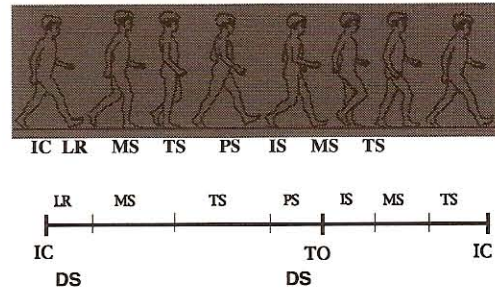


Kinematics - Review and Interpretive Issues in Typical Gait

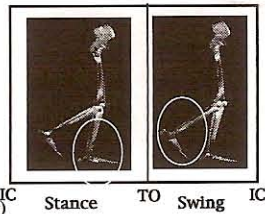
- Tom F. Novacheck, MD
- Director, Center for Gait and Motion Analysis Gillette Children's Specialty Healthcare
- St. Paul, MN, USA

Gait Cycle -- Walking



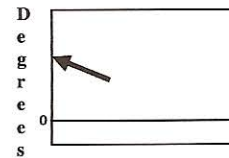
Understanding Kinematic Plots: X axis

- There are no absolute time measures indicated!
- The scale never changes!
 - 0 - 100%
 - IC to IC
 - TO (stance & swing)



Understanding Kinematic Plots: Y axis

- A measure of degrees of movement.
- Sometimes there is a zero line.
- The scale changes for each plot!

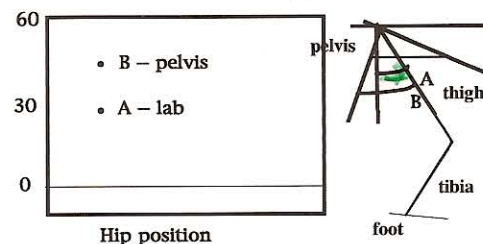


Y axis

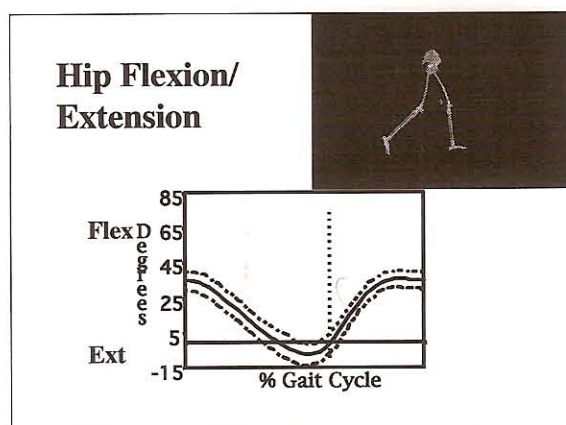
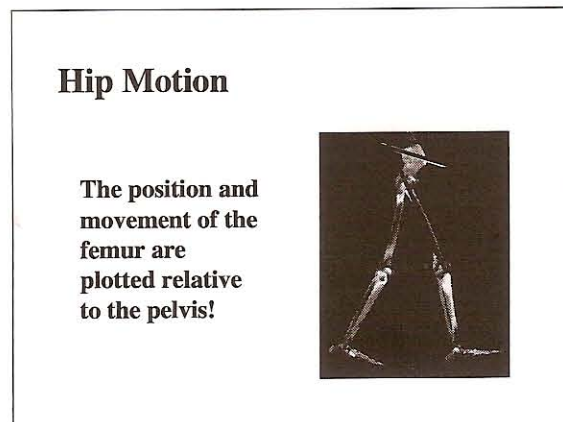
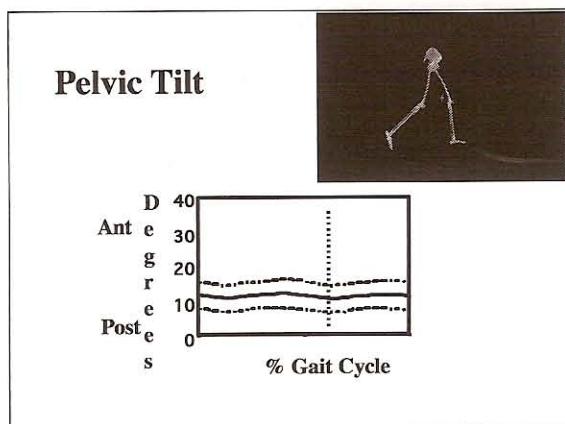
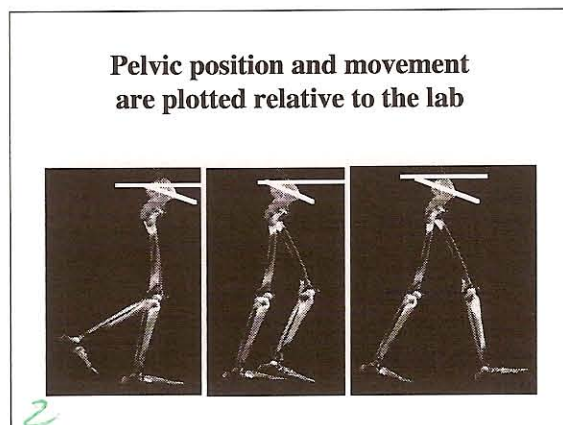
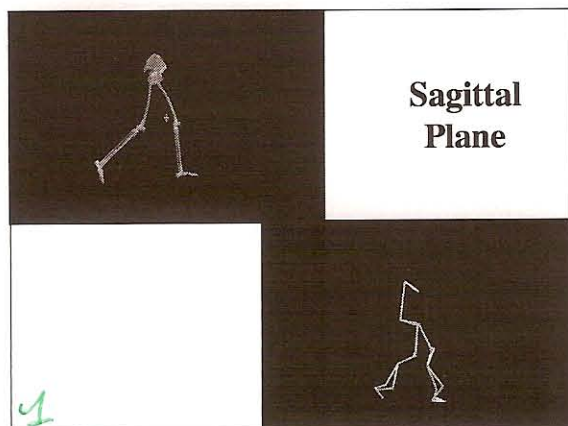
- 50 points of data, i.e. every 2% of the gait cycle
- A smooth line connecting those points is drawn.
- The 'picking' of toe-off and initial contact is crucial!

