Oxford Foot Model Training Day

3rd July 2008

Why use a foot model?

- The foot contains 26 bones, 33 joints, 107 ligaments and 19 muscles.
- Intricate mechanics – particular issue where deformity present

Foot Anatomy and Function

Motivation for Development

- Original model proposed by Melissa Carson and Marian Harrington
- Measure foot deformity and outcome of treatment in Club Feet

Evolution of the OFM

- Aims:
  - Compatible with known foot function
  - Repeatable
  - Adaptable to foot deformity

Evolution of the OFM

- Include stance and swing phase
- Hallux definition
- Axis definitions
- Marker placement
- Static trial

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Children and foot deformity

Challenges posed by:

- small surface area of the foot
- greater variability of foot motion
- deformities present in pathological feet

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Published Studies

- Healthy Adults
  Carson et al, *J Biomech 2001*
- Club Feet
  Theologis et al, *JBJS 2003*
- Children
  Stebbins et al, *Gait and Posture 2006*

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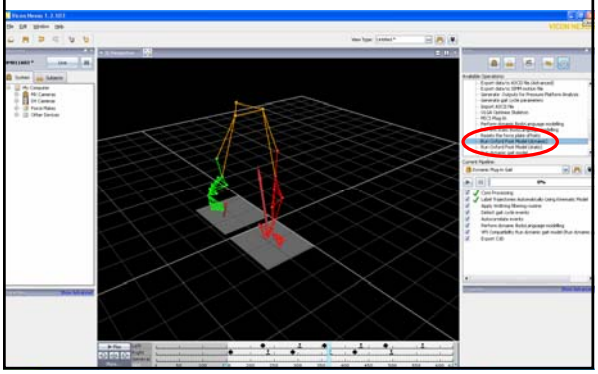
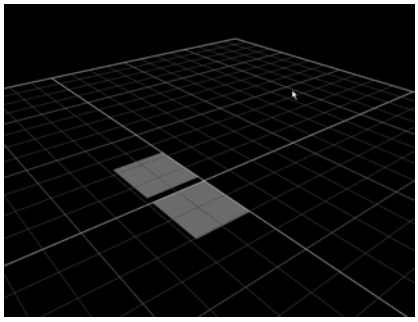
Implemented as Vicon PlugIn



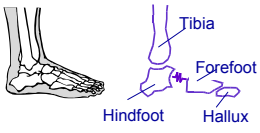
The Oxford Foot Model

- 3 segment model with optional hallux



Unique characteristics

- 4 markers per segment
- Not reliant on neutral position
- Not reliant on x-ray
- Primary axes on long axis of foot
- Compatible with PlugInGait
- Easily understood



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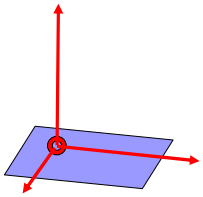
Understanding the OFM

- Described primarily by planes
- Origin + 3 axes



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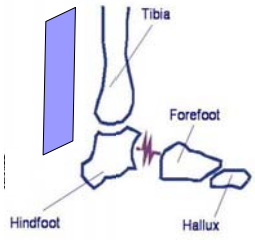
Description of axes

- Tibia
  - Described by frontal plane



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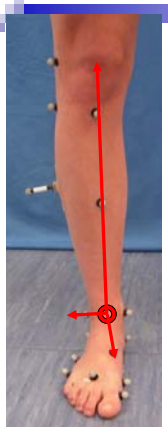
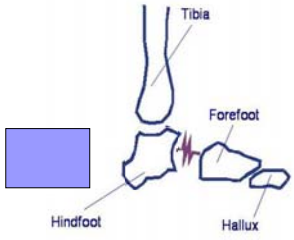


- Origin: AJC
- Primary axis: AJC – KJC
- Medio-lateral axis: Bimalleolar axis
- 3rd Axis: mutually perpendicular
- Same as for PlugIn Gait

- Hindfoot
  - Mid-sagittal plane of calcaneus



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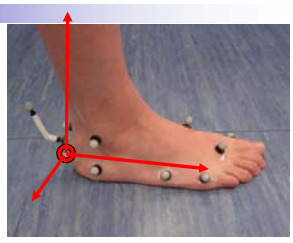

