



Oxford University Hospitals



NHS Trust



Oxford Foot Model

Julie Stebbins

Oxford Gait Laboratory, UK

Oxford Foot Model

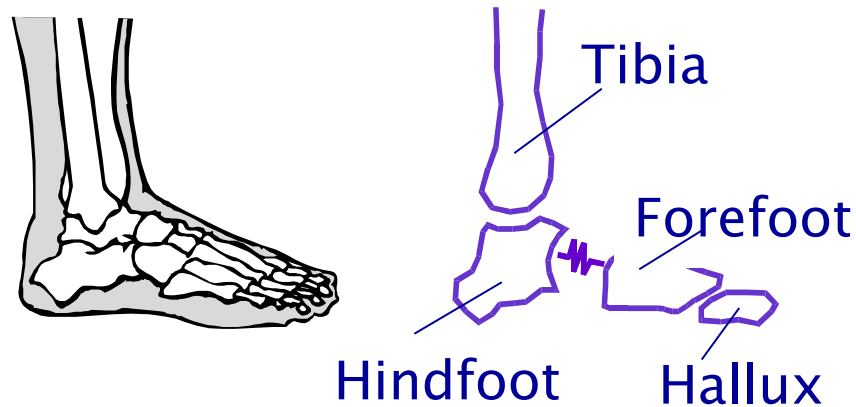
- ▶ Collaboration between
 - Nuffield Orthopaedic Centre
 - Oxford University
- ▶ Development 1995 –2005
- ▶ Aim to measure foot deformity in children with clubfoot
- ▶ Clinical implementation from 2006...

Characteristics

- ▶ Marker redundancy (4 per segment)
- ▶ Does not require “neutral” static position
- ▶ Does not require use of x-ray
- ▶ Primary axis along long axis of the foot
- ▶ Compatible with conventional lower-limb gait model

