Clinical Use of the mSHCG Multi-Segment Foot Model

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SGL Vancouver

- .5 fte Director
- 1.0 Engineer
- .8 PT (shared by 2)
- 2 Orthopaedic Surgeons

Mandate

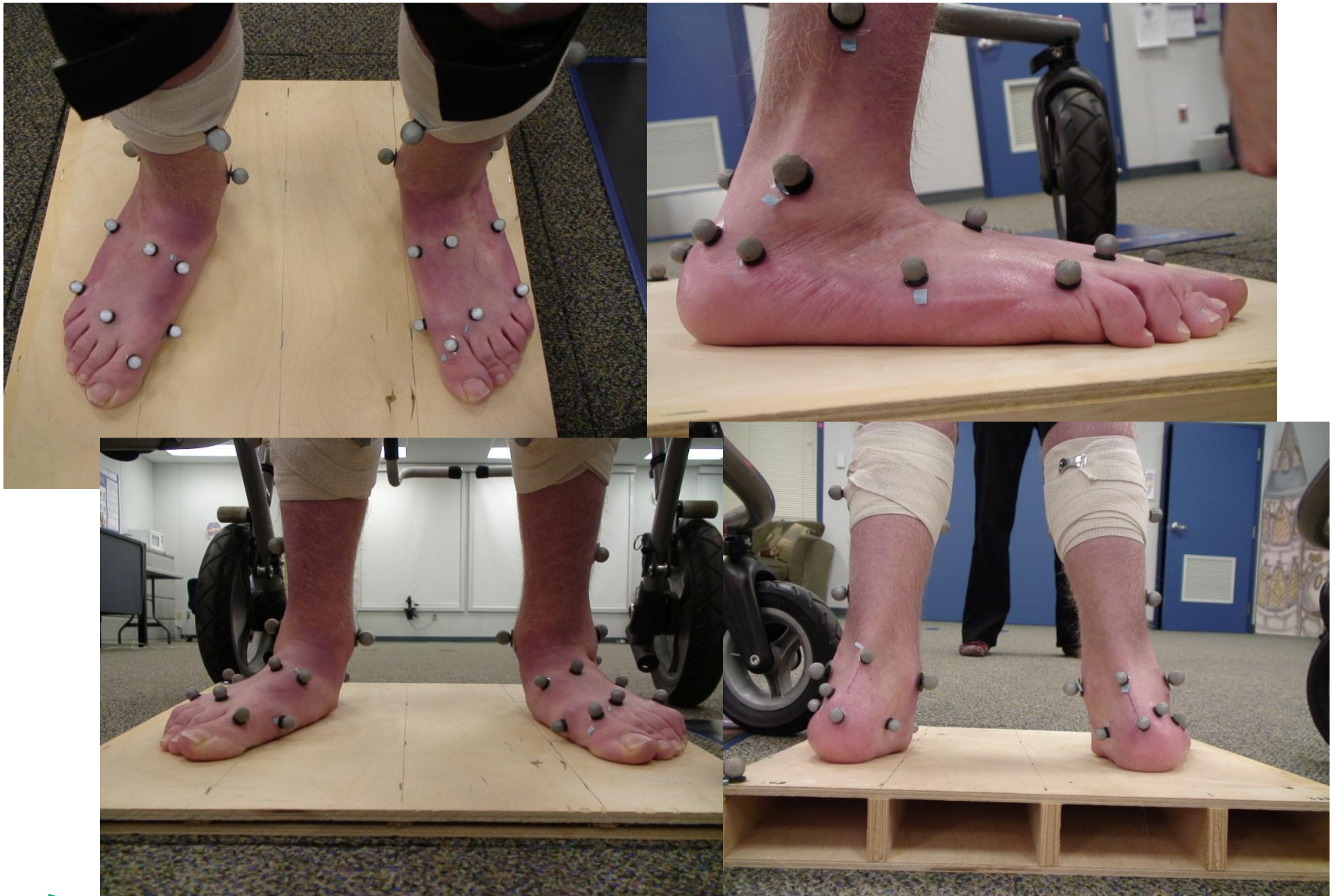
- To provide clinical decision support to Orthopaedic Surgeons, Physiotherapists and Orthotists
- To conduct clinically relevant research to aid our decision support role

History of MSFM

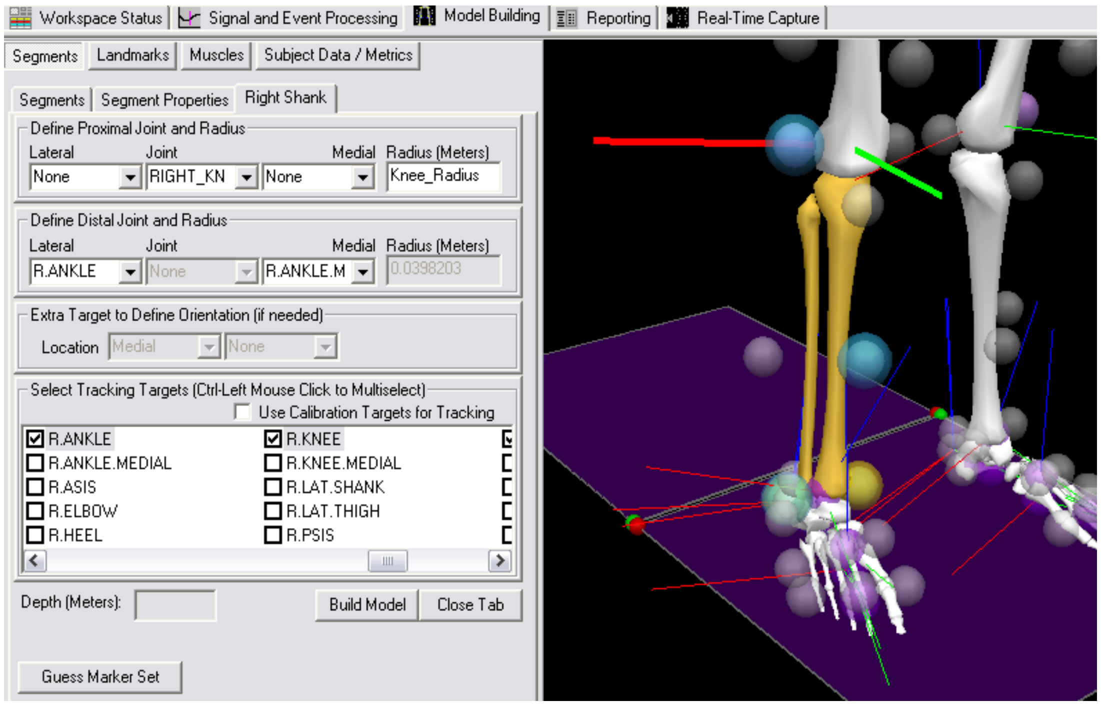
- 2004 – GCMAS Foot Modeling Symposium
- 2004 – 2 Mech Eng Students OFM in V3D
- 2007 – Hired an Engineer
- 2008 – Compared the OFM to other models
- 2010 – Settled on Shriners Hospital for Children Greenville (SHCGFM)

Presentations

- Maurer, J. D., Black, A.H., Alvarez, C. M., Ward, V., Davies, K R., & Beauchamp, R. D.(2009). Classification of Mid-foot Break Using a Multi-segment Foot Model. *GCMAS* (Vol. 23, pp. 204–205). Denver, Colorado.
- Maurer, J. D., Black, A.H., Alvarez, C. M., Ward, V., Davies, K. R., & Beauchamp, R. D. (2010). Classification of Mid-foot Break Using a Multi-segment Foot Model. *2nd Congress of the International Foot and Ankle Biomechanics Community* (Vol. 23).
- Black, A. H., Maurer, J. D., Alvarez, C. M., Ward, V., Davies, K. R., Mayson, T. A., & Beauchamp, R. D. (2012). CLASSIFICATION OF MID-FOOT BREAK USING A MULTI-SEGMENT FOOT MODEL AND PEDOBAROGRAPHY. In *Gait & Clinical Movement Analysis Society 2012 Annual Conference* (pp. 185–186). Grand Rapids Michigan.



