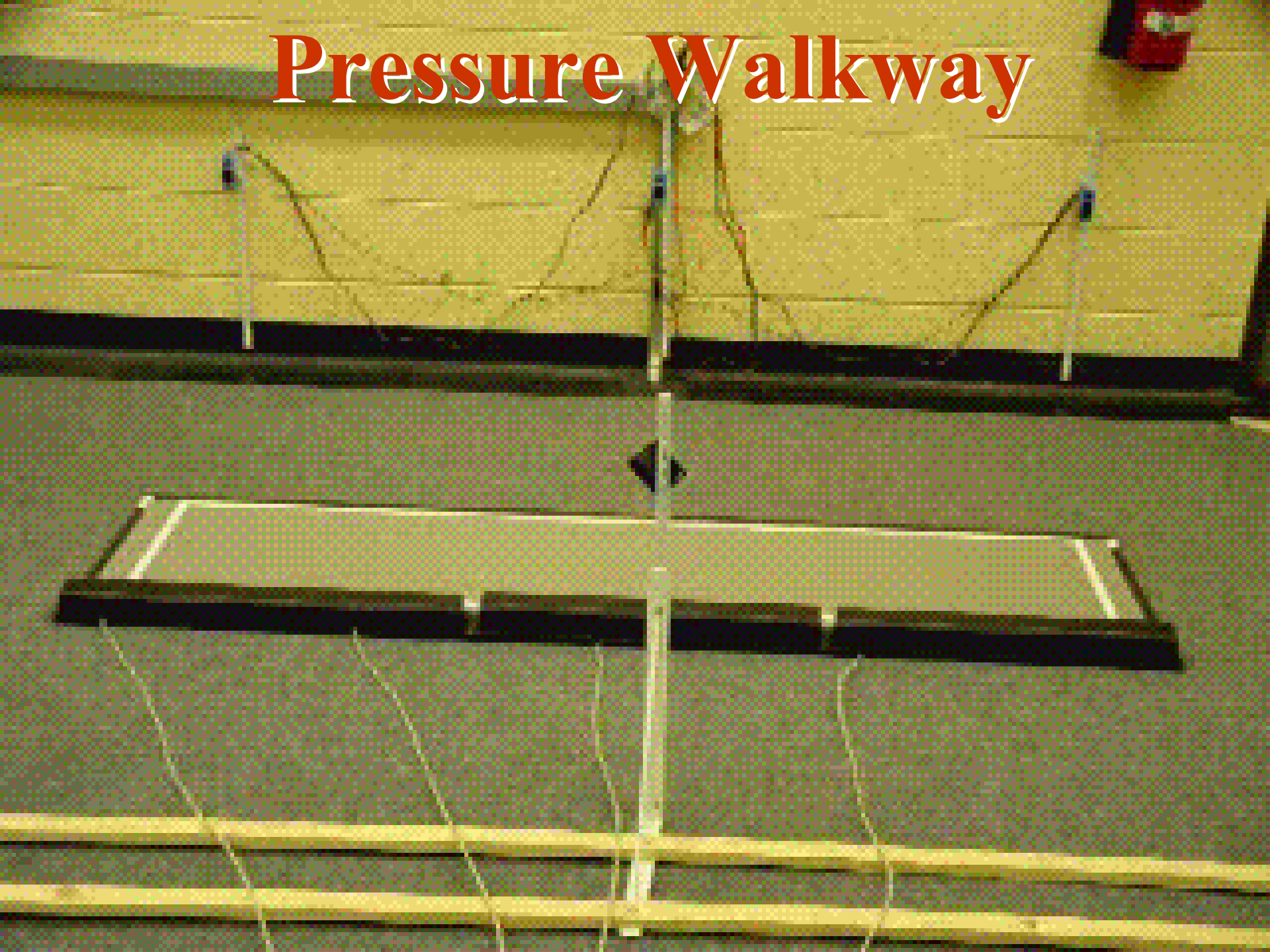
-Even with gait data normalized to body weight, dogs of a similar size should be compared. Dogs should be group into weight categories.

What is a trial?