Understanding Kinematic Plots

What is this movement being plotted relative to?



⑬ → Hip Pelvis



Hip Motion ROM -- 42°

■ Stance	
- LR/MST/TST	-- extension (35° flex to 7° ext)
- PS	-- flexion (7° ext to 0°)
■ Swing	
- ISW/MSW	-- flexion (0° to 35° fl)
- TSW	-- minimal movement

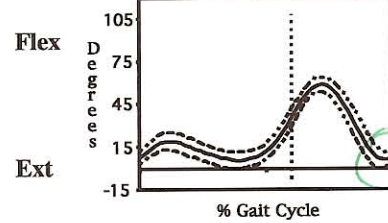
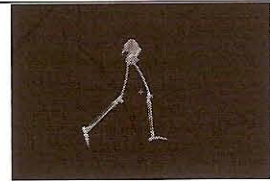
- peak Δ

Sagittal Plane Knee Motion

- The tibia is plotted relative to the femur!



Knee Flexion/Extension



Knee Motion ROM -- 55°

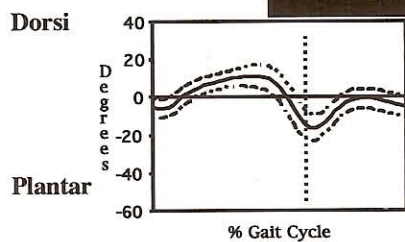
- Stance
 - LR -- flexion (8° to 19°)
 - MST/TST -- extension (19° to 5°)
 - PS -- flexion (5° to 35°)
- Swing
 - ISW -- flexion (35° to 60°) X
 - MSW -- extension (60° to 35°)
 - TSW -- extension (35° to 8°)

Sagittal Plane: Ankle Motion

- The foot is plotted relative to the tibia!