Shank



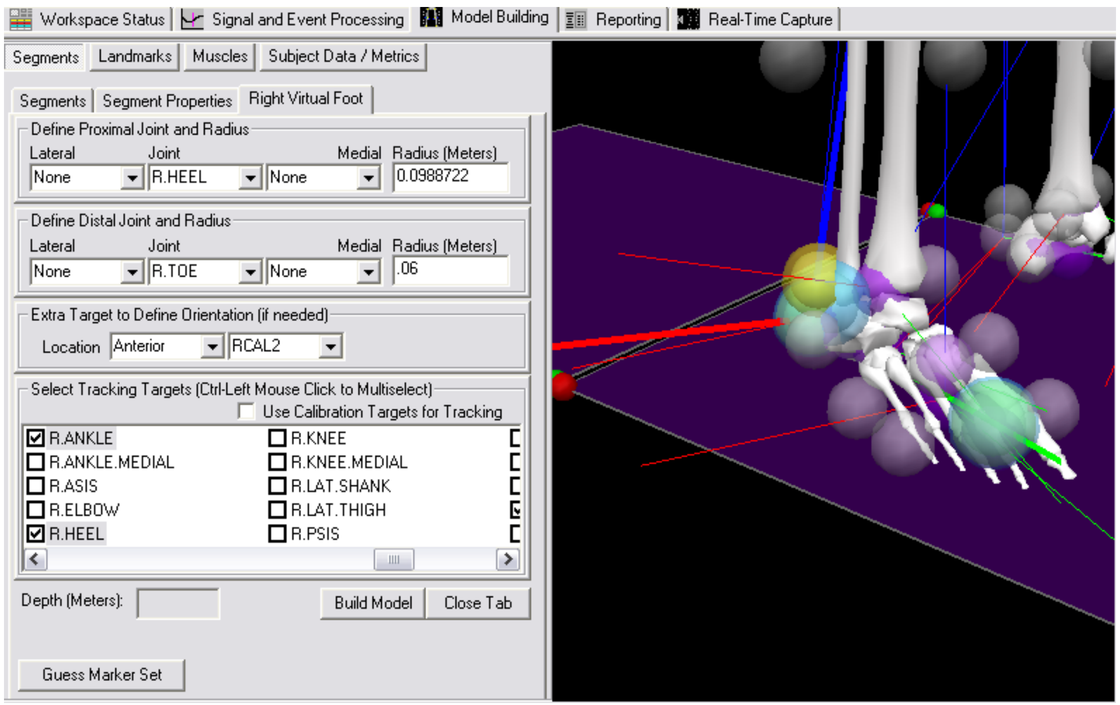
- **Coordinate System Alignment:** The shank coordinate system (right shank is used for this example) is aligned with the plane formed by Right_Knee (mid-point of R.KNEE and R.KNEE.MEDIAL), R.ANKLE, and R.ANKLE.MEDIAL.

  Proximal End:
  Right_Knee

  Distal End:
  Right_Ankle - mid-point between R.ANKLE and R.ANKLE.MEDIAL

  Tracking Markers:
  R.ANKLE, R.KNEE, R.SHANK

Foot



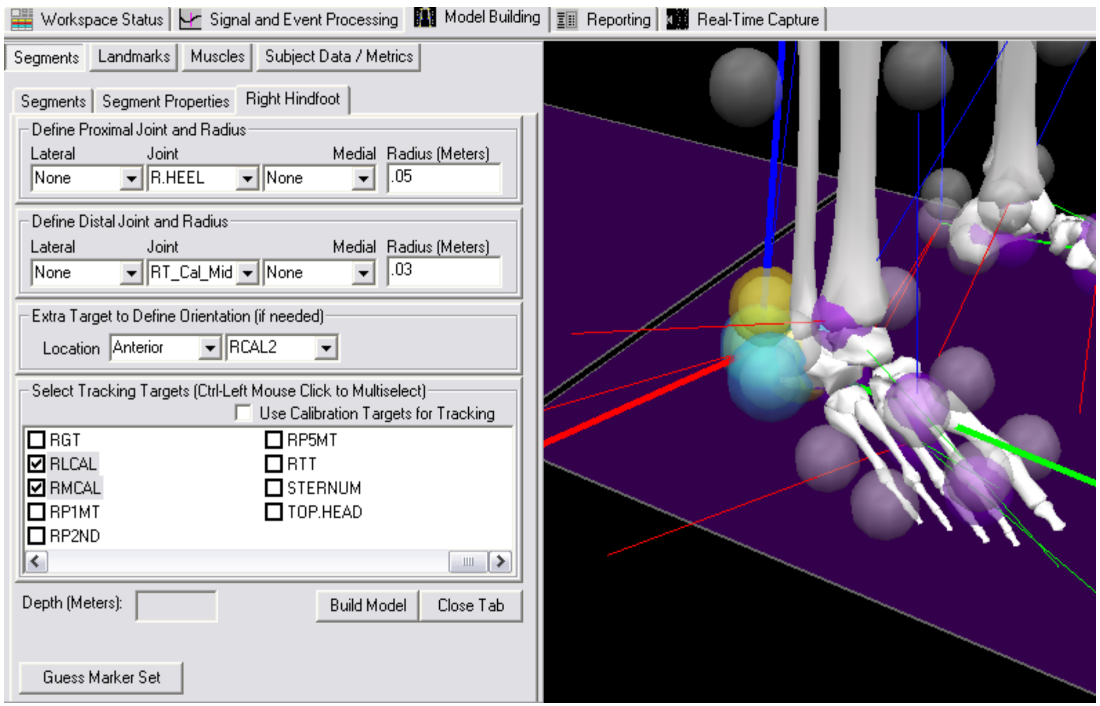
- **Coordinate System Alignment:** The virtual foot coordinate system (right foot is used for this example) is aligned with the plane formed by R.HEEL, R.TOE, and RCAL2.

Proximal End:
R.Heel

Distal End:
R.Toe

Tracking Markers:
R.HEEL, R.TOE, RP1MT, RP5MT

Hindfoot



- **Coordinate System Alignment:**
  The hindfoot coordinate system (right foot is used for this example) is aligned with the plane formed by R.HEEL, RT_Cal_Midpoint, and RCAL2.