- Origin: HEEL marker
- Primary Axis: Parallel to floor and in plane of HEE, PCA and midpoint between STL and LCA
- Medio-Lateral Axis: Perpendicular to this plane
- 3rd Axis – mutually perpendicular

- Midfoot
  - Linking mechanism only

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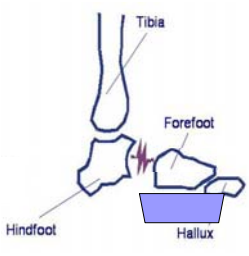
- Forefoot
  - Transverse plane of metatarsals



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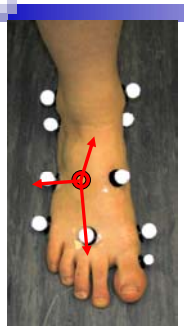

- Origin: Midpoint between P5M and P1M
- Primary Axis: Origin to TOE projected into plane of P5M, D5M and D1M
- Vertical Axis – Perpendicular to this plane
- 3rd Axis – Mutually perpendicular

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- Hallux
- Vector: D1M - HLX

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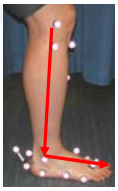
Calculation of Angles



- Grood and Suntay* sequence
  - Flexion extension about transverse axis of proximal segment
  - Axial rotation about long axis of distal segment
  - Ab/Adduction about "floating" mutually perpendicular axis
  - NB – turn the corner at the ankle

* Grood ES, Suntay WJ. A joint coordinate system for the clinical description of three-dimensional motions: application to the knee. J Biomech Eng 1983;105:136–44.

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Demonstration

- Foot clinical examination
- Marker placement
- Practice!

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Demonstration

- Collecting and processing OFM

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Practical Guidelines

- Camera set-up required

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Practical Guidelines

- Who is suitable?
  - Age
  - Co-operation
  - Foot question
  - Degree of deformity
- Walking Aides
- Markers staying on

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Practical Guidelines

- Processing
  - Tracking markers
  - Labelling
  - Checking for “sensibleness”
- Displaying Results

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Practical Guidelines

- Interpreting Graphs
  - How many trials?
  - Consistency
  - What is abnormal?

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Interpretation of Graphs

- Case Studies

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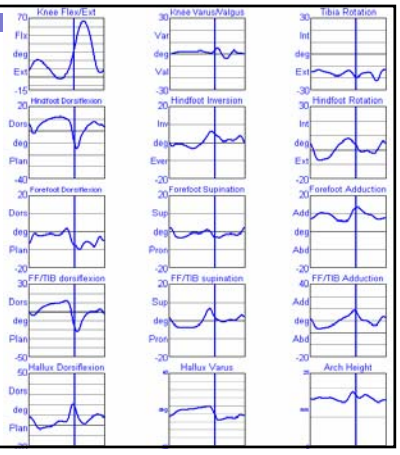
Graphs



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Case 1: Cavo-varus Foot (C769B)

- 9 year old boy with Cerebral Palsy
  - (R Hemiplegia) – considering surgery
- Independent community ambulator
- Uses R AFO and 1cm shoe raise
- Previously received B-toxin injections
- Walks up to 15 min, PE at school
- Walking recently deteriorated
- Pain in R ankle and heel

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Clinical Examination

- (R) 5º hip flexion contracture
- (R) 50º popliteal angle
- (R) 10º equinus contracture with flexible cavo-varus foot posture (WB)
- 1.5cm leg length discrepancy (R shorter)

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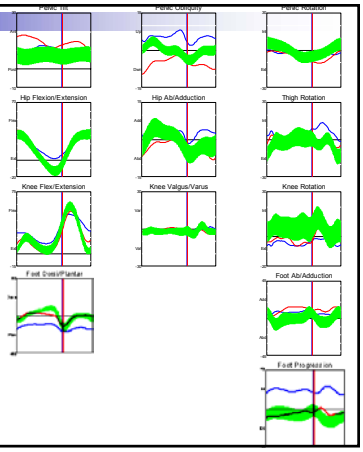
Lower Body Kinematics