Ankle Dorsi/Plantarflexion

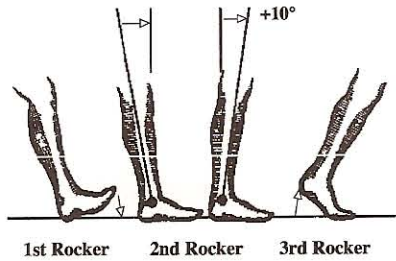


Ankle Motion ROM -- 28°

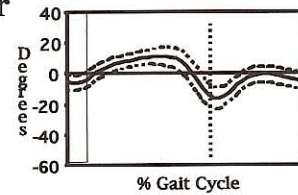
- Stance
 - LR -- plantarflexion (5°pf to 6°pf)
 - MST/TST -- dorsiflexion (6°pf to 12°df)
 - PS -- plantarflexion (12°df to 7°pf)
- Swing
 - ISW -- cont. pl. flexion (7°pf to 16°pf)
 - MSW -- dorsiflexion to neutral (16°pf to neutral)
 - TSW -- min. pl. flexion (neutral to 5°pf)

A Timing A

Ankle Rockers (Perry)



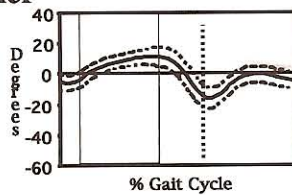
First Rocker



■ Plantarflexion

- Loading Response
- eccentric contraction dorsiflexors
- controlled lowering of the foot to the floor

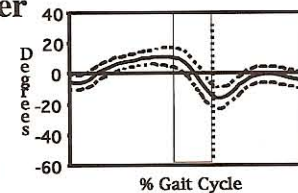
Second Rocker



■ Dorsiflexion

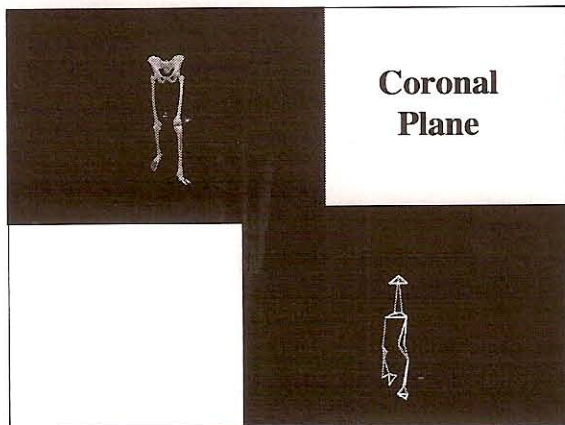
- (MST/TST)
- eccentric contraction plantarflexors
- control of forward motion of the shank over the plantigrade foot