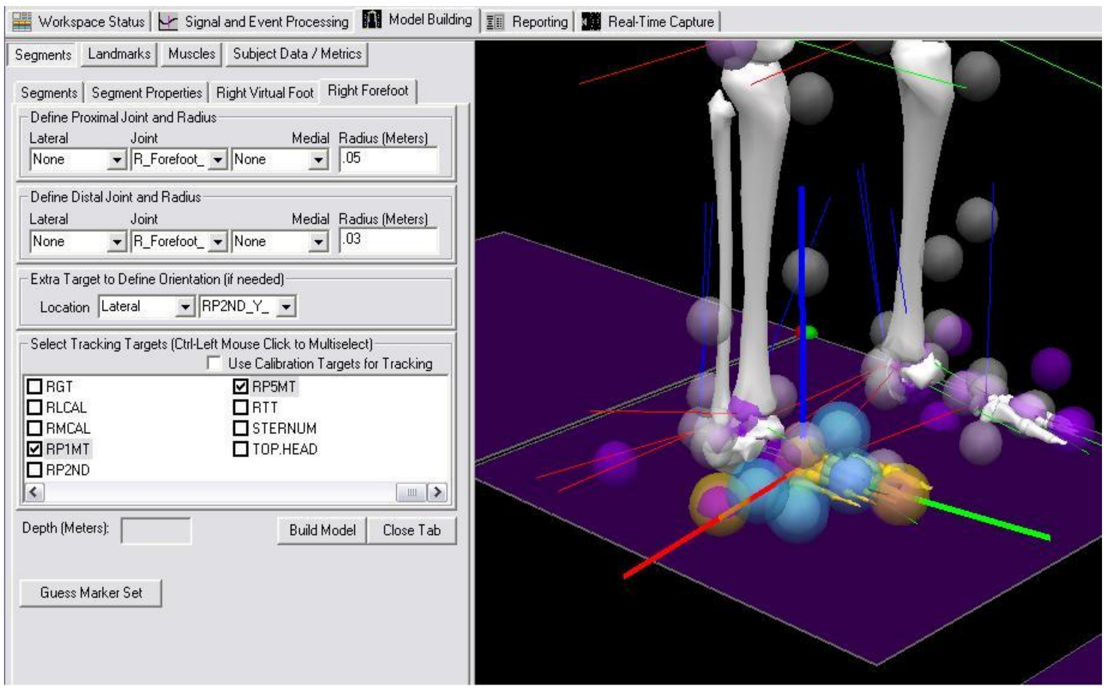
  The vector from R.HEEL to RT_Cal_Midpoint_Projected (Cal Mid-point is offset such that this vector is parallel to the ground) forms the Y-axis, the X-axis is perpendicular to the hindfoot plane (described above), and the Z-axis is orthogonal to X and Y.

  Proximal End:
  R.Heel

  Distal End:
  RT_Cal_Midpoint

  Tracking Markers:
  R.HEEL, RMCAL, RLCAL, RLCAL2

Forefoot



- **Coordinate System Alignment:**
  The forefoot coordinate system is set parallel to the floor at the same height as the heel marker (for convenience to match the HF coordinate system). The forefoot origin (R_Forefoot_Origin) is located at RP2ND, projected onto the forefoot plane described above. The vector from R_Forefoot_Origin to R_Forefoot_Distal (the R.Toe marker projected onto the forefoot plane) forms the Y-axis, the X-axis is perpendicular to the Y-axis, within the forefoot plane, and the Z-axis is orthogonal to X and Y.

  Proximal End:
  R_Forefoot_Origin

  Distal End:
  R_Forefoot_Distal

  Tracking Markers:
  RP5MT, RD5MT, RP1MT and R.TOE

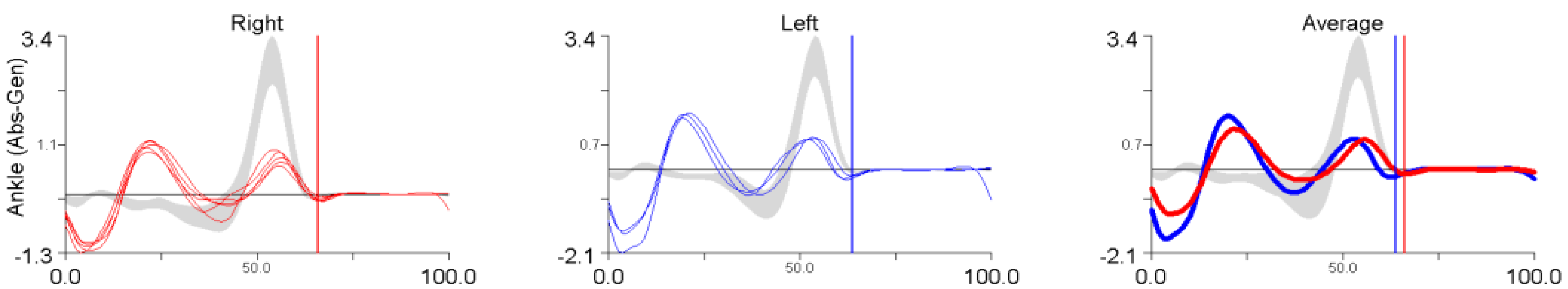
Repeatability

- Intra/Inter tester Reliability.
- 2 PT's , 1 adult , 3 sessions
- mSHCGFM forefoot angles: PT1(M 5.8°, **SD** 1.5°) PT2 (M 6.5°, **SD** 0.7°)
- mSHCGFM hindfoot angles: PT1(M 7.1°, **SD** 2.3°) PT2 (M 6.0°, **SD** 1.2°)

What's Wrong With a Mid-Foot Break (MFB)?

- Pain
- Foot Mechanics
  - – lever arm dysfunction
    - Reduced moment arm
    - Reduced power generation

Sagittal Joint Powers (Watts/kg)