- Canine gait is function of all 4 limbs
- Traditional trial collects 1/2 of data to describe gait
- Need to measure continuous footfalls
 - multiple force platforms
 - pressure walkway

Pressure Walkway



Pressure Walkway



Advantages

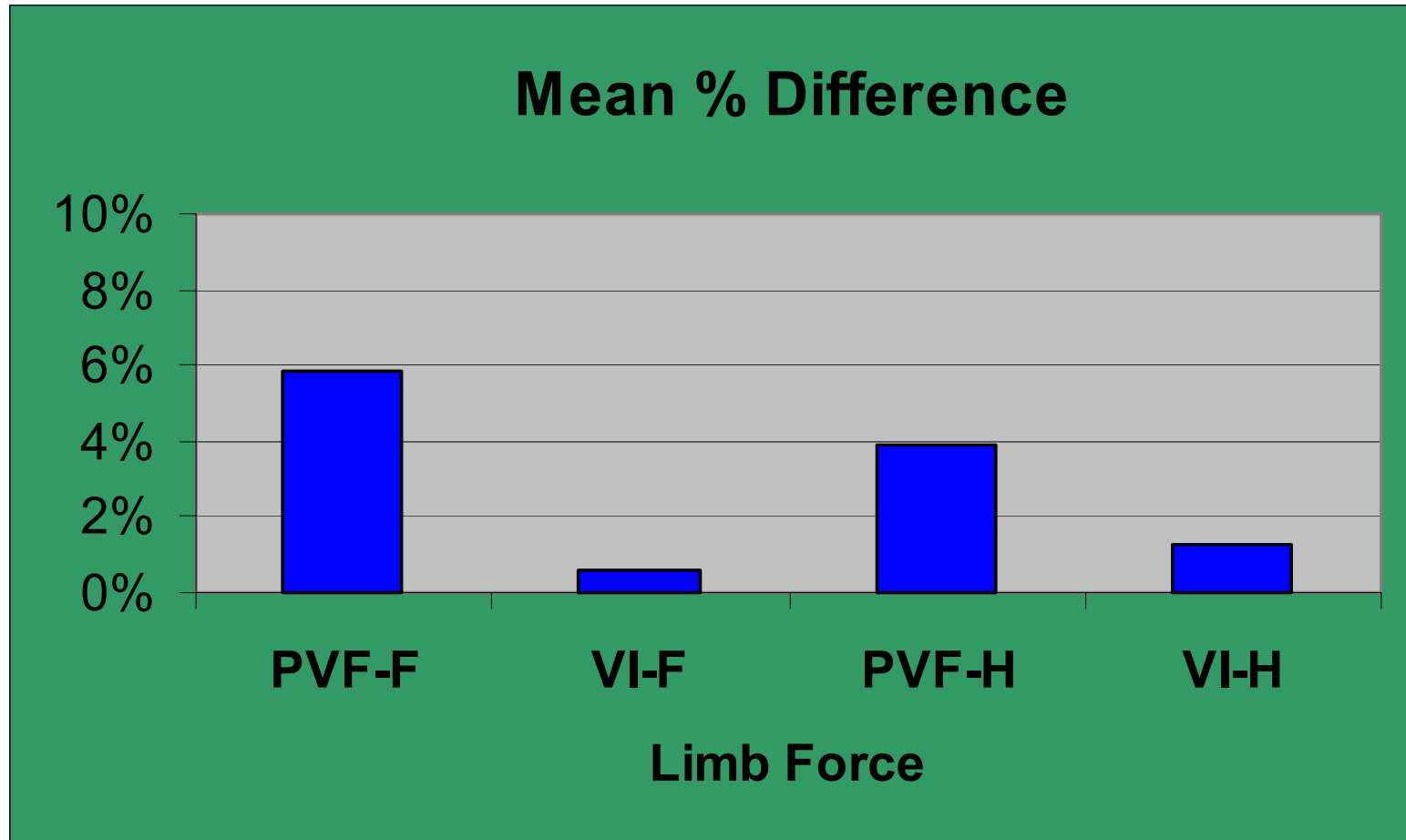
- ↑ Size
 - ↑ Multiple readings in a single pass
 - ↑ Consecutive, contralateral and simultaneous foot-strikes recorded
 - ↑ Ability to easily calculate limb velocity
 - ↑ Patients of extreme size can be evaluated
- ↑ Pressure distribution throughout the foot
- ↑ Mobile