Third Rocker



■ Plantarflexion

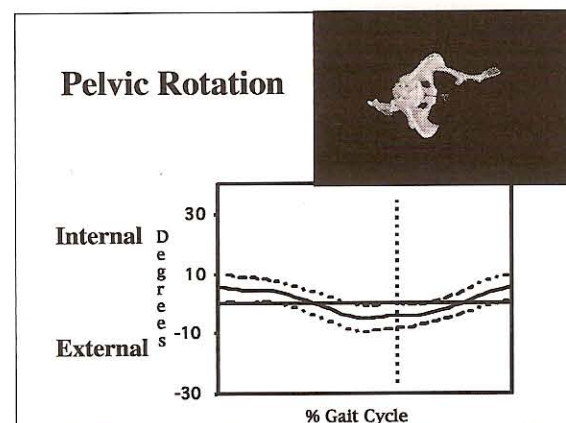
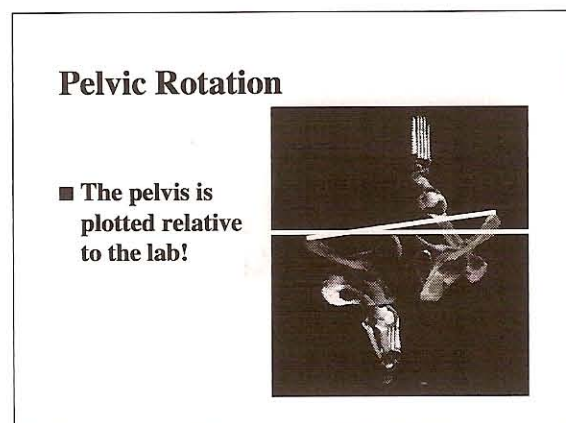
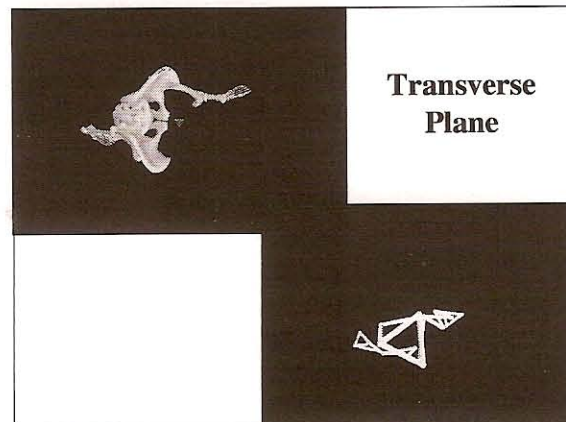
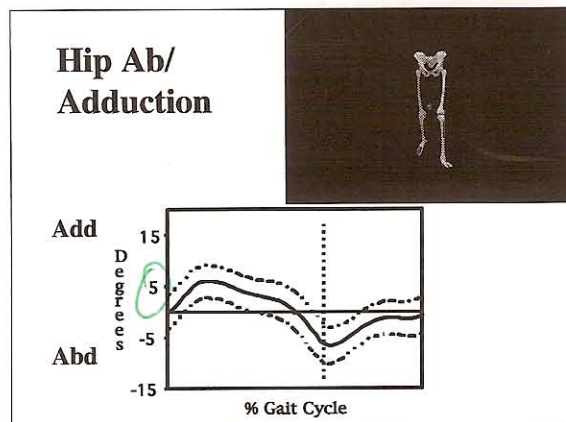
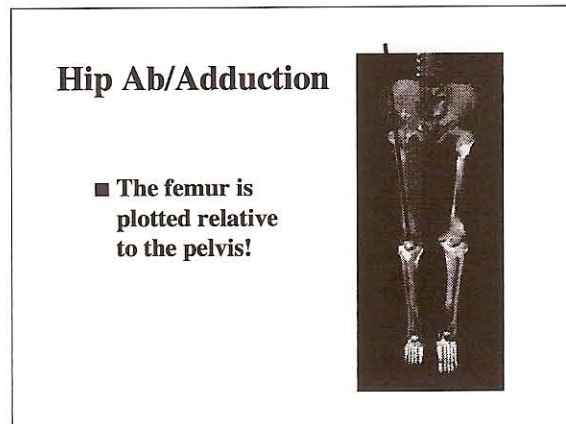
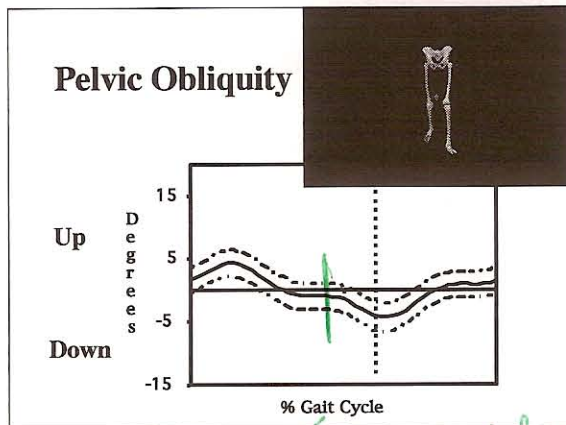
- Preswing
- concentric contraction plantarflexors
- ankle plantarflexion
- push off



Pelvic Obliquity

- The pelvis position and movement are plotted relative to the lab!