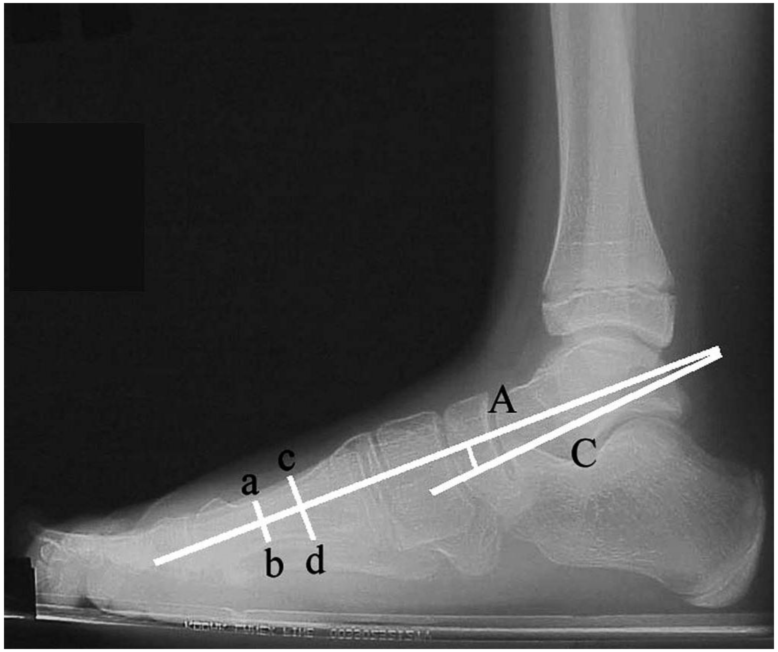
Ways to Identify MFB

- Clinical
- Radiographic
- Plantar Pressures
- Kinematics

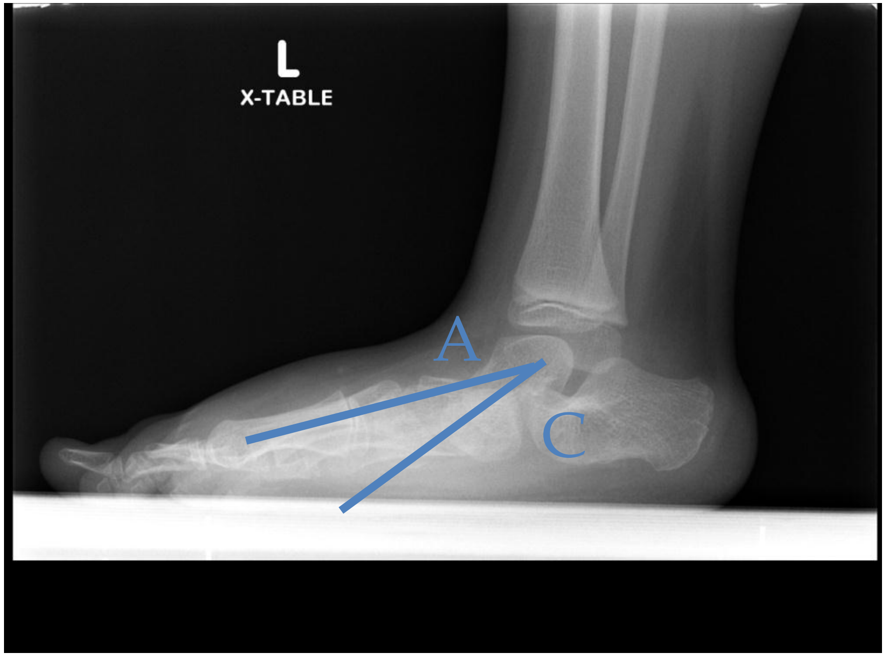
Clinical

- Sagittal Plane:
  - HF in equinus
  - FF dorsiflexed relative to HF
- Coronal Plane:
  - HF valgus
  - FF pronated
- Transverse Plane:
  - FF abducted

Normal X-Ray

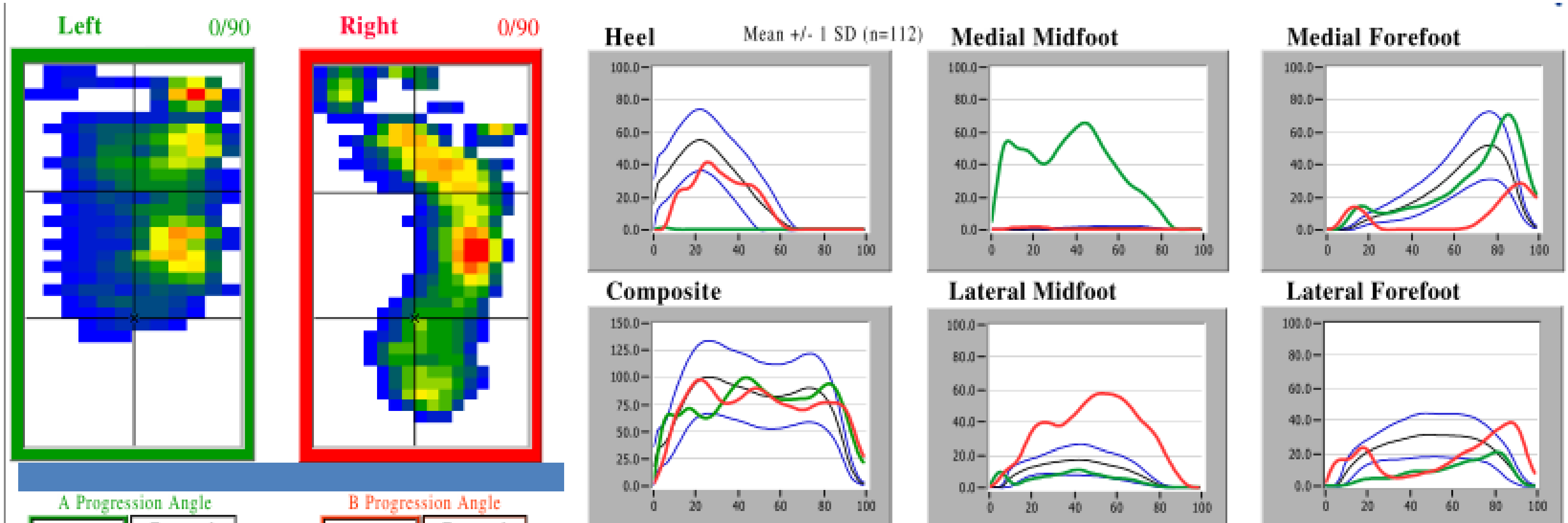


MFB X-Ray



Davids, J.R. et al. *J Pediatr Orthop* **25**, 769-76 (2005).

Pedobarography



A Progression Angle

15.00 External

B Progression Angle

3.00 External

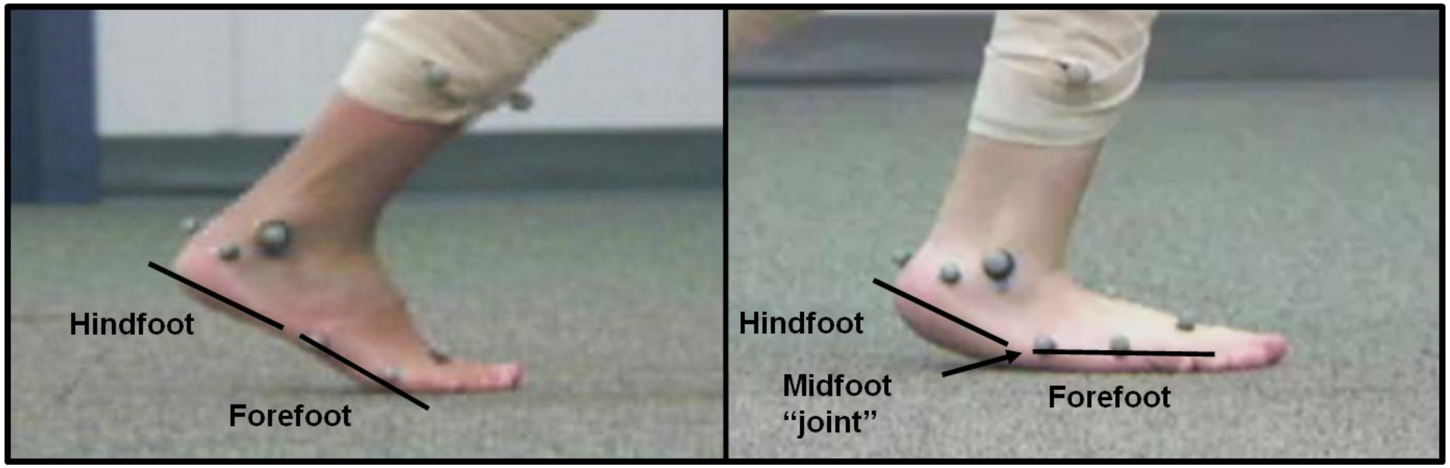
* The data in the graphs are represented as a percentage of the total load assumed by the foot for each segment.
* The data in each graph begins with heel strike and ends with toe off (stance). Data were dilated to 100 points (x axis).