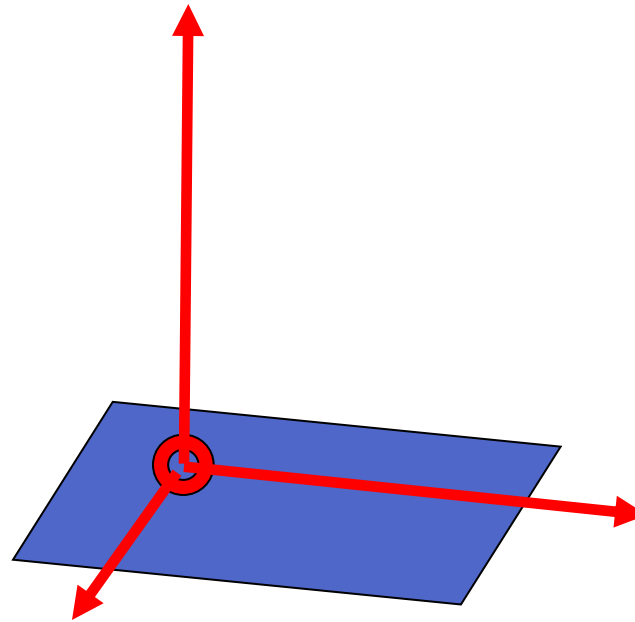
Oxford Foot Model

- ▶ 3 segment model with optional hallux

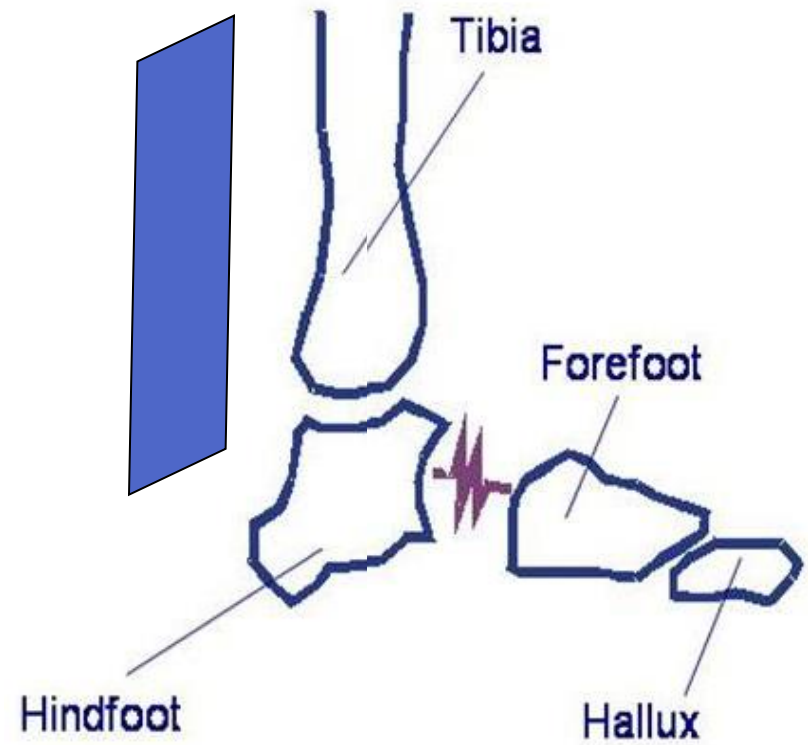


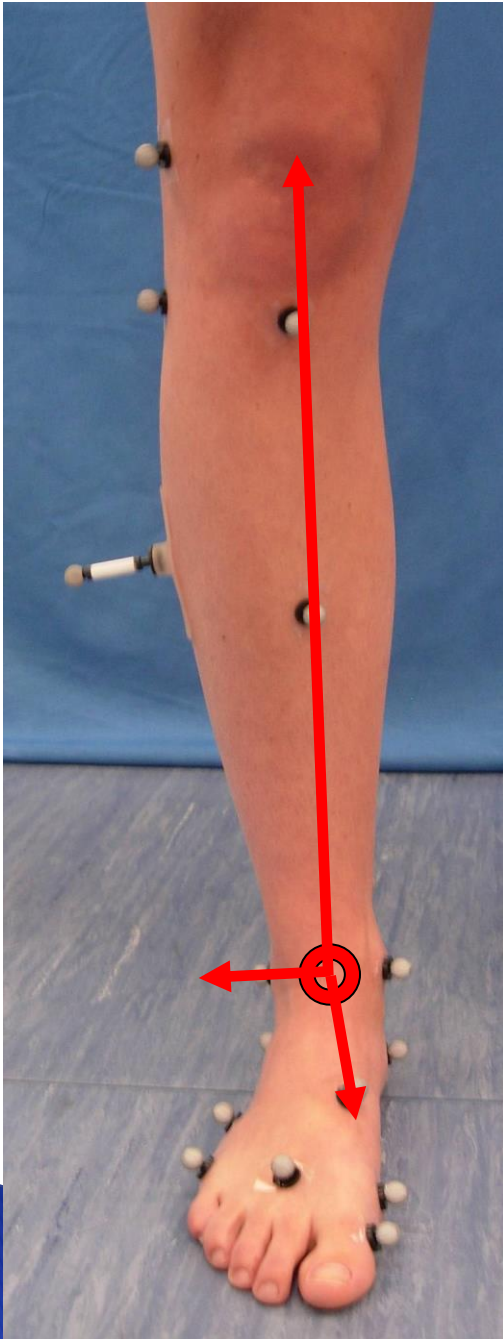
Defining the OFM

- ▶ Described primarily by planes
- ▶ Origin + 3 axes



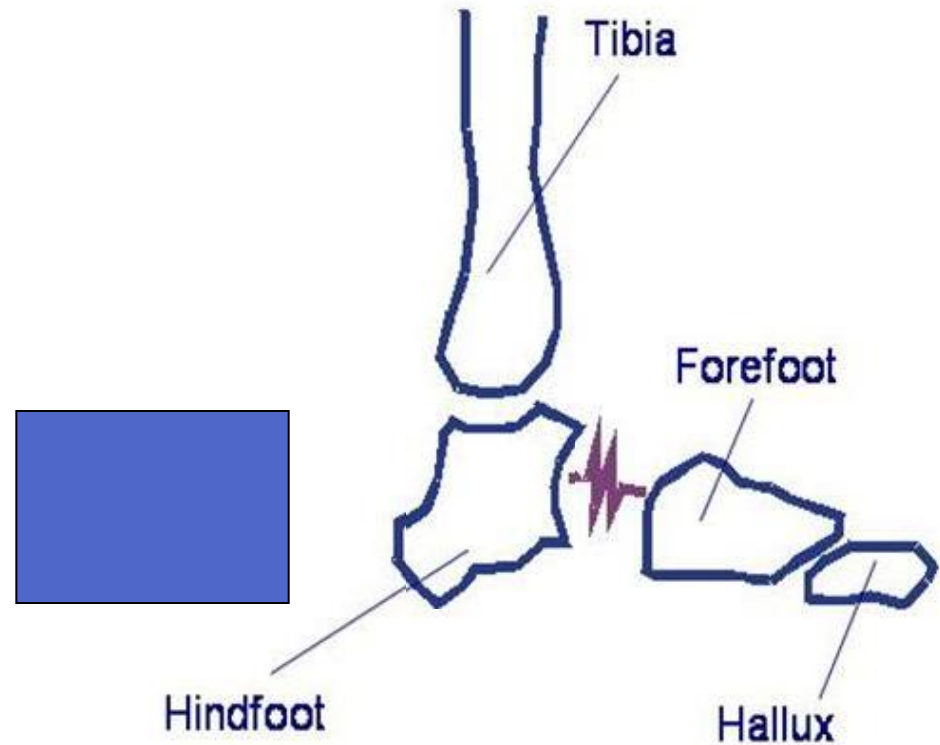
- ▶ Tibia
 - Described by frontal plane

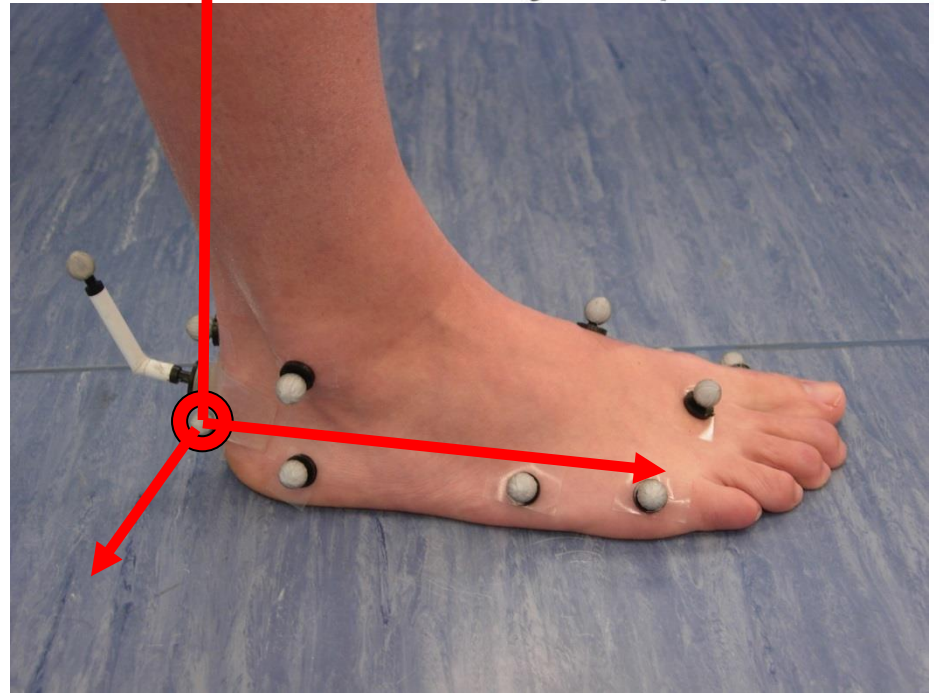




- Origin: AJC
- Primary axis: AJC – KJC
- Medio–lateral axis: Bimalleolar axis
- 3rd Axis: mutually perpendicular
- Same as for PlugIn Gait

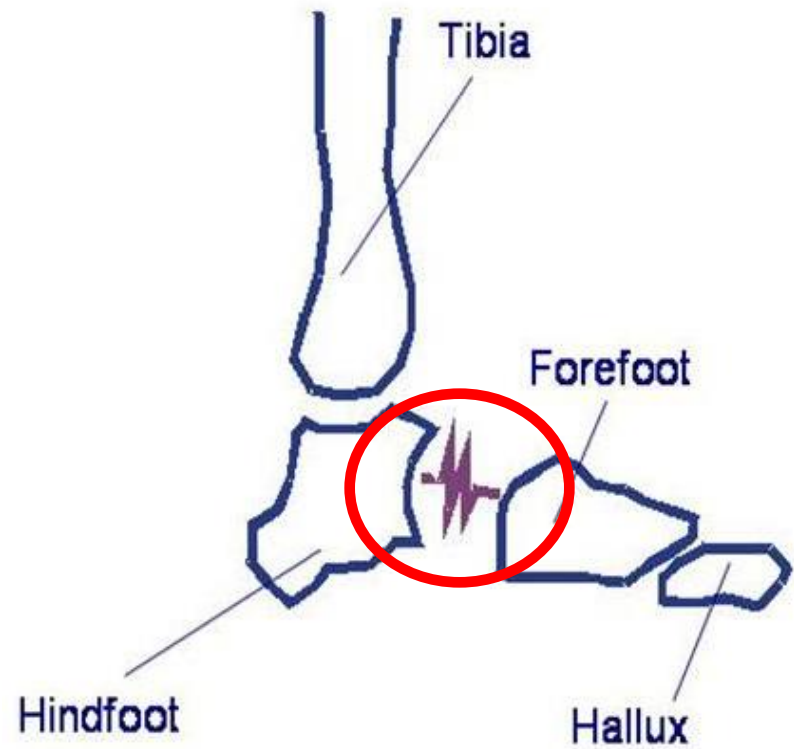
- ▶ Hindfoot
 - Mid-sagittal plane of calcaneus