Relative

Pelvic Motion ROM -- 10°

■ Stance

- LR/MST -- internally rotated 5°
- TST/PS -- ext. rotates 10° to -5°

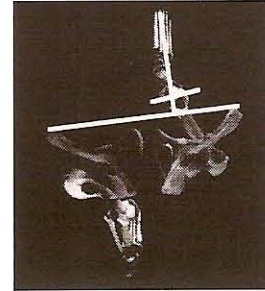
■ Swing

- cont. int. rotation of 10° (from -5° to 5°)

■ Neutral position twice in the gait cycle

Hip Rotation

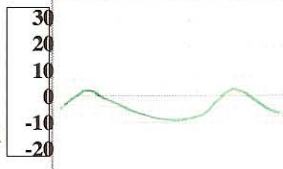
- The hip (as reflected by the distal femoral condyles) is plotted relative to the pelvis!



Hip Rotation

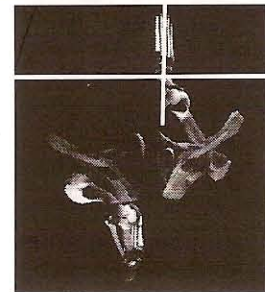
Internal

External



Foot Progression

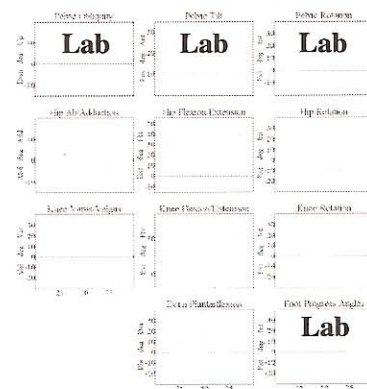
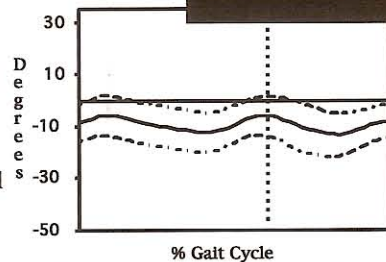
- The foot is plotted relative to the lab!



Foot Progression

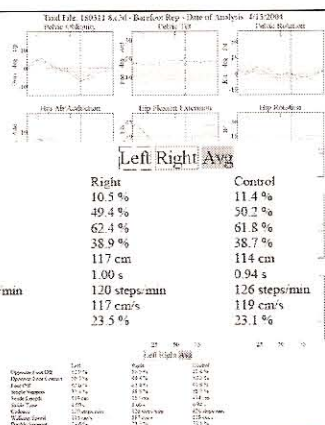
Internal

External

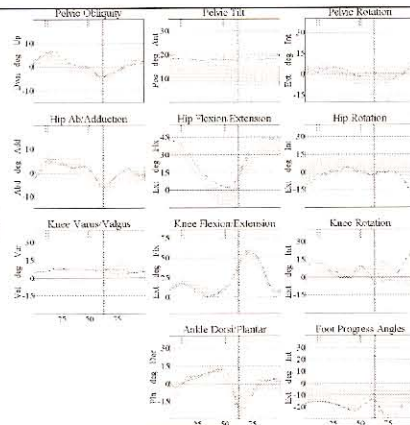


Kinematics

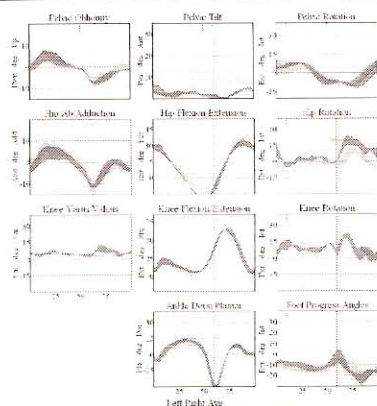
	Left	Right	Control
Opposite Foot Off	12.9 %	10.5 %	11.4 %
Opposite Foot Contact	50.3 %	49.4 %	50.7 %
Foot Off	62.0 %	62.4 %	61.8 %
Single Support	37.4 %	38.9 %	38.7 %
Stride Length	116 cm	117 cm	114 cm
Stride Time	1.00 s	1.00 s	0.94 s
Cadence	120 steps/min	120 steps/min	126 steps/min
Walking Speed	115 cm/s	117 cm/s	119 cm/s
Double Support	24.6 %	23.5 %	23.1 %