- Type IV



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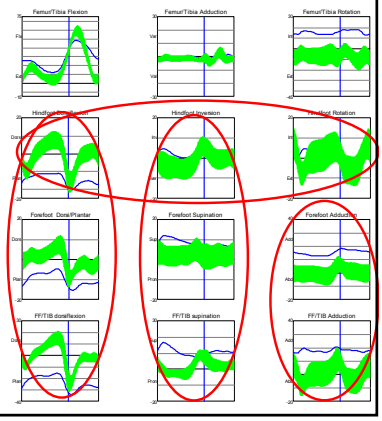
Foot Model Kinematics



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Conclusions

- Equinus from both hindfoot and forefoot
- Combination of both hindfoot varus AND forefoot supination (unusual)
- Adduction of foot from forefoot level
- Reduced ankle ROM
- Tibial torsion and hamstring tightness also contributing

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Recommendations

- Option 1- Serial casting and orthotics, would need to correct flexible cavus and forefoot adduction
- Option 2- Surgery: gastroc lengthening, tib post lengthening, split tib ant transfer, derotation tibia, hamstring lengthening
- **Option 3- early surgery: gastroc and tib post lengthening**

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Case 2: Planovalgus Foot (C303F)

- 17 year old boy with Cerebral Palsy/ Spastic Diplegia who walks with crutches or a Kaye walker and GRAFOs
- Previous multi-level soft tissue surgery in 2000
- Referred for consideration of further surgery

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Clinical Examination

- 35º hip flexion contractures
- 5º (R) and 10º (L) knee flexion contractures
- 15º (R) and 25º (L) equinus contractures
- Uncorrectable planovalgus feet with mid-foot breaks

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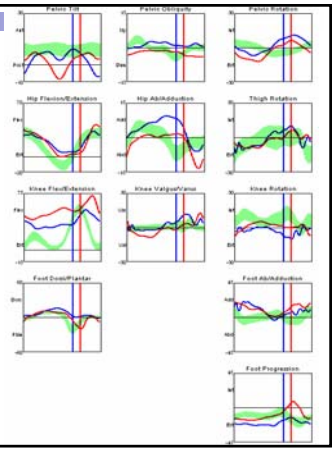
Lower Limb Kinematics



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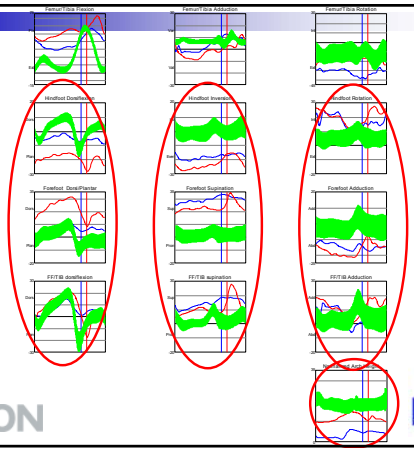

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Conclusions

- (L) hindfoot plantarflexion and forefoot dorsiflexion
- Reduced ankle ROM
- Bilateral hindfoot eversion and forefoot supination
- Bilateral hindfoot internal rotation and forefoot abduction
- Reduced arch height (R)>(L)

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Recommendations

- Subtalar arthrodesis and calcaneal lengthenings with gastroc lengthenings
  - + multi-level surgery

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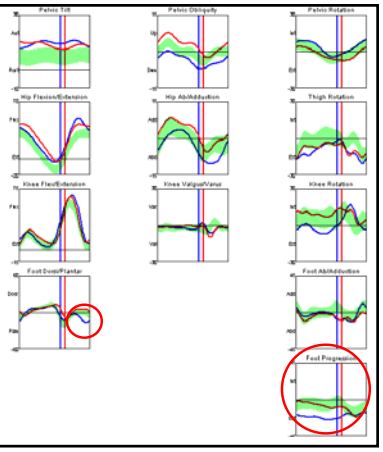
Case 3: Plano-valgus Foot (C521B)

- 10 yr old with (R) hemiplegia (CP)
  - but bilateral planovalgus feet
- Diagnosis unclear
- Wears bilateral AFOs
- No functional limitations