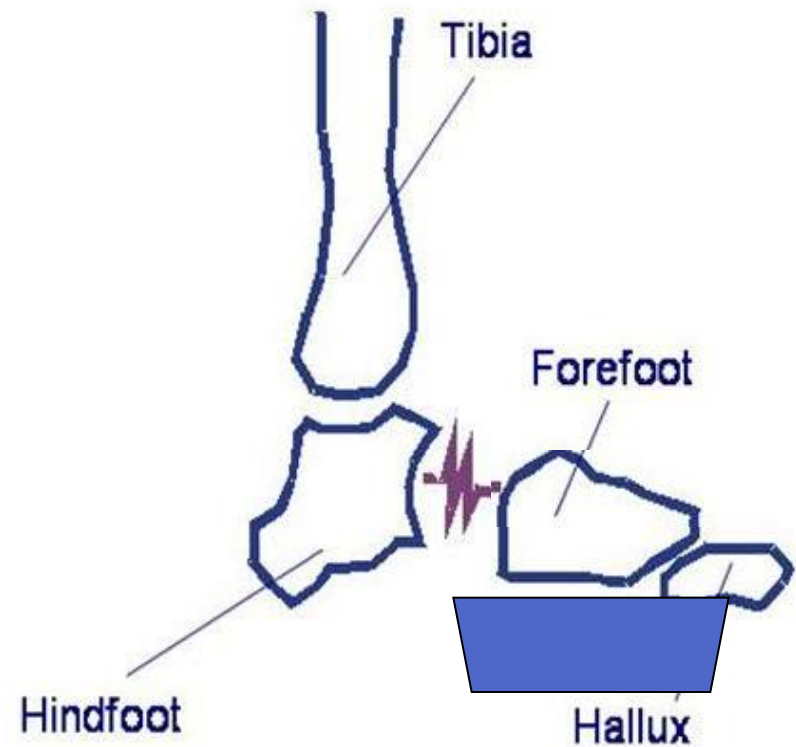


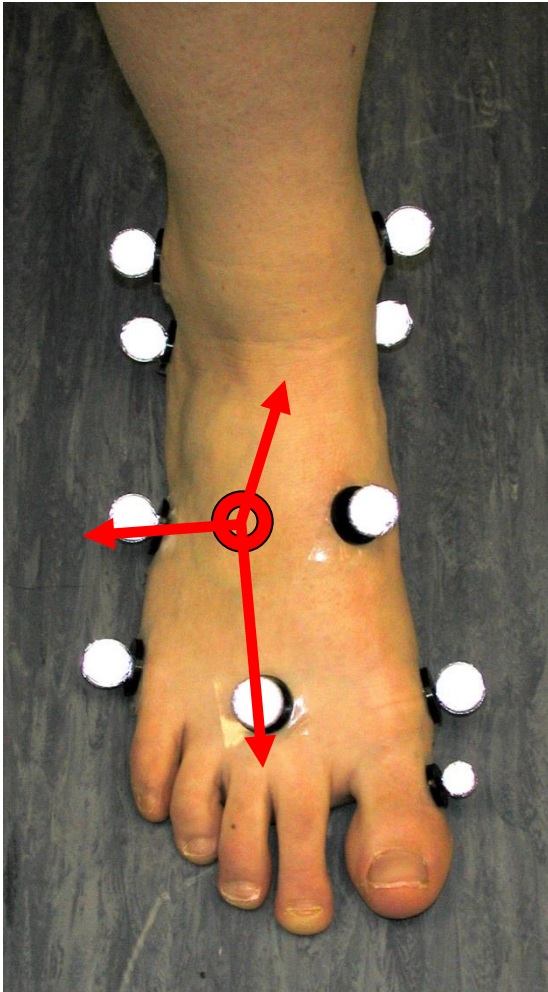
- Origin: HEEL marker
- Primary Axis: Parallel to floor and in plane of HEE, PCA and midpoint between STL and LCA
- Medio-Lateral Axis: Perpendicular to this plane
- 3rd Axis – mutually perpendicular

- ▶ Midfoot
 - Linking mechanism only



- ▶ Forefoot
 - Transverse plane of metatarsals





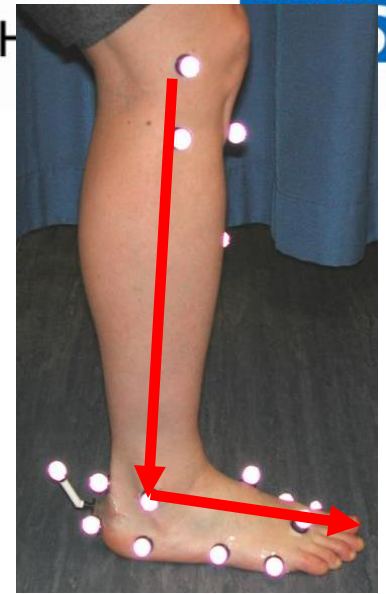
- Origin: Midpoint between P5M and P1M
- Primary Axis: Origin to TOE projected into plane of P5M, D5M and D1M
- Vertical Axis – Perpendicular to this plane
- 3rd Axis – Mutually perpendicular

- Hallux
- Vector: D1M – HLX



Calculation of angles

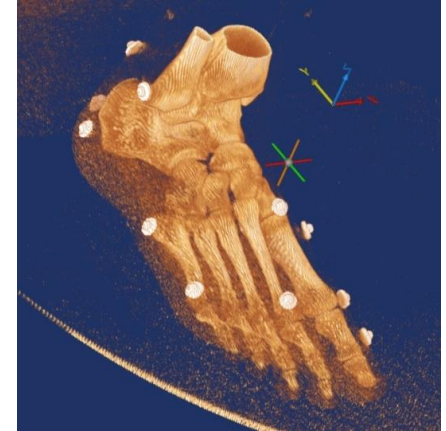
- ▶ Grood and Suntay* sequence
 - 1st rotation is flexion / extension
 - 2nd rotation is abduction/ adduction
 - 3rd rotation is axial rotation
 - **NB – turn the corner at the ankle**



* 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.

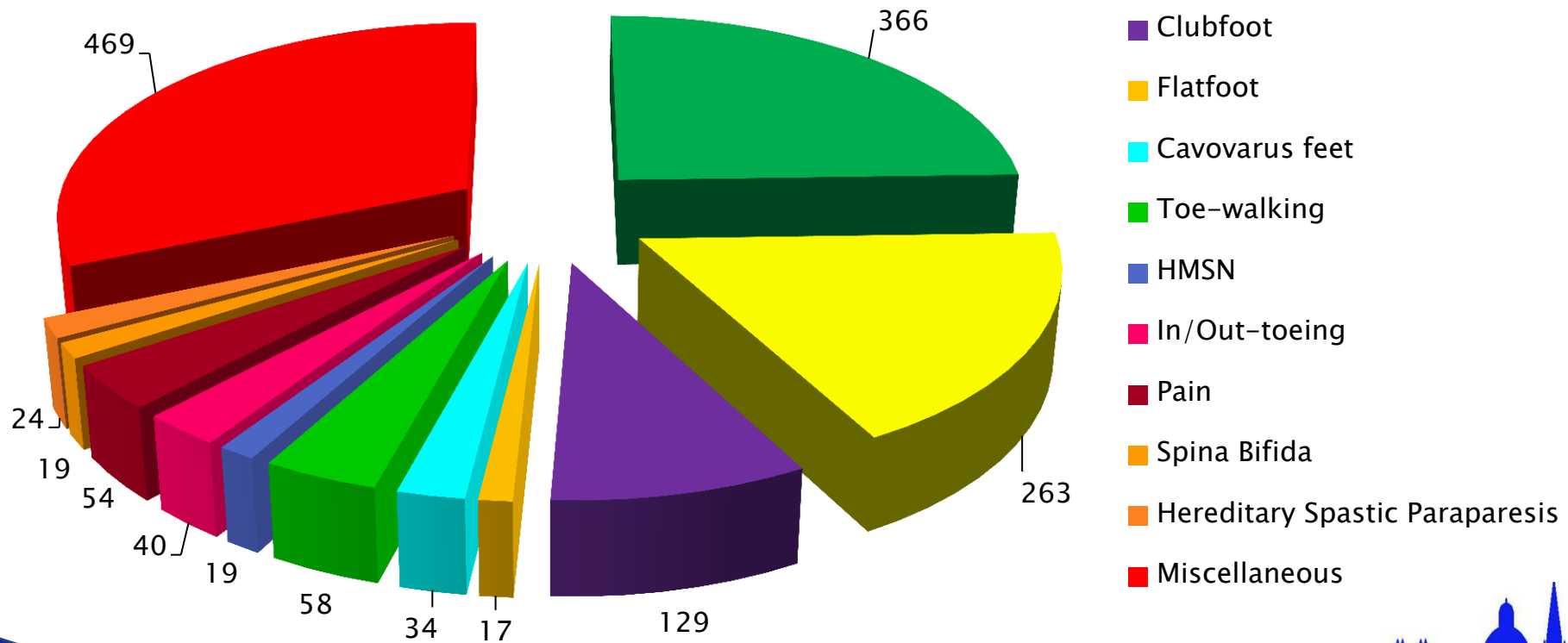
Validation

- ▶ Repeatability
 - Adults, children, pathology
 - Similar repeatability
- ▶ Accuracy
 - Using CT with markers in place
 - Generally within 5mm of actual landmark



Clinical Practice

► ~1 500 patients (2006 – 2015)