Disadvantages

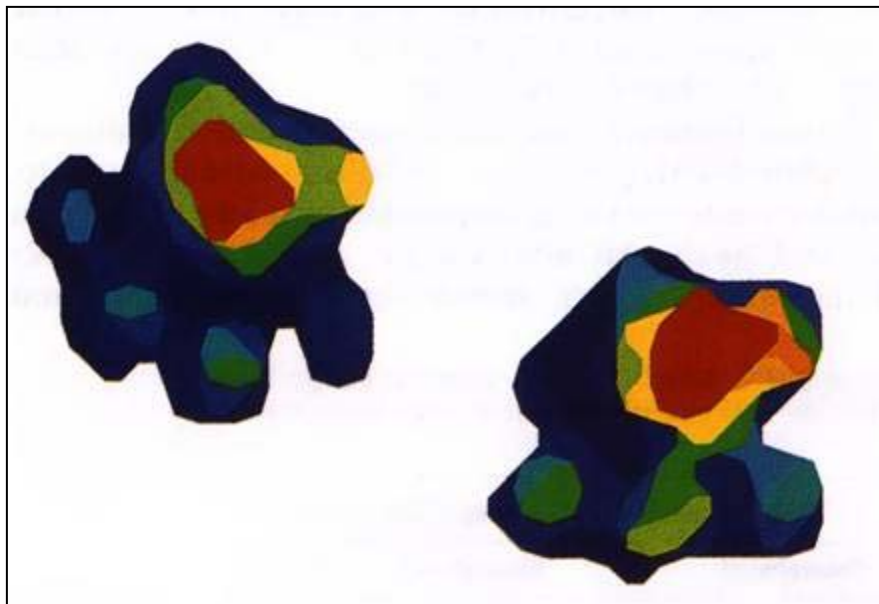
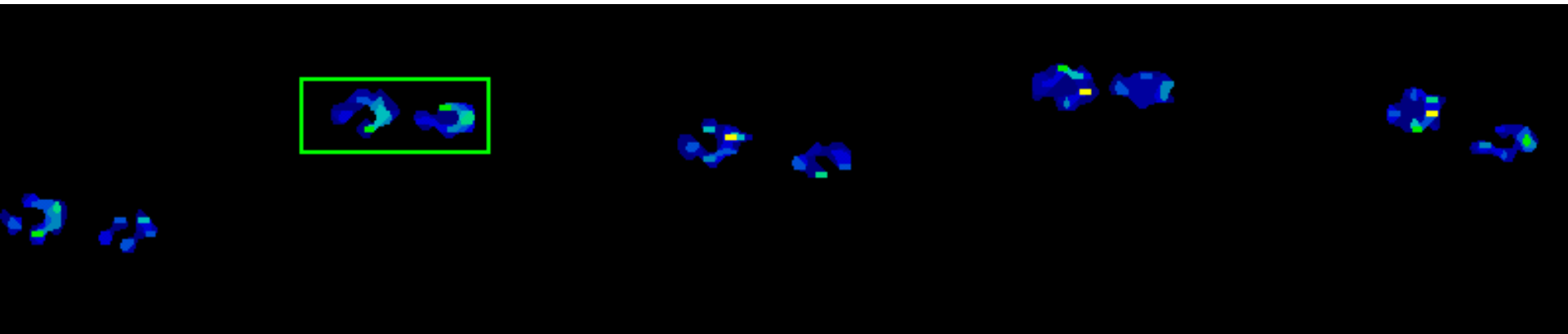
- ↑ Cost (2x single force platform)
- ↑ Current software needs improvements
 - ↑ Time needed to extract data can be prolonged
 - ↑ Inability to measure F_x and F_y