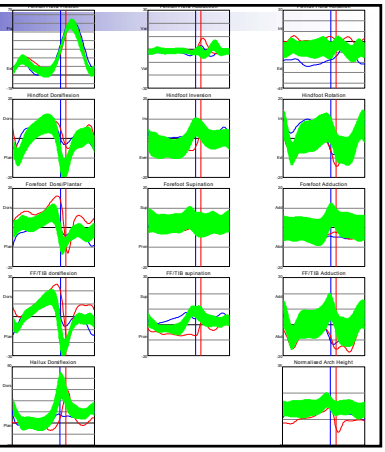
Clinical Examination

- (R) hip flexion contracture of 5º
- (R) popliteal angle 70º
- (R) achieve plantargrade position, with fixed planus and midfoot break, flexible valgus, hallux valgus
- Leg length discrepancy (2 cm shorter R)

Lower Body Kinematics



Foot Model Kinematics



Conclusions

- Dynamic foot deformity not as obvious as in static assessment
- Dynamic insufficiency at ankle level
- Compromised hallux function

Recommendations

- (R) side: AFO
- (L) side: AFO / foot orthosis
- may be surgical candidate if foot deformity deteriorates on either side.

Case 4: – Pre/Post Surgery

HISTORY

- 8 year old girl with R Hemiplegia
- Community ambulator
- Wears R fixed AFO and night splint
- Previous Botulinum Toxin injections and serial casting with some success

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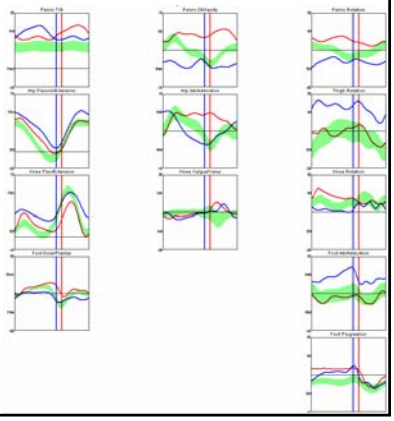
Clinical Examination – R side

- Hip flexion contracture - 15º
- Excessive anteversion - 25º
- Knee flexion contracture - 15º
- Fixed equinus - 20º
- Excessive external tibial torsion
- Mild Rectus and Gastrocnemius spasticity
- Poor strength and selective control at foot
- 3cm leg length discrepancy (R shorter)

Pre-op kinematic graphs



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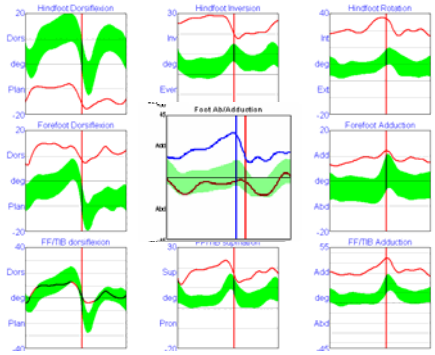
Oxford Foot Model



Surgery

- Plantarflexor lengthening
- Tibialis Posterior lengthening
- Split Tibialis Anterior transfer

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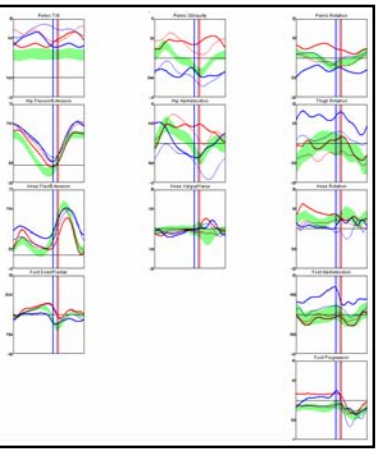
Conventional graphs – outcome

"Bold is Old"



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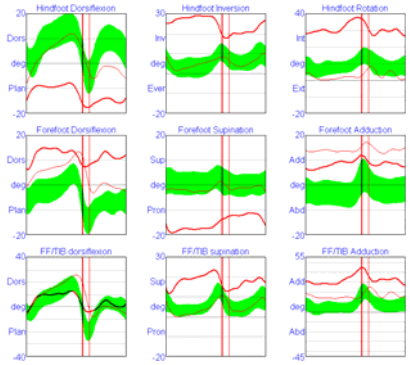
Foot model – outcome of surgery



Clinical Implications and Research

- Repeatability
  - Healthy
  - CP
- Findings from clinical practice
- Further work

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Repeatability

- Intra/Inter-tester: Healthy Adults
  Carson et al, *J Biomech 2001*
- 2 testers/ 2 subjects
- 1º to 6.5º variability