Case Examples

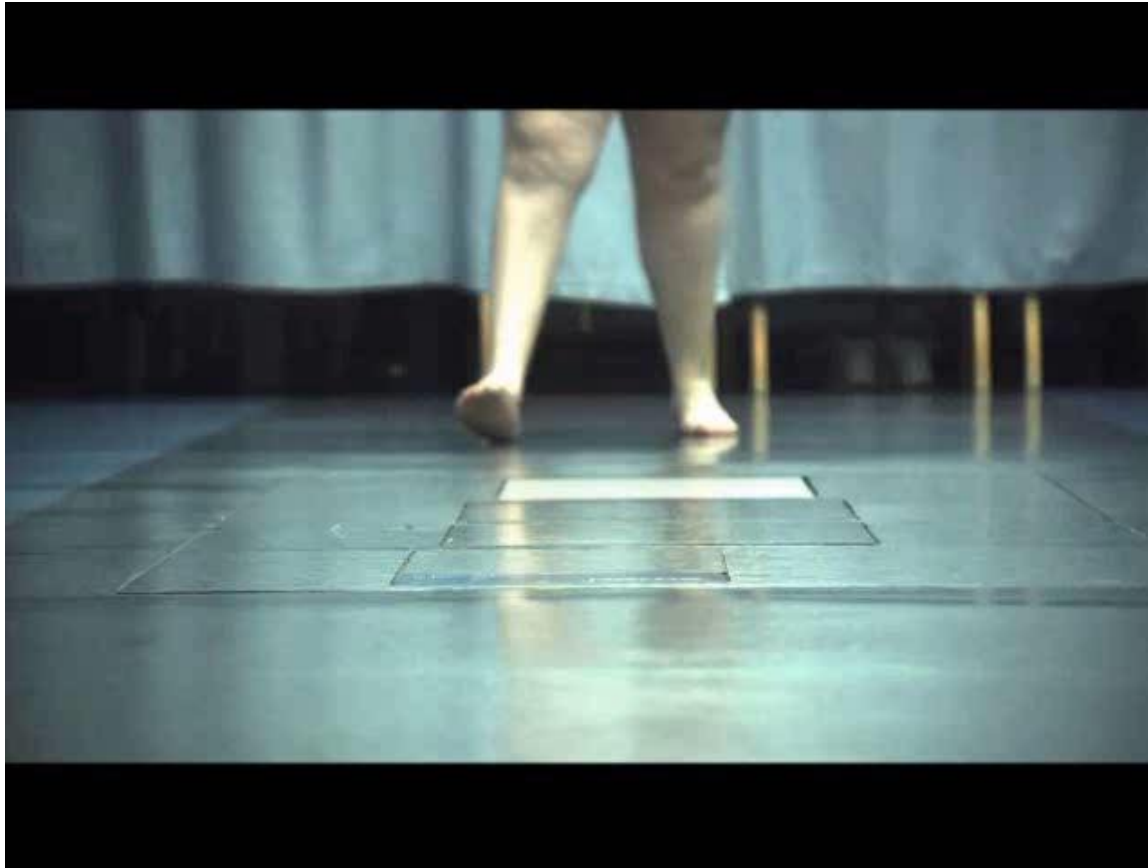
History (TV143A)

- ▶ 20 year old with (R) clubfoot
- ▶ Surgical correction casting at 1 year of age
- ▶ Lateral ankle pain experienced over the past 3 years
- ▶ Considering surgical correction
 - Triple fusion
 - Tendon transfer

Physical Exam

- ▶ Internal to normal tibial torsion (R)
- ▶ Knee hyperextension (R + L)
- ▶ Ankle dorsiflexion to neutral only (R)
- ▶ Reduced strength of the plantarflexors and evertors (R) (*MRC* = 2) + calf wasting

Video images



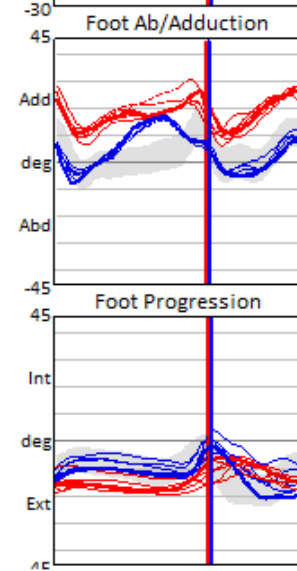
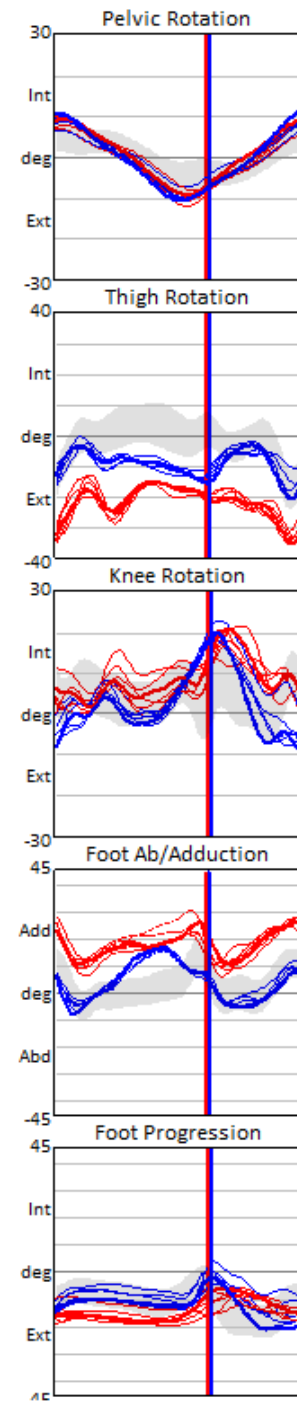
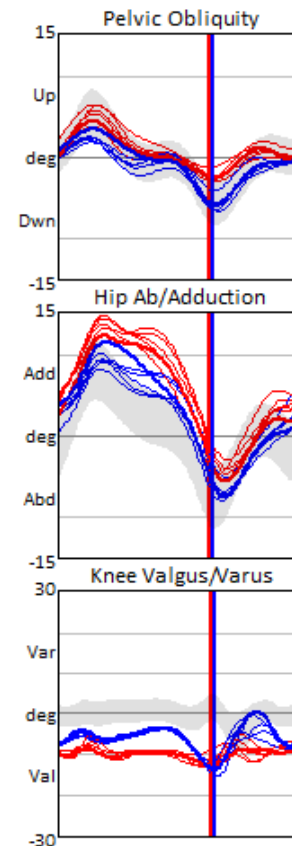
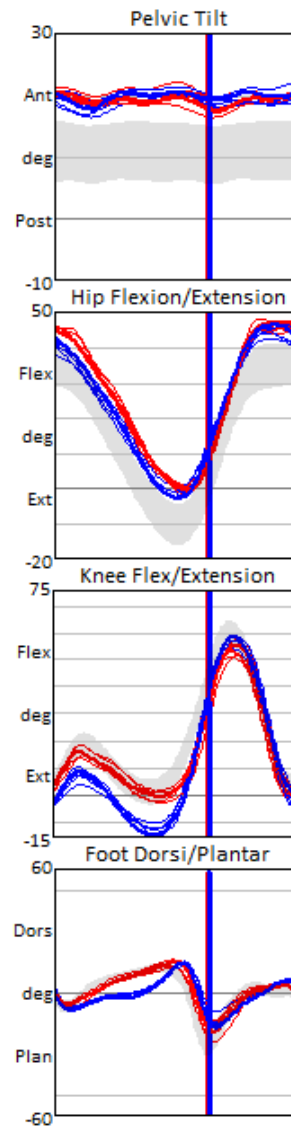
Kinematics