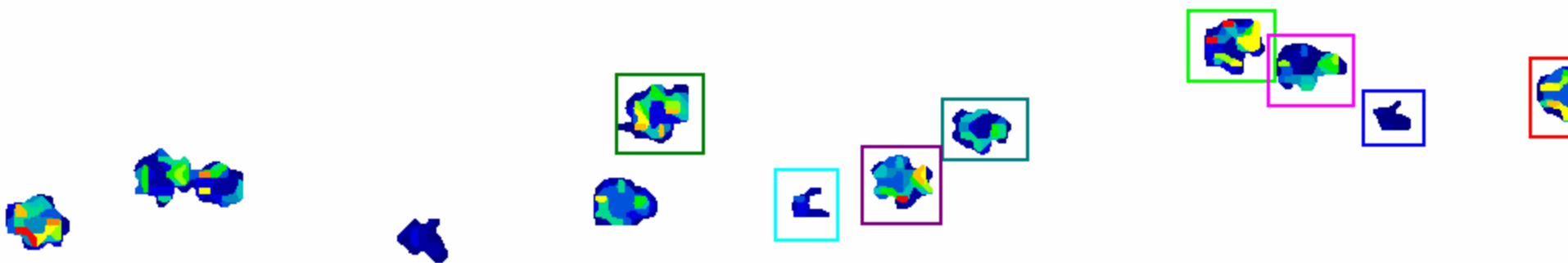


Force Plate vs. Walkway



Pressure Walkways

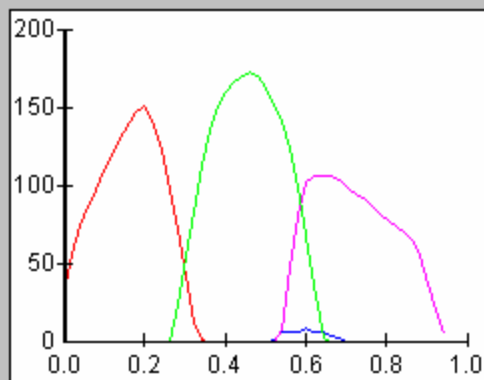


Area: 284.54 cm²

Graph1



Force vs. Time

Force,
Newtons

Time, Seconds

hanson243

0-2.89 (2.89) sec (Time)

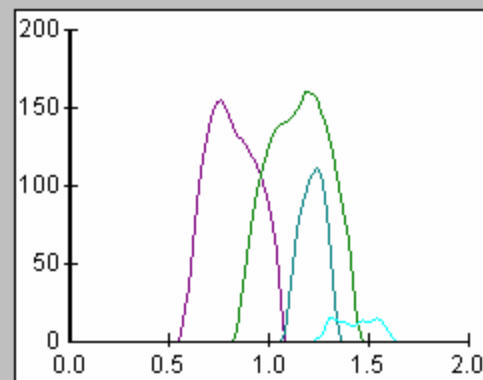
- F: min=0.00, max=8.41, m
Int: 0.934 N*sec
- F: min=0.00, max=105.66,
Int: 30.4 N*sec
- F: min=0.00, max=150.47,
Int: 32.7 N*sec
- F: min=0.00, max=172.78,
Int: 43.8 N*sec