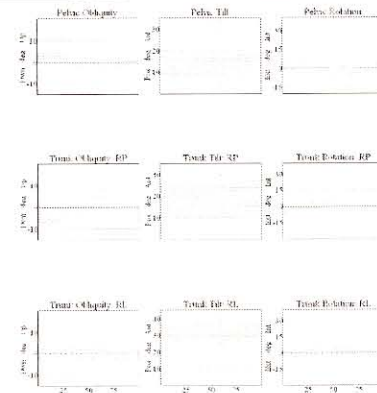
Kinematics consistency



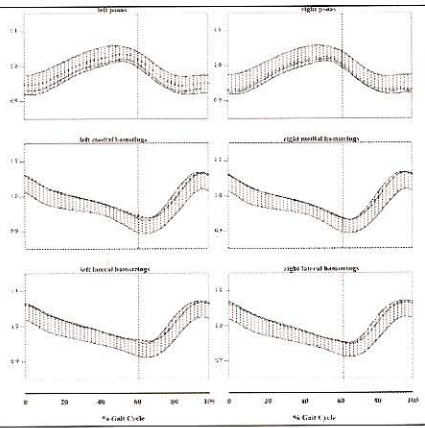
Kinematics consistency



2006 Trunk Kinematics



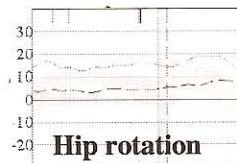
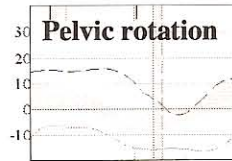
Muscle lengths



Some details and specifics ... advanced

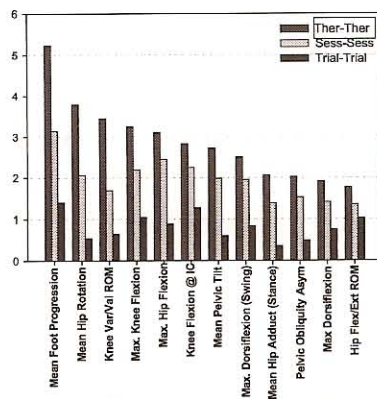
Pelvis and Hip

- Hip is plotted relative to the pelvis, so
- don't assess hip without considering the pelvic alignment.



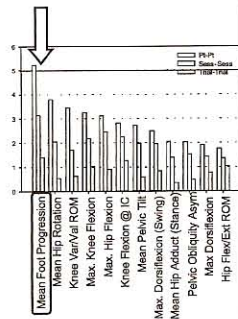
Quality assurance

How it has been incorporated into our day to day activities ...
How it will affect the cases that you will be seeing ...



Surprising Results

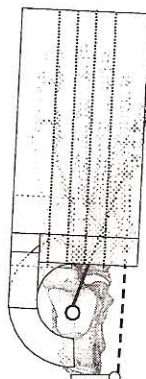
- QA study revealed that foot alignment was poor
- Major Concern
 - Foot progression related to tibial torsion



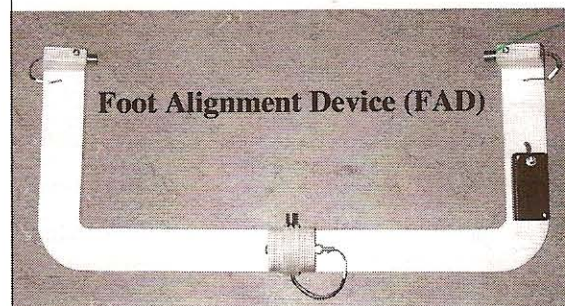
Source of Problem

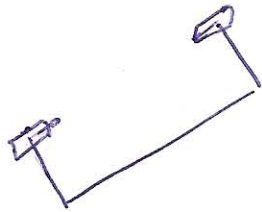
- Manual Palpation
- Visual Alignment
- Awkward Position