Blue = right

Red = left

Grey = reference data

Kinematics: Consistency



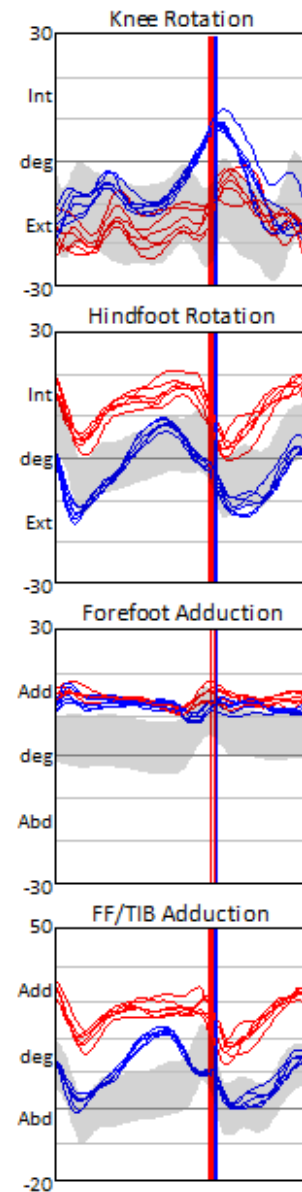
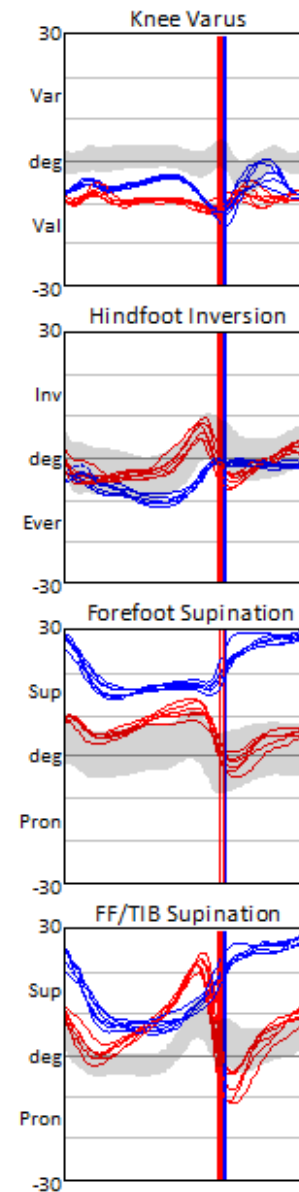
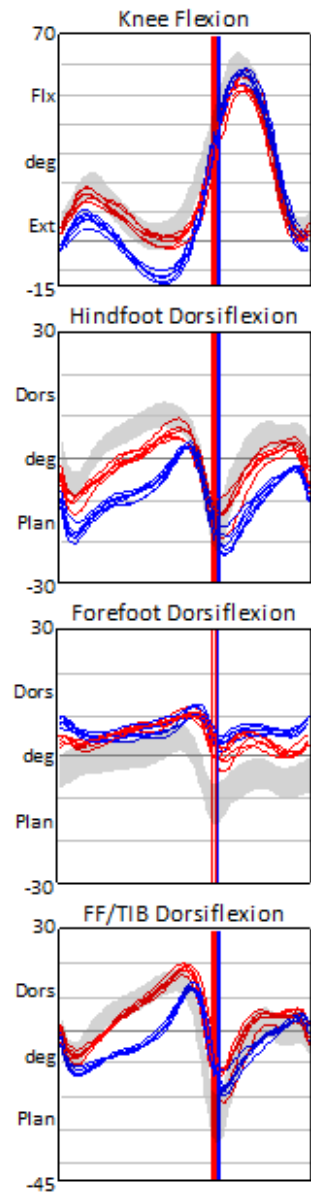
Foot Model

Blue = right

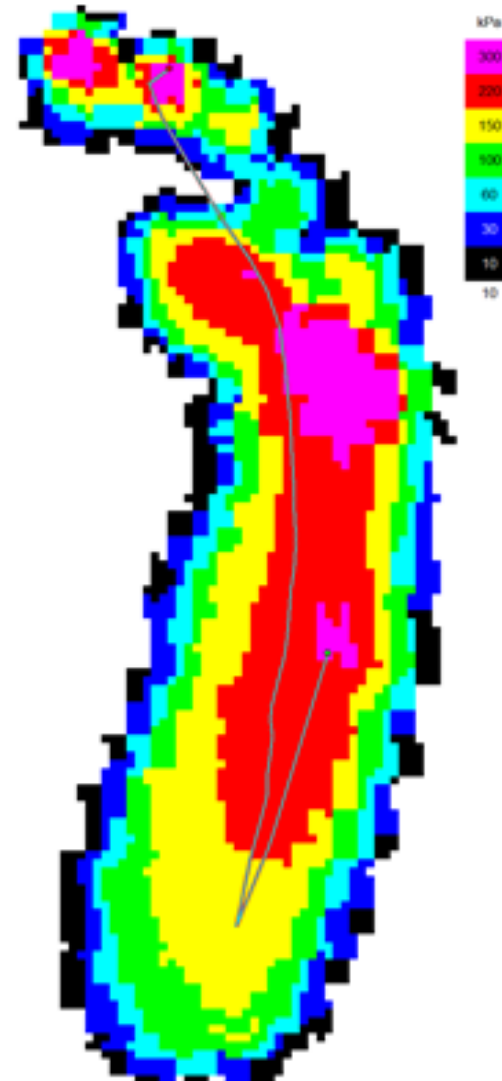
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Foot Kinematics: Consistency



Plantar pressure



Conclusion

- ▶ Limited dorsiflexion primarily an ankle
 - (hindfoot relative to tibia problem)
- ▶ Supination occurs a forefoot level
 - Off-loading 1st met head (with hallux flexion)
- ▶ Orthotic options unrealistic
- ▶ Surgery would need to address equinus of hindfoot and supination of forefoot

History (R448A)

- ▶ 22 year old with painful (L) foot
- ▶ Previous surgery to correct valgus foot deformity
- ▶ Pain in (L) ankle after walking and standing for extended periods
- ▶ Currently wears insoles

Physical Exam

- ▶ 5 degree valgus knee alignment (R + L)
- ▶ 5 degrees dorsiflexion (knees straight)
- ▶ Full subtalar mobility (R + L)
- ▶ Cavo-varus foot postures in NWB
- ▶ Weight-bearing foot position
 - Neutral (L) foot
 - Varus (R) foot