Graph2



Force vs. Time

Force,
Newtons

Time, Seconds

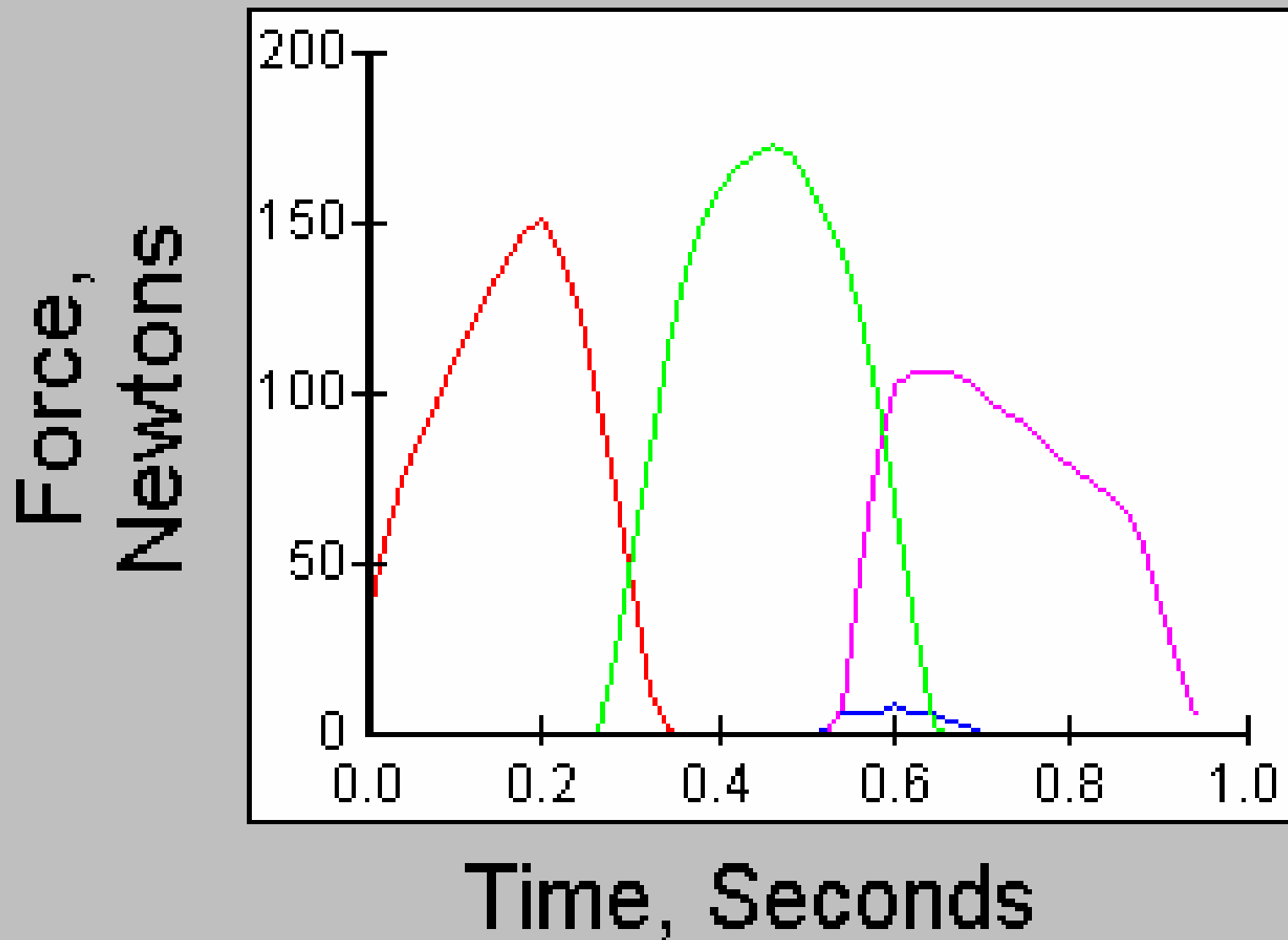
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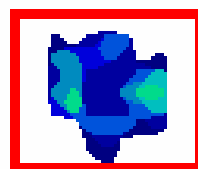
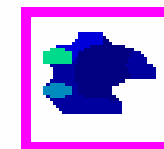
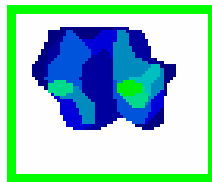
0-2.89 (2.89) sec (Time)

- F: min=0.00, max=150.47,
Int: 53.3 N*sec
- F: min=0.00, max=110.00,
Int: 19.6 N*sec
- F: min=0.00, max=160.00,
Int: 67.6 N*sec
- F: min=0.00, max=15.00,
Int: 4.41 N*sec