Unreliable foot rotation offset

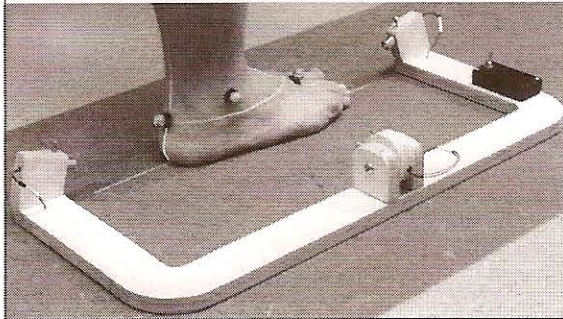


Solution

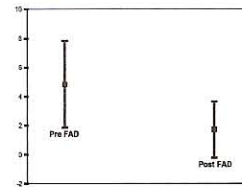




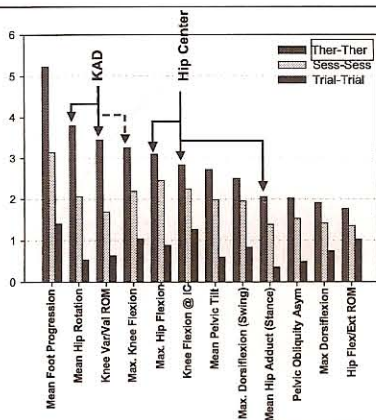
FAD Operation



FAD Performance

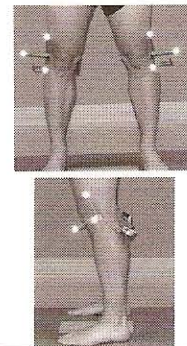


Mean error $\downarrow >3^\circ$
Variability $\downarrow >50\%$



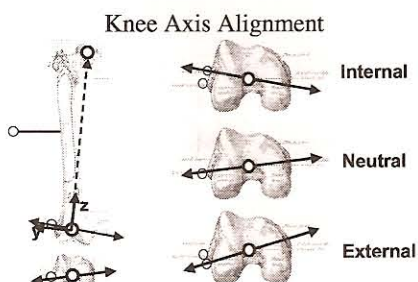
Knee Axis Alignment

- Source of problem:
 - manual alignment of KAD
 - Identification of axis
 - Attaching device
 - Soft tissue artifact



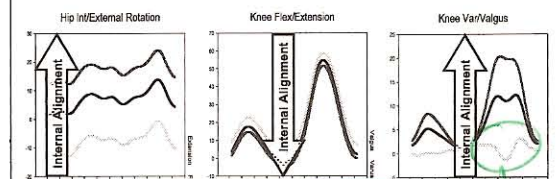
→ à faire évolution des sources d'erreurs

Clinical Gait Analysis



Effect on Kinematics

- Internal (red)
 - Internal hip rotation
 - Diminished peak knee flexion
 - Amplified varus ROM
 - Coupled coronal-sagittal waves
- Proper
 - largest peak knee flexion
 - smallest varus ROM
 - Flat varus wave in stance
 - "s-curve" varus wave in swing?



Dynamic Joint Definition aka Functional Model Calibration

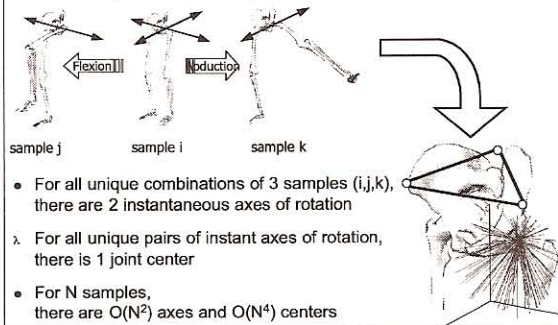
Centers and axes of rotation between body segment positions (joints) are localized based on measured motion

Functional

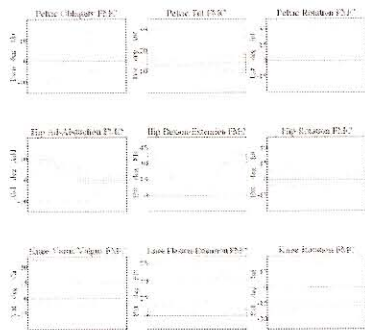
Objective

Subject-specific

Graphical Explanation



Kinematics (Functional Model)



Knee varus/valgus (coronal plane)