Video images

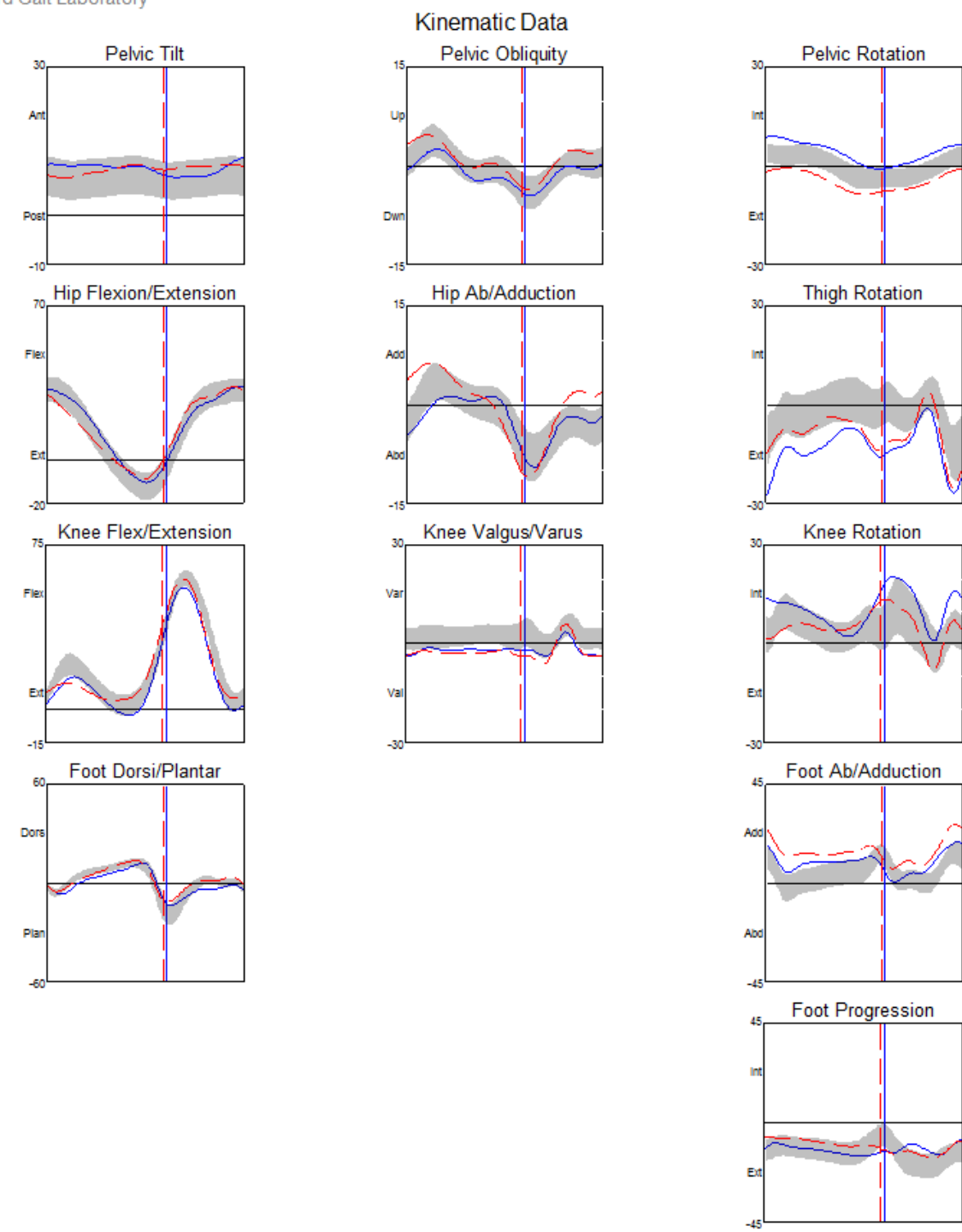


Kinematics

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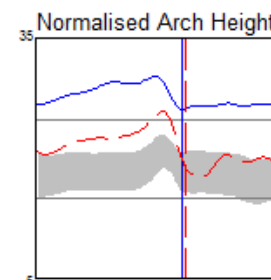
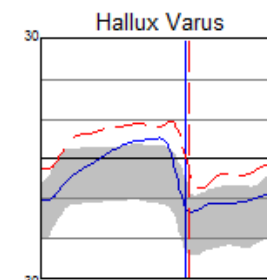
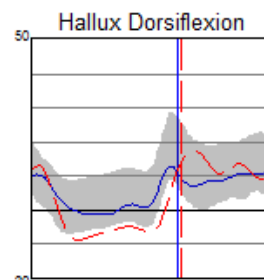
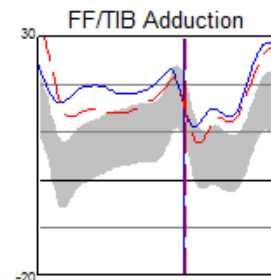
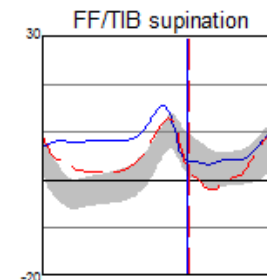
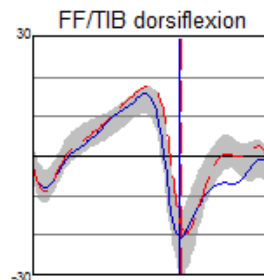
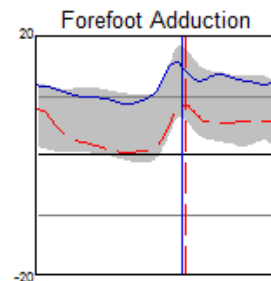
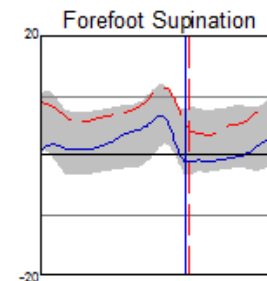
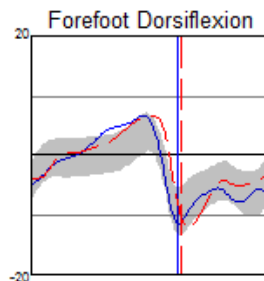
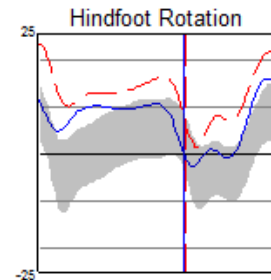
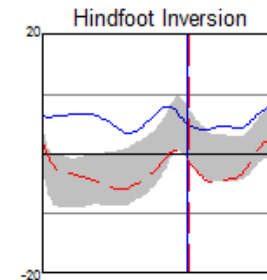
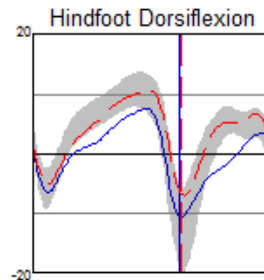
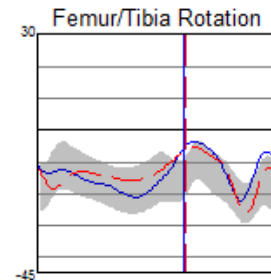
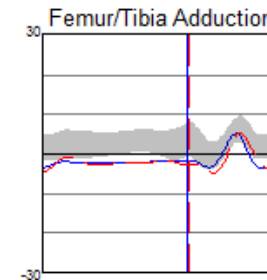
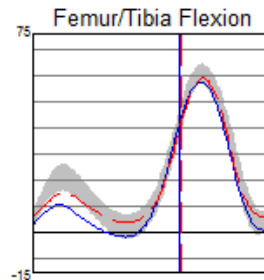


Foot Model

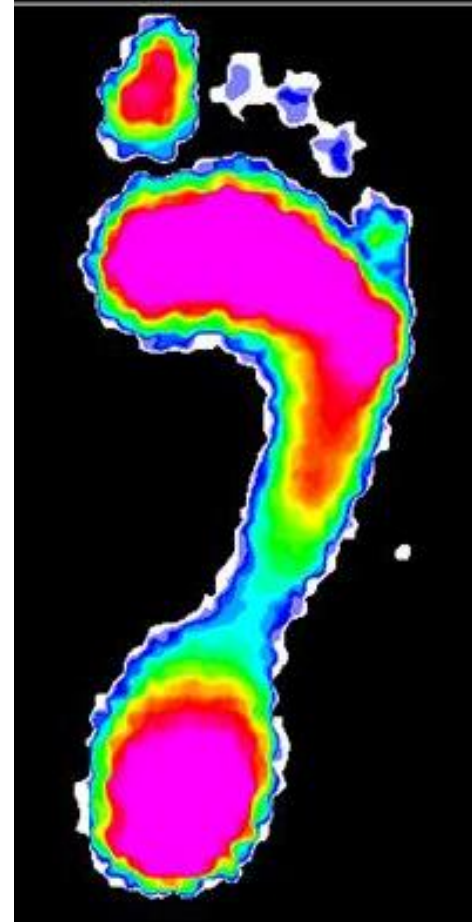
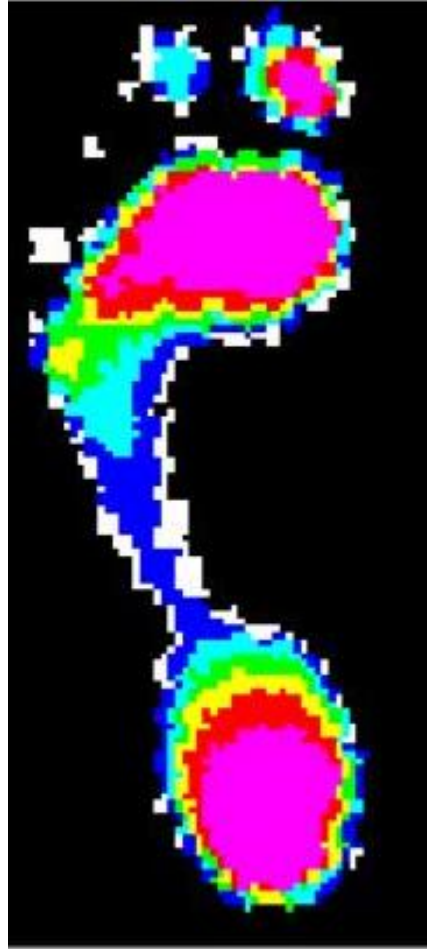
Blue = right

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Plantar pressure



Conclusion

- ▶ (R) side – valgus knee alignment balanced by varus ankle position
 - Uniform medio–lateral loading of foot
- ▶ (L) side – valgus knee alignment NOT balanced by ankle position
 - Excessive loading on medial aspect of foot

History (N371B)

- ▶ 10 year old with HMSN type 1
- ▶ Bilateral surgery to correct cavo-varus feet 6 months prior to gait lab visit
- ▶ Patient pleased with the outcome
 - Reduced foot pain
 - Better foot contact

Physical Exam

- ▶ Persistent knee hyperextension (R + L)
- ▶ Ankle dorsiflexion to 5–10 degrees (R + L)
- ▶ Mild forefoot adduction (L)
- ▶ Improved plantarflexion and pronation strength (R + L)