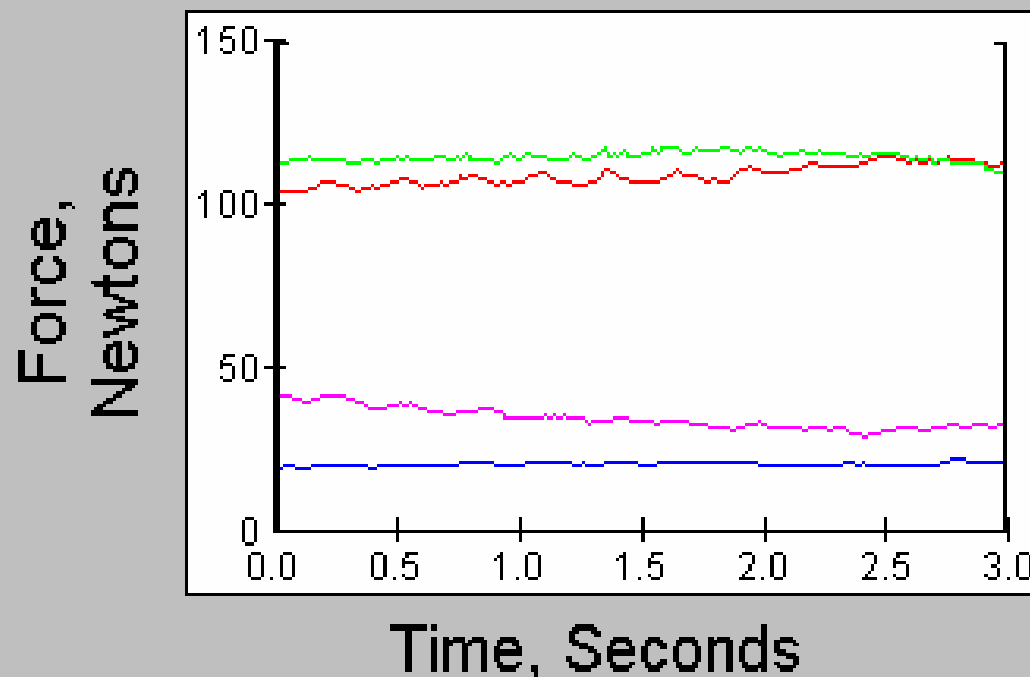


Force vs. Time





Force vs. Time



hanson24stand 2

0-2.99 (2.99) sec (Time)

- F: min=19.18, max=21.92, me
Int: 62.1 N*sec
- F: min=29.35, max=41.48, me
Int: 104 N*sec
- F: min=103.51, max=115.06,
Int: 328 N*sec
- F: min=109.58, max=117.99,
Int: 345 N*sec

Cyclooxygenase-II



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COX-I and II



- Difference between COX-I and II
- Potential advantages of COX-II specificity
- Potential disadvantages of COX-II specificity
- Nonsurgical management of OA
- Inflammation vs. arthritis

Cell membrane damage

Steroids \longrightarrow \downarrow \longleftarrow Phospholipase A2

Arachidonic

Acid



COX reaction (prostaglandin H synthase)



Prostaglandin G2



Peroxidase reaction



Prostaglandin H2



Prostaglandin

Prostacyclin

Thromboxanes

COX-I and II



- COX-I
 - House keeping gene found in nearly all tissues
 - Homeostasis
- COX-II
 - Promotor on gene that is not present on gene that regulates COX-I
 - Promotor has binding sites for transcription factors
 - Gene expression upregulated by mediators of inflammation

COX-I Isoenzyme



- Homeostasis (House keeping)
 - mucosa protection
 - platelet aggregation
 - renal blood flow

COX-II Isoenzyme



- Pathophysiology
 - inflammation, pain, fever, CNS ischemia
 - Alzheimer, cancer
- Adaptation
 - renin secretion
 - wound/ulcer healing
 - female reproductive functions
 - bone metabolism
 - vascular protection

COX-II Specificity



- Structural
 - w/in hydrophobic channel of COX-II enzyme a single AA difference in position 523 is critical for selectivity
 - COX-1=isoleucine
 - COX-II=valine
 - smaller valine size provides a “side pocket” for binding of COX-II selective agents
 - binding site is ~17% larger in COX-II isoform

COX-II Specificity

- **Pharmacologic Estimation**-may be regarded specific if “it causes no clinically meaningful COX-I inhibition at maximal therapeutic doses”.
- **Whole blood assay (human)**-direct indication of test substance to inhibit
 - COX-I activities (thromboxane formation from platelets during clotting)
 - COX-II activities (PGE₂ synthesis in LPS-stimulated monocytes.
 - Overcomes plasma binding problem ass. W/ other tests

COX-II Specificity (human)

Etoricoxib	= COX-I IC ₅₀ /COX-II IC ₅₀	=106
Rofecoxib		=35
Valdecoxib		=30
Celecoxib		=7.6
<u>Aspirin</u>		=0.32
<u>Etodolac</u>		=8.33

IC-inhibitory concentration at 50% of a drug
against each respective isoenzyme

COX-II Specificity (canine)



- Ricketts et al. *AJVR* 1998;59:1441-6
- carprofen was highly selective for COX-II
- etodolac and meloxicam were marginally selective for COX-I
- these results are polar to findings in people

Clinical Use



- Dogs more susceptible than humans
 - extensive enterohepatic circulation
 - higher GI absorption rates
 - longer half-life
- Cats more susceptible to NSAID complications
 - poor glucuronyl transferase activity and ↓ ability to metabolize NSAIDs

Inflammation



- Induction
 - Lipopolysaccharide
 - Proinflammatory cytokines (IL-1, TNF)
 - Prostaglandin positive feedback loop
- Inhibition
 - Glucocorticoids
 - anti-inflammatory cytokines (IL-10)
 - cell dependent negative feedback loop