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Repeatability

- Intra-tester: Healthy Children
  Stebbins et al, *Gait and Posture 2006*
- 1 tester/ 15 subjects
- 1º to 7.5º variability

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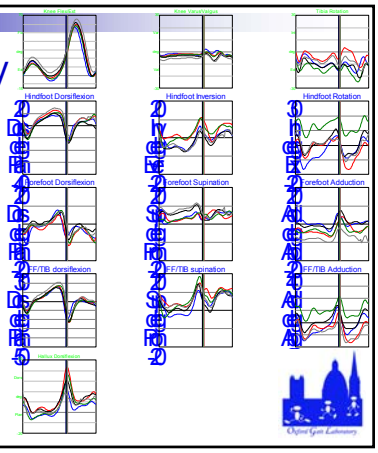
Repeatability

- Inter/intra-tester: healthy adult
- 5 testers
- 1 subject
- 0.5º - 7º



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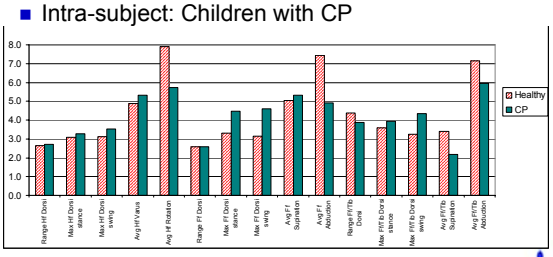
Repeatability

- Intra-subject: Children with CP



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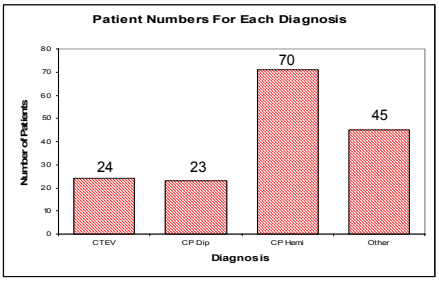
Clinical Findings

OFM Data …

From 2004 to present: 163 patients



Cerebral Palsy - Diplegia

- 23 patients (43 feet) assessed

Cerebral Palsy - Diplegia

- Foot model information used to:
  - Determine cause of in-toeing/out-toeing
  - Determine level of foot drop
  - Guide orthotic intervention
  - Confirm visual impression of foot deformity
  - Aid clinical assessment

Cerebral Palsy - Diplegia

- Significant difference compared to healthy control data
  - ↓ ROM sagittal hindfoot
  - ↓ ROM sagittal forefoot
- Coronal and transverse planes:
  - Equal numbers in both directions
  - Diversity of foot deformity

Cerebral Palsy - Hemiplegia

- 70 patients (6 – 38 years)
- 6 bilateral (just started)

Cerebral Palsy - Hemiplegia

- Foot model information used to:
  - Assess dynamic foot motion
  - Assess outcomes of treatment
  - Monitor progression of foot deformity
  - Clarify controversial findings from lower limb kinematics
  - Determine level of foot drop
  - Corroborate clinical findings

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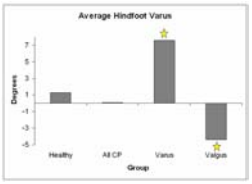
Cerebral Palsy - Hemiplegia

- Significant difference with healthy controls
  - ↓ROM hindfoot and forefoot sagittal
  - ↓Maximum hindfoot and forefoot dorsiflexion
  - ↑Hindfoot internal rotation



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Club Foot

- 24 patients (7 female and 17 male, age range 6 to 24 years)
- 13 bilateral, 6 right and 5 left clubfeet = total of 37 feet
- Early age posterior-medial release

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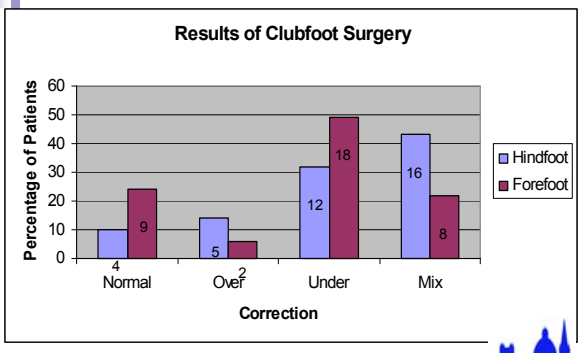