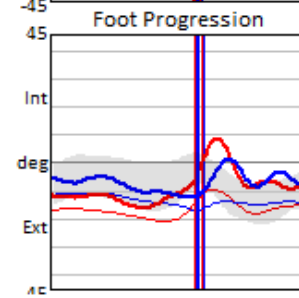
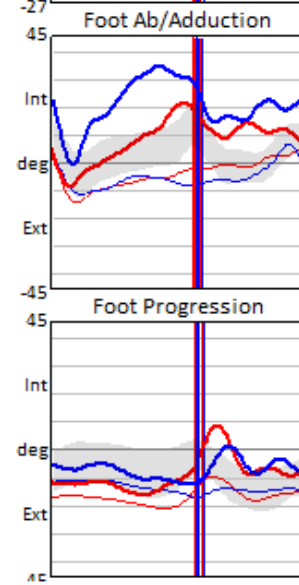
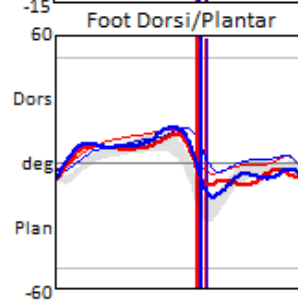
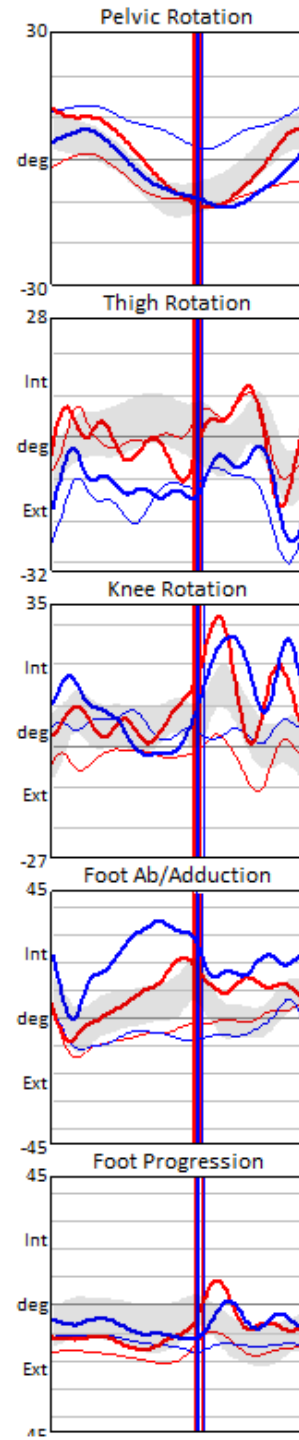
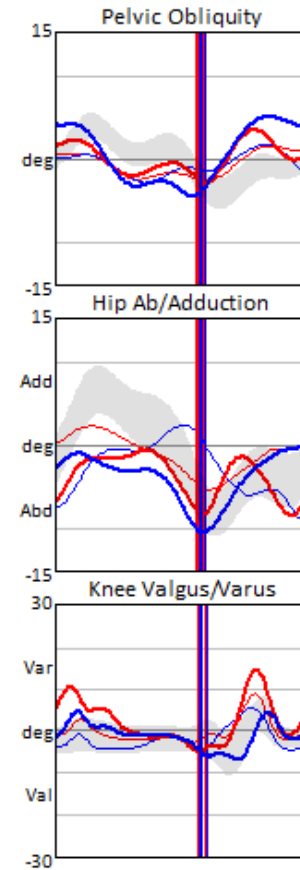
Kinematics

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BOLD = pre-op



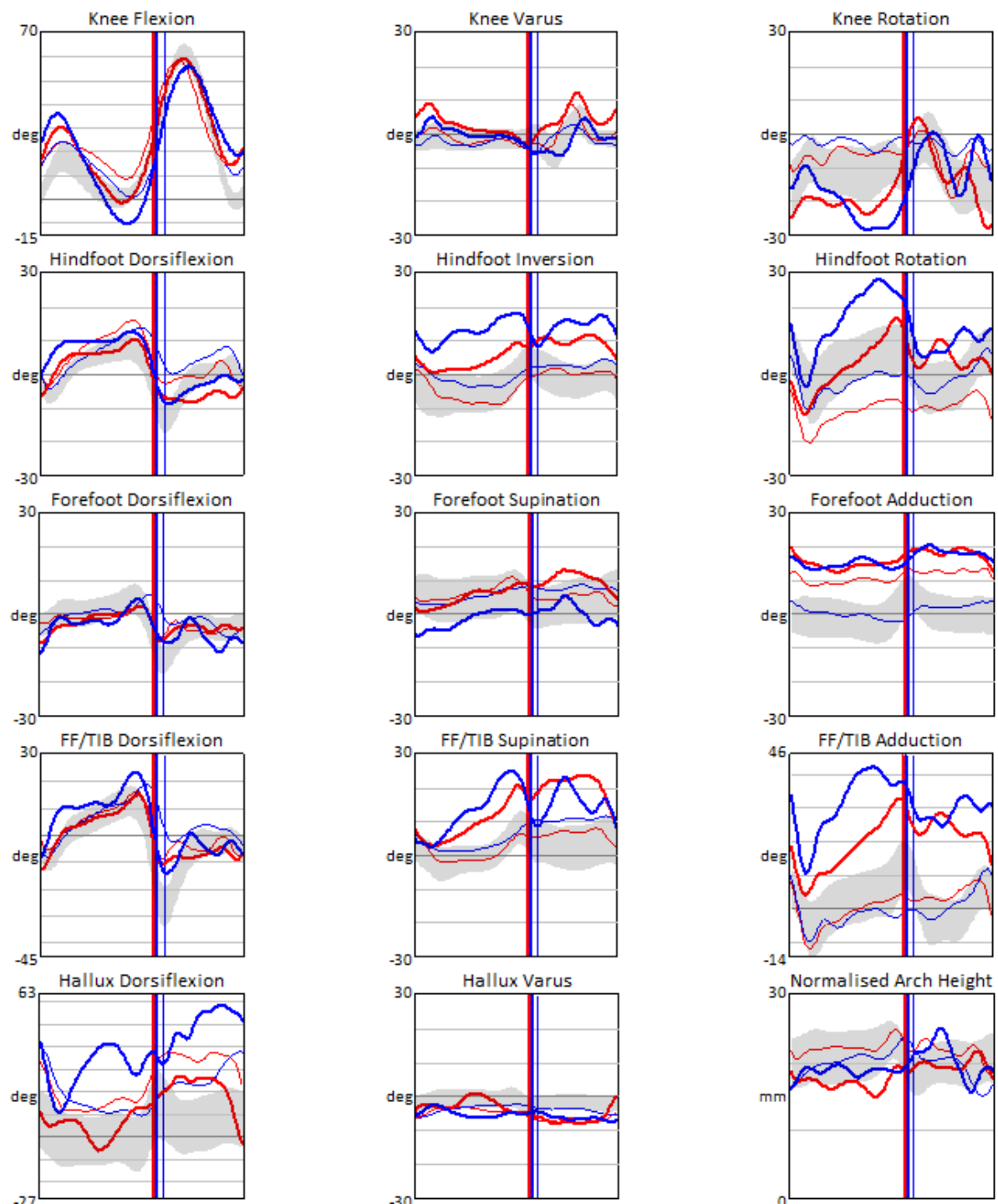
Foot Model

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Conclusion

- ▶ Surgery successful in correcting all element of the foot deformity
- ▶ Wouldn't be evident in conventional kinematics

History (C674F)

- ▶ 19 year old with bilateral cerebral palsy
- ▶ 2 years post SEMLS, including correction of:
 - (R) planovalgus
 - (L) equinus deformity
- ▶ Reports (L) leg starting to turn in more, and experiencing falls over past year

Physical Exam

- ▶ Joint contractures corrected following surgery
- ▶ Residual equinus contracture 10° (L)
- ▶ Correction of anteversion (R + L)
- ▶ Now has planovalgus foot posture (L)