Pain Perception



- Pain is an emotional response to a negative nociceptive event
- Inflammation causes increase in prostaglandins which sensitize peripheral nociceptors and cause pain hypersensitivity
- Prostaglandins also cause central hyperalgesia
 - excessive sensitivity to pain

Pain Perception



- COX-II is expressed in dorsal horn of spinal cord and is upregulated after trauma
- Induction of spinal cord COX-II expression facilitates transmission of nociceptive input
- COX-II specific inhibitor (celebrex) suppresses prostaglandin levels in cerebrospinal fluid whereas, COX-I inhibitor (SC-560) does not

Gastrointestinal Tract



- Prostaglandins derived from COX-I are considered to confer cytoprotection in the GI tract
- VIGOR and CLASS studies demonstrated that use of COX-II specific inhibitors increased risk-benefit ratio
 - Vioxx Gastrointestinal Outcomes Research
 - Celebrex Long-term Arthritis Safety Study

Cancer



- COX-II specific inhibitors are chemoprotective against colon cancer in rats
- COX-II prostaglandins increase tumor angiogenesis
- COX-II overexpression provides for resistance to apoptosis in epithelial tumors
 - lung, breast, gastric, prostate, and pancreatic cancers
- COX-II inhibitors could be used as adjuvants for treatment or for prevention

Kidney Functions



- COX-II plays a role in normal renal physiology
 - glomerular blood flow, renin release
- Collectively, data are consistent with the expectation that COX-II inhibitors do not spare kidney function.
- Use with caution in patients with fluid retention, hypertension and heart failure

Reproductive Functions



- COX-II deficiency leads to failure to ovulate
- Plays a role in embryo implantation
- Necessary for normal fetal renal development
- Should be very carefully used in pregnant patients

Glaucoma



- POAG-primary open angle glaucoma
- COX-II expression is lost during POAG and during steroid-induced glaucoma
- COX-I expression is unchanged
- Use of COX-II medications could increase a resistance to outflow making condition worse

Clinical Indications



- Chronic pain for OA
 - pain vs. inflammation
 - FDA approved (Rimadyl, Etodolac)
- Acute perioperative pain
 - Reports on Carprofen and Ketoprofen have been mixed
 - Carprofen is not FDA approved
- Inflammatory conditions
 - Panosteitis, HOD, cancer pain, dental pain

Clinical Contraindications



- History of vomiting, diarrhea, anorexia with NSAID use
 - can use with carafate (~1 gm/35 kg PO TID)
 - always provide written instructions to stop medication and call a veterinarian if signs develop
- History of renal, hepatic disease or glaucoma
- Dehydration, pregnancy, hypotension, coagulopathy, concurrent steroid use, asthma
- Prior to surgery when normal hemostasis is essential

Arthritis vs. Inflammation



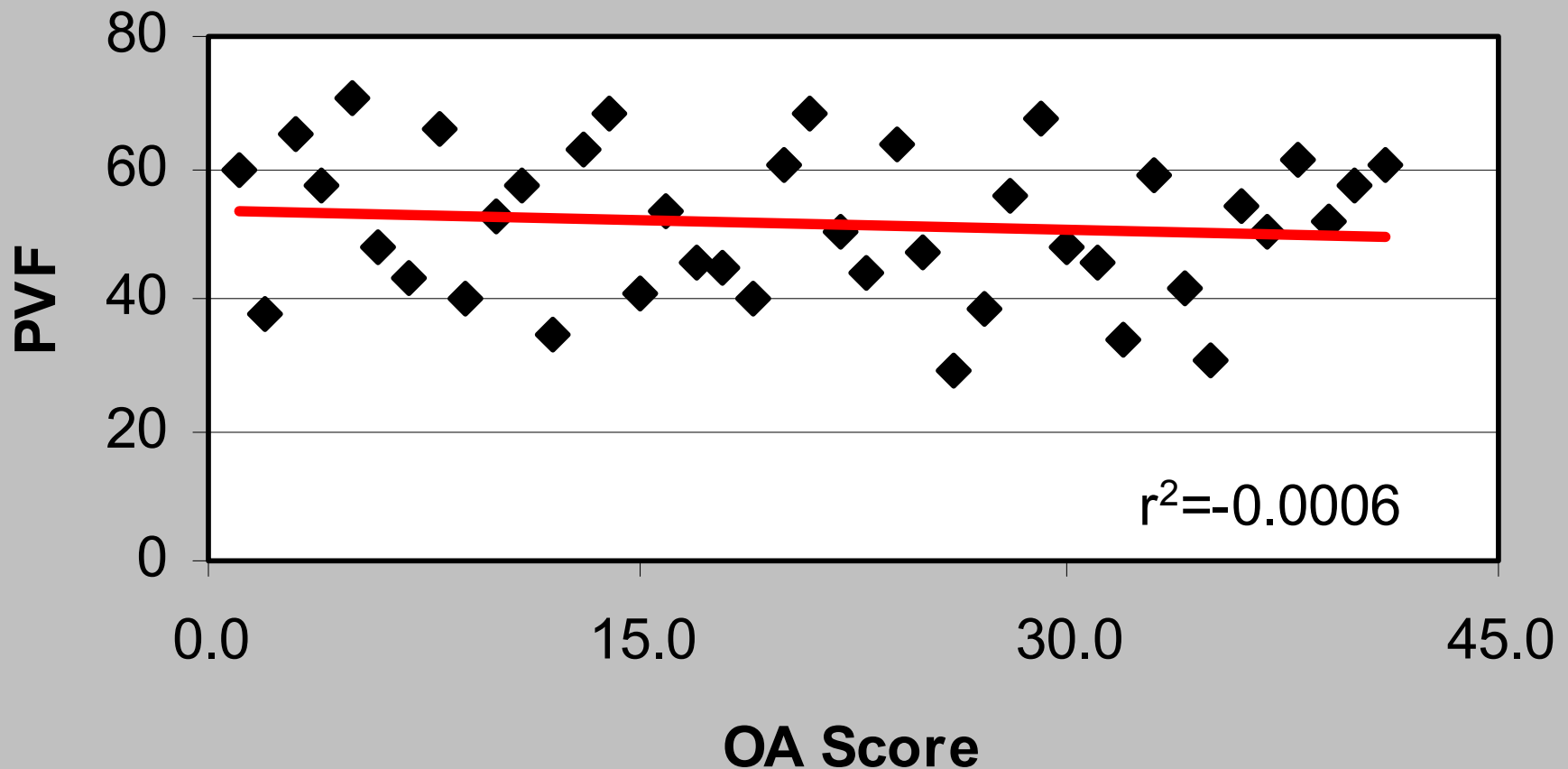
Arthritis vs. Inflammation



As severity of OA ↑; limb function will ↓
or

There is no relationship between
radiographic disease and clinical disease

- Trotted 46 dogs twice (7 days apart)
 - no NSAIDS for 4 weeks
 - no surgery for 6 months
 - all had visible lameness



0.06% of the variation found in the OA Score explains the variation in the PVF. No relationship!

Nonsurgical Management



- Nonsteroidal Anti-inflammatories
 - Rimadyl, etogesic, ascriptin, feldene
 - COX-II inhibitors (Celebrex, Vioxx)
 - avoid naproxin
- Glycosaminoglycans
 - adequan, cosequin
 - some protection for immature dogs with laxity (Lust)
 - no treatment effect for adult dogs with OA (de Haan)

Nonsurgical Management



- Physical therapy
 - swimming, daily leash walks
- Dietary management
 - reduction in BCS increases vertical forces
 - reduced dietary anion gap ($\text{Na}^+ + \text{K}^+ - \text{Cl}^-$) (Kealy)

Empirically...



- Meloxicam

- parenteral and oral suspension
- Europe and Canada
- no experience with it

- Etodolac

- FDA approved for dogs with chronic pain or OA
- I don't use it...they vomit

- Carprofen

- FDA approved for dogs with chronic pain or OA
- Approved for perioperative pain in cats and some recommend it for dogs-mixed reports

Empirically...



- Ketoprofen

- parenteral or tablet
- approved for acute and chronic pain in Europe and Canada
- nonselective for COX pathways
- never used it

- Piroxicam

- strong NSAID...very ulcerogenic in dogs

- Acetaminophen

- contraindicated in cats; I just avoid it

- Aspirin

- Inexpensive, easily available
- Ascriptin is coated with Maalox; works well

Empirically...



- Naproxin
 - 7-day half-life in the dog...do not use
- Celebrex, Vioxx
 - safe and seems to be very effective
 - used routinely in our hospital
- When a COX-II specific drug that is FDA approved for dogs is available these other drugs will be of historical interest only
- If you use your imagination more than one COX-II drug will be on the market for dogs in the near future