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Club Foot

- The findings from the OFM were used to identify:
  1. Level of dynamic foot deformity (hindfoot and/or forefoot)
  2. Specify the type of surgery required
  3. Justify type of casting appropriate
  4. Clarify the source of foot rotation (tibia, hindfoot or forefoot)
  5. Corroborate clinical findings
- The OFM directly influenced the future management recommendations in 45% of patients seen

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Other Populations

Neuro- 23 patients

- Polio
- Multiple Sclerosis
- HMSN
- Charcot Marie Tooth
- Nerve lesion
- Stroke
- Head Injury
- Spina Bifida

Ortho – 22 patients

- Rotational Mal-alignment
- In-toeing
- Flat feet
- Pain (hip, knees, feet)

- Toe walkers

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Hemiplegic cerebral palsy: foot kinematics of 'good' foot

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Method

- Subjects
  - 10 children (8-17 years)
  - Hemiplegic cerebral palsy
  - 6 pre-op, 4 post-op to affected side
  - Mildly affected (6 type I)
- Looked at
  - clinical exam
  - foot model (static & dynamic)

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Clinical exam

- Non weight-bearing
  - Neutral (9 subjects)
- Weight-bearing
  - Planovalgus (5 subjects)
  - Valgus (2 subjects)

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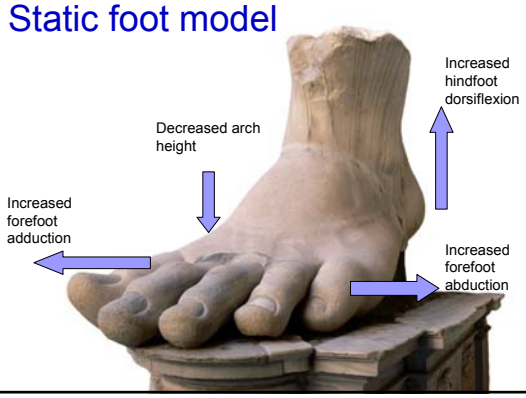
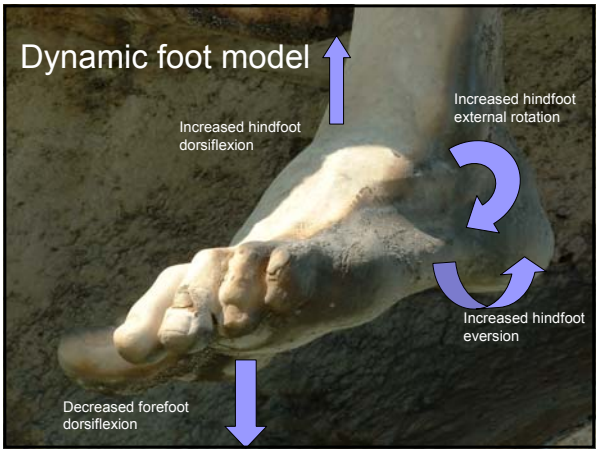
Static foot model



Dynamic foot model



Ongoing Development

- Hallux varus/valgus
- Normal static weight-bearing foot position compared to clinical exam and kinematics
- Quantifying skin/marker movement on the foot – use of markers
- Functional calculation of ankle joint complex axes
- Correlate with imaging

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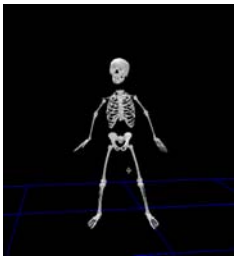
Questions?



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Contributors to the Oxford Foot Model

- Dr Melissa Carson
- Dr Marian Harrington
- Dr Amy Zavatsky
- Mr Tim Theologis
- Mrs Nicky Thompson
- Dr Claudia Giacomozzi

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- Dr Richard Baker
- Mr Timothy Pitt
- The Oxford Gait Lab team
- Vicon

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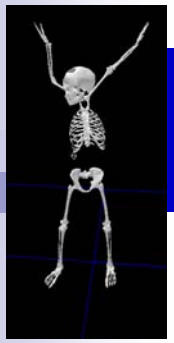

Thank you