Force Summary

	LHeel	RHeel	-1 SD	+1 SD	LLMF	RLMF	-1 SD	+1 SD	LMMF	RMMF	-1 SD	+1 SD	LLFF	RLFF	-1 SD	+1 SD	LMFF	RMFF	-1 SD	+1 SD	LAll	RAll	-1 SD	+1 SD
% Stance at Initiation	2.0	2.0	0.0	0.0	0.0	0.0	3.5	9.9	0.0	6.0	30.7	100.0	10.0	0.0	3.4	9.6	5.0	0.0	6.4	14.8	0.0	0.0	0.0	0.0
% Stance at Termination	7.0	63.0	33.8	71.6	80.0	95.0	49.0	98.6	87.0	26.0	0.0	57.4	95.0	100.0	57.2	100.0	100.0	100.0	60.0	100.0	100.0	100.0	60.0	100.0
% of Total Impulse	0.1	19.9	19.0	41.4	6.7	44.9	6.3	18.9	47.3	0.4	0.0	1.4	11.3	24.3	17.5	40.4	34.5	10.5	18.8	42.9	100.0	100.0	60.0	100.0
Maximum % Force	1.4	42.6	37.2	76.0	11.0	59.0	10.4	28.1	65.9	1.7	0.0	2.6	20.9	39.6	21.0	48.0	71.2	29.3	31.4	73.0	100.0	100.0	60.0	100.0
% Stance at Maximum Force	4.0	23.0	12.2	27.0	41.0	51.0	19.5	51.5	43.0	19.0	29.2	67.6	81.0	87.0	23.4	61.2	85.0	91.0	46.1	92.3	43.0	20.0	10.8	48.2
Braking Maximum % Force																					100.0	100.0	59.3	100.0
Braking % Stance at Max Force																					43.0	20.0	14.1	34.9
Propulsion Maximum % Force																					94.2	78.4	51.9	100.0
Propulsion % Stance at Max Force																					82.0	81.0	38.7	83.3

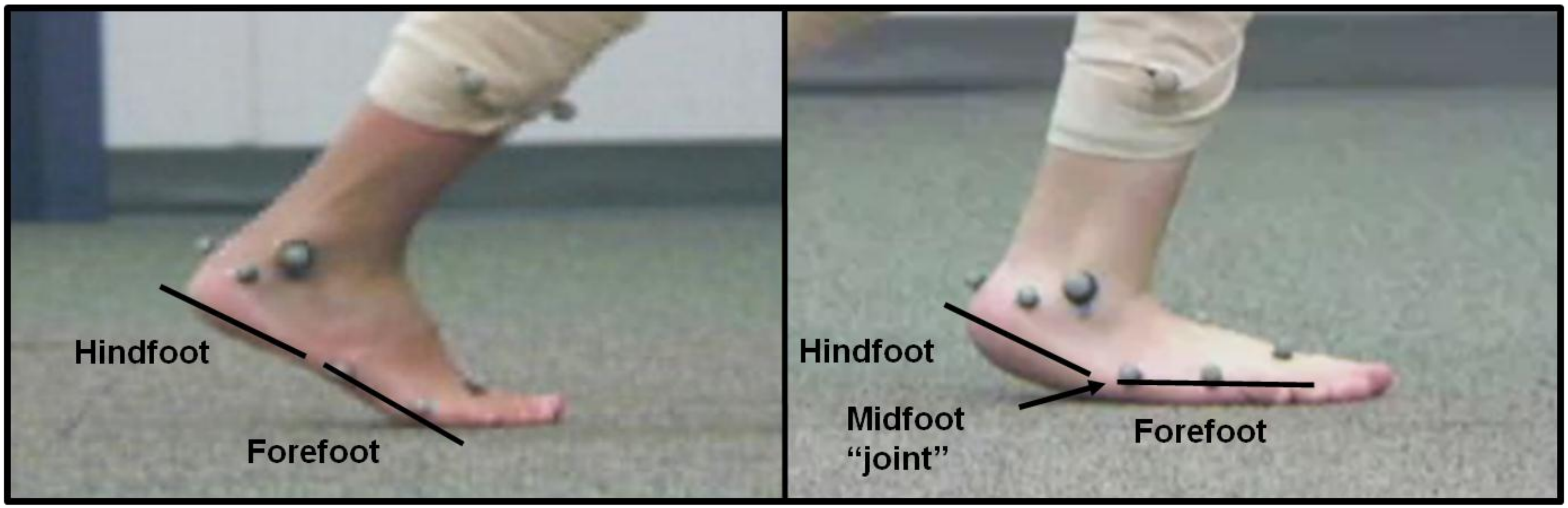
Kinematics

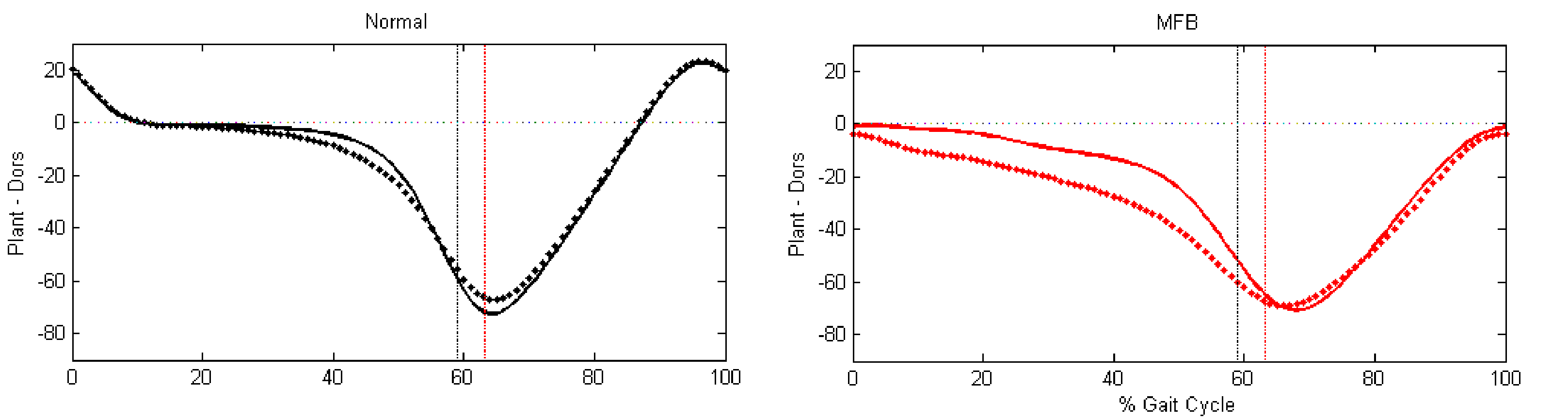
a new perspective on MFB



Normal MFB

Normal MFB

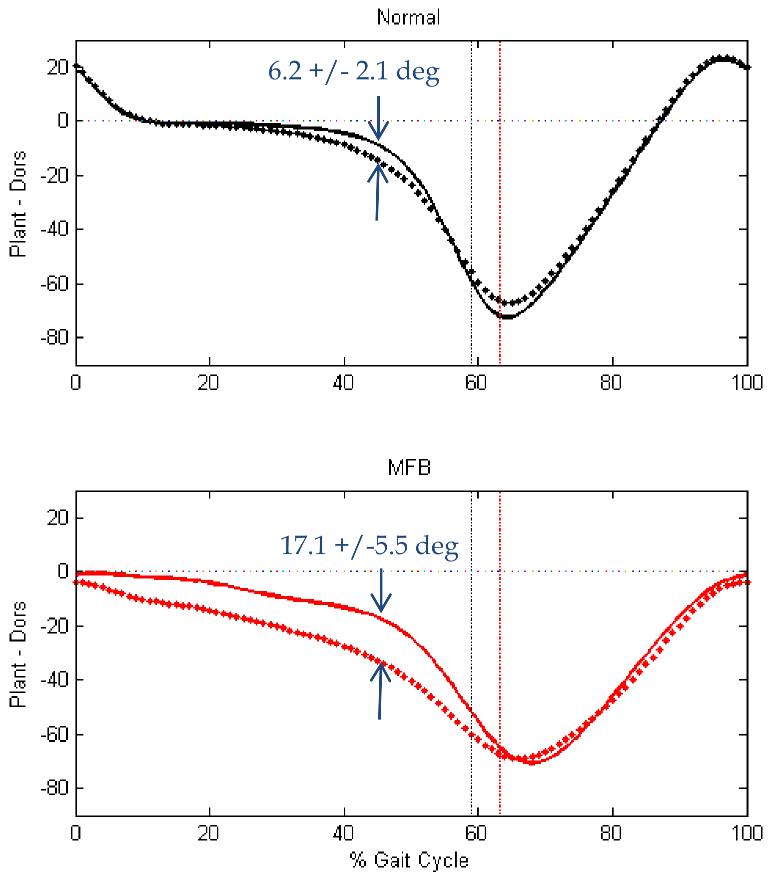




Forefoot and hindfoot angles with respect to the lab. FF = solid line, HF = dotted line. Black: Normal Mean, n=30. Red: MFB Mean, n=30.

MFB Vs Normal

- In the MFB Group, the HF moves into plantarflexion starting at foot strike, while the FF remains in contact with the floor initially and moves into plantarflexion at a slower rate.
- Relative to the floor, there was a much greater difference between the FF and HF angle in the MFB group (p<.05).
  - 17.1 +/-5.5 deg (MFB)
  - 6.2 +/- 2.1 deg (Normal)

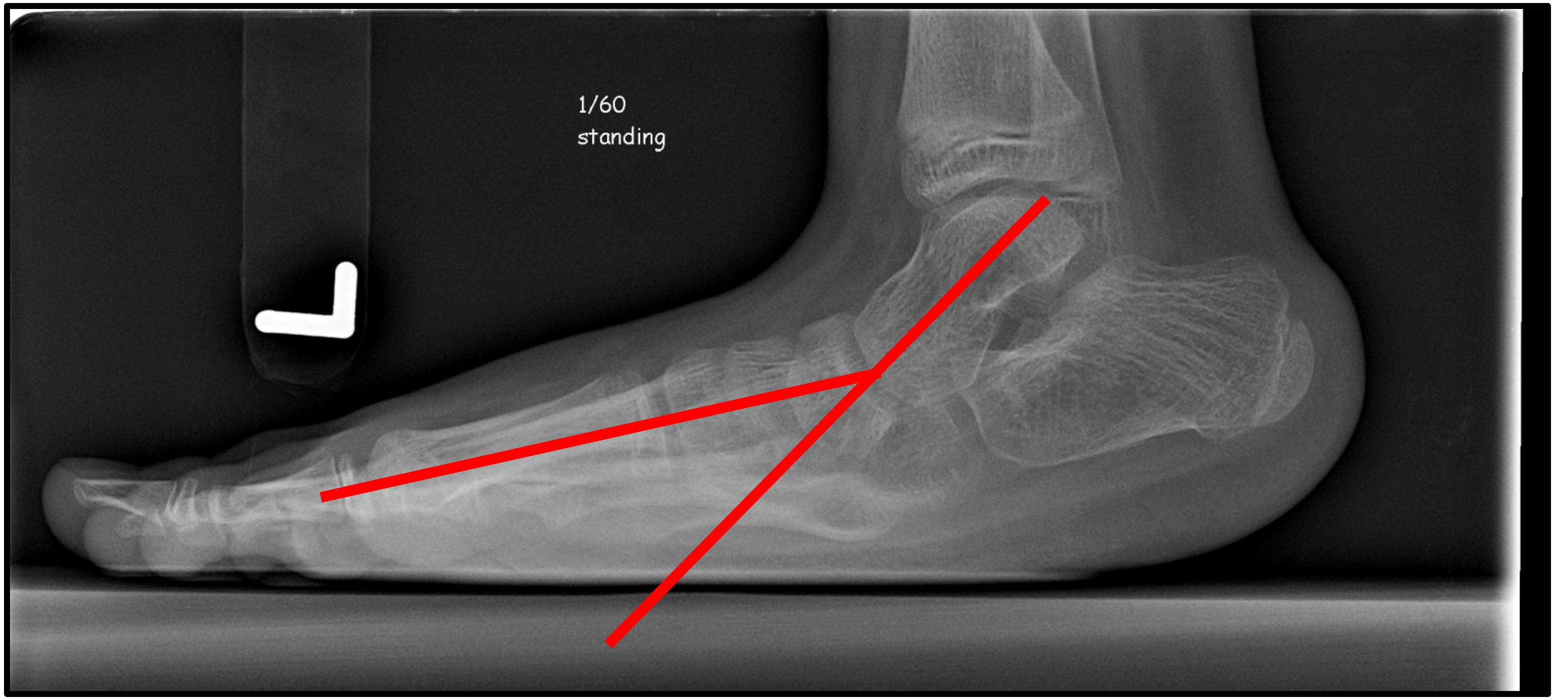


Forefoot and hindfoot angles with respect to the lab. FF = solid line, HF = dotted line. Black: Normal Mean, n=30. Red: MFB Mean, n=30.

Clinical Case 1

- 8 year old female with CP Diplegia
- GMFCS level 2
- FMS in 2009 4, 3, 3
- FMS in 2011 5, 5, 3

Pre-Op Xray

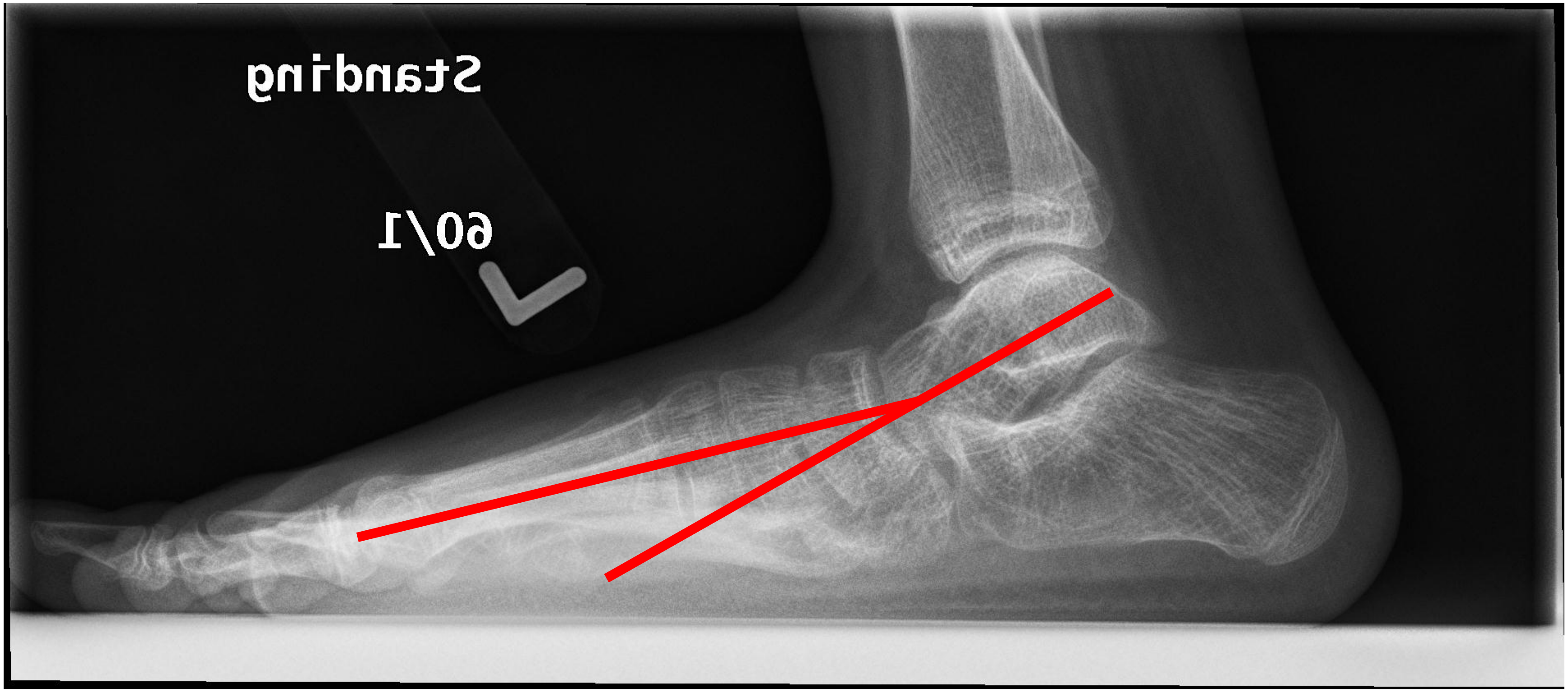


Pre-op/Post-op Comparison

Surgery:

- bilateral gastrocnemius recessions

Post-Op Xray



Pre-op

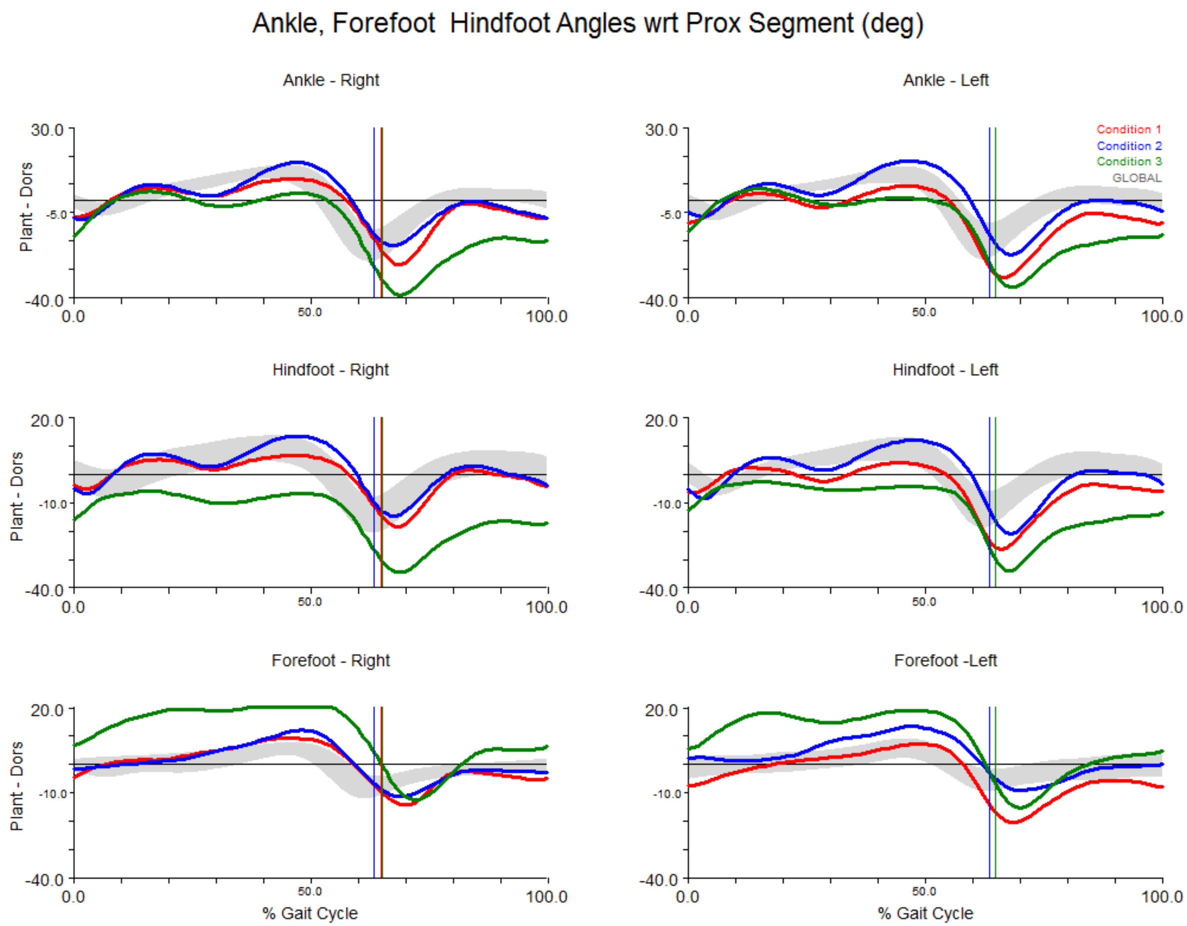
Post-Op

Pre-op/Post-op Comparison

Pre-op

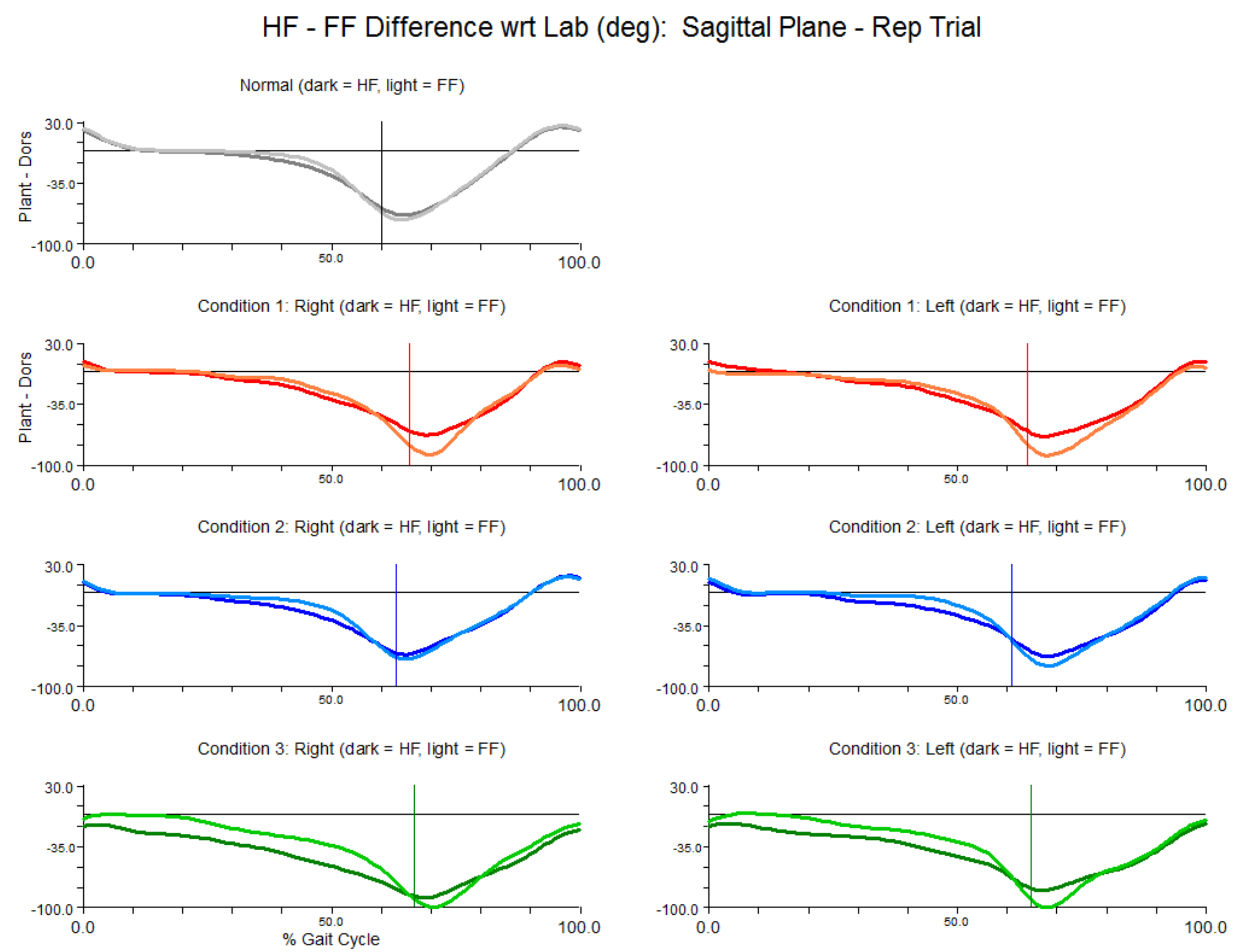
Post-op

Kinematics



Shriners Gait Lab at Sunny Hill Health Centre - HM - (Condition 1 = 2014. Condition 2 = 2011 Post-op, Condition 3 = 2009 Pre-Op)

Kinematics



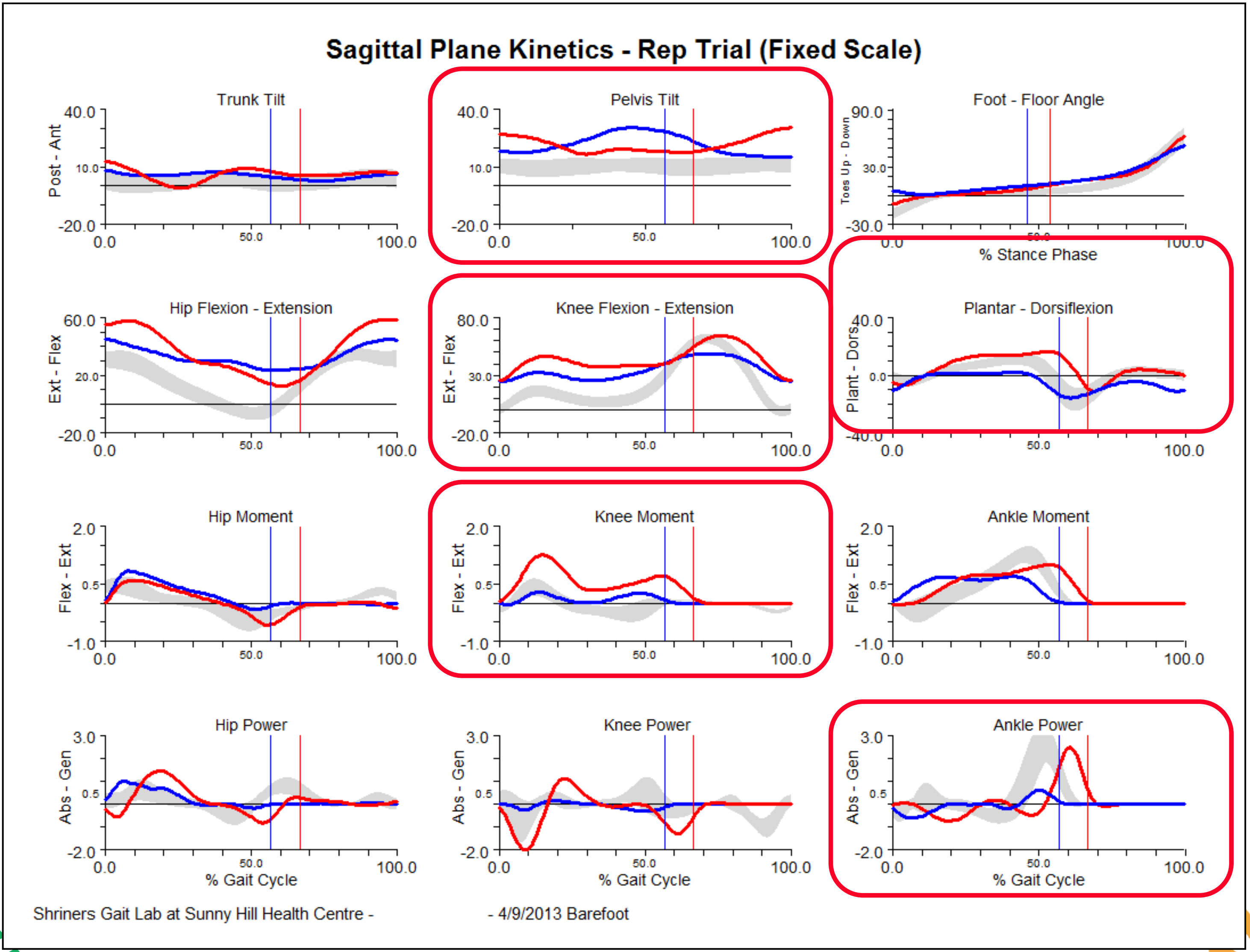
Shriners Gait Lab at Sunny Hill Health Centre - HM - (Condition 1 = 2014. Condition 2 = 2011 Post-op, Condition 3 = 2009 Pre-Op)

Clinical Case 2

- 12 yr old male with Diplegic CP
- 2013 Bilateral calcaneal lengthenings, gastroc recessions, H/S releases, RF transfer, LT peroneal lengthening
- Pre-op FMS 6,5,5
- GMFCS 2
- GDI 67 bilaterally

Pre-op Xray