Video



Pre-op

Post-op



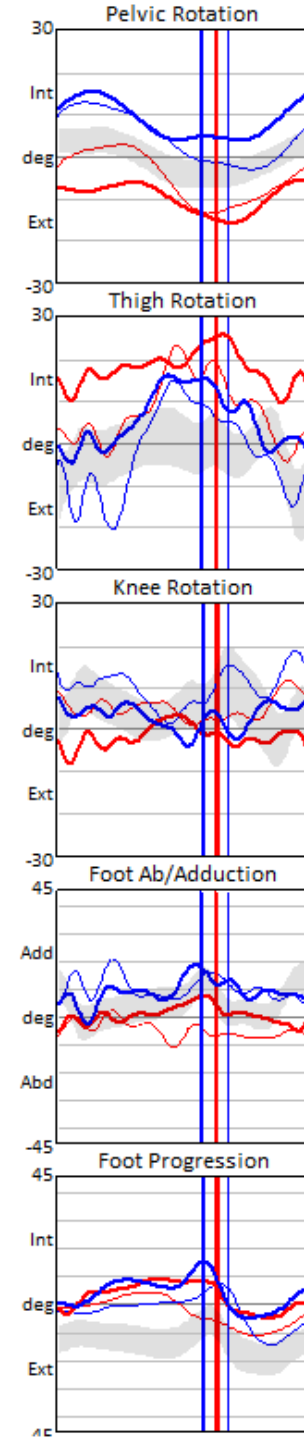
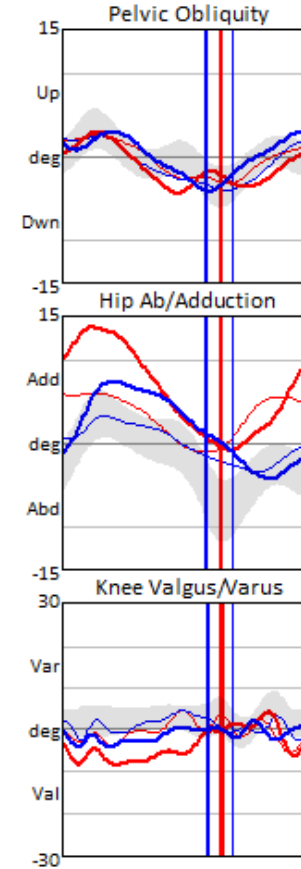
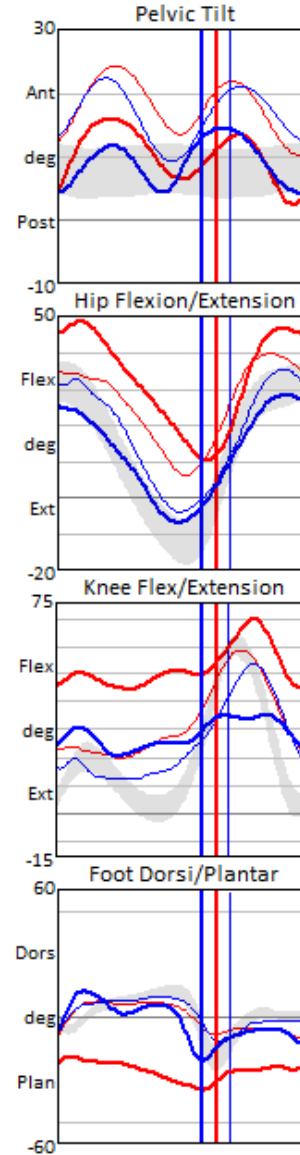
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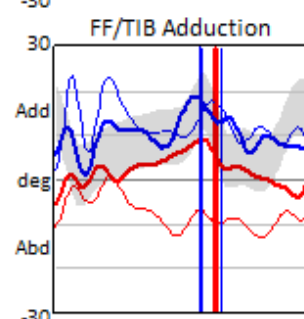
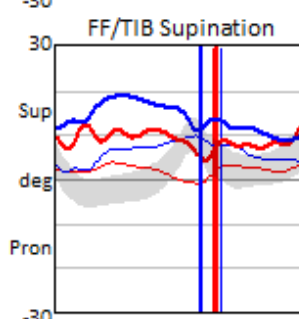
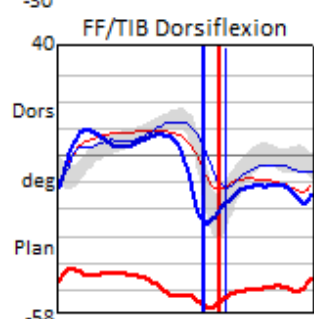
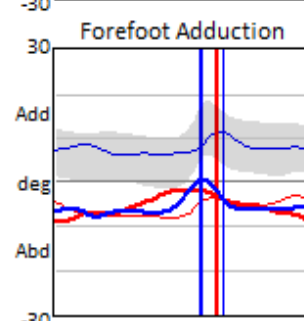
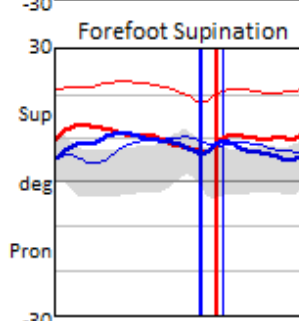
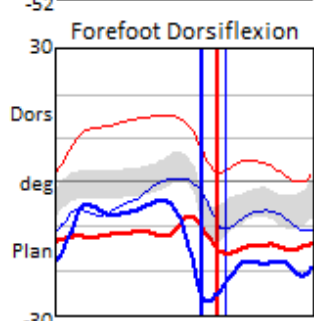
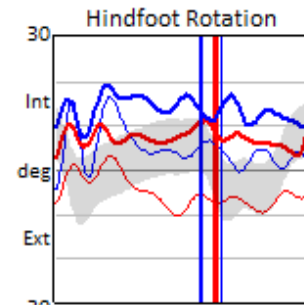
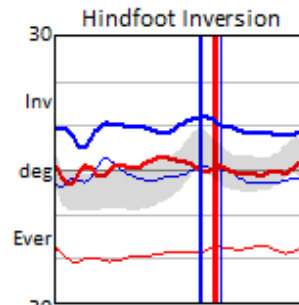
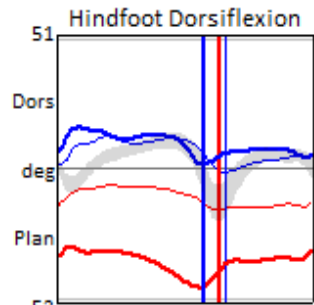
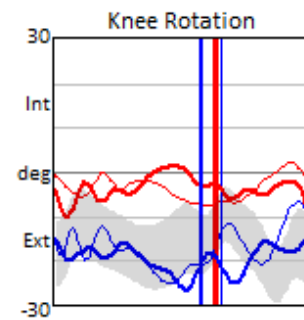
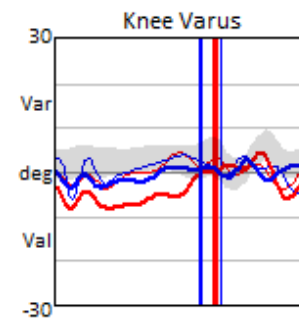
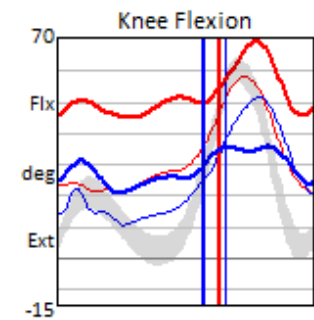
Foot Model

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Conclusion

- ▶ Significant equinus (L) improved but...
- ▶ Foot model data shows some remaining hindfoot equinus (forefoot dorsiflexion)
- ▶ Also now has hindfoot valgus
 - Compensatory forefoot supination
- ▶ Forefoot abduction – similar to pre-op
- ▶ Further foot management indicated by foot model data only

Summary of cases

- ▶ Foot model data influenced treatment decision making in some cases:
 - Help to plan specific surgical intervention
 - Help to identify reason for pain
 - Outcome measure: identify real change
 - Outcome measure: identify where outcome was unsatisfactory

Cerebral palsy

- ▶ Foot model information used to:
 - Confirm clinical assessment of foot deformity
 - Determine cause of in-toeing/out-toeing
 - Determine level of foot drop
 - Monitor progression of foot deformity
 - Assess outcomes of treatment
 - Clarify controversial findings from lower limb kinematics
 - Guide orthotic intervention



Clubfoot

- ▶ Foot model used to:
 - Identify level of dynamic foot deformity
 - Specify the type of surgery required
 - Justify type of casting appropriate
 - Clarify the source of foot rotation
 - Corroborate clinical findings



Conclusion

- ▶ Foot model data now collected routinely
- ▶ Data significantly impacts on currently clinical decision making
- ▶ Current audit to determine impact on clinical decision making overall



Oxford University Hospitals



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Thank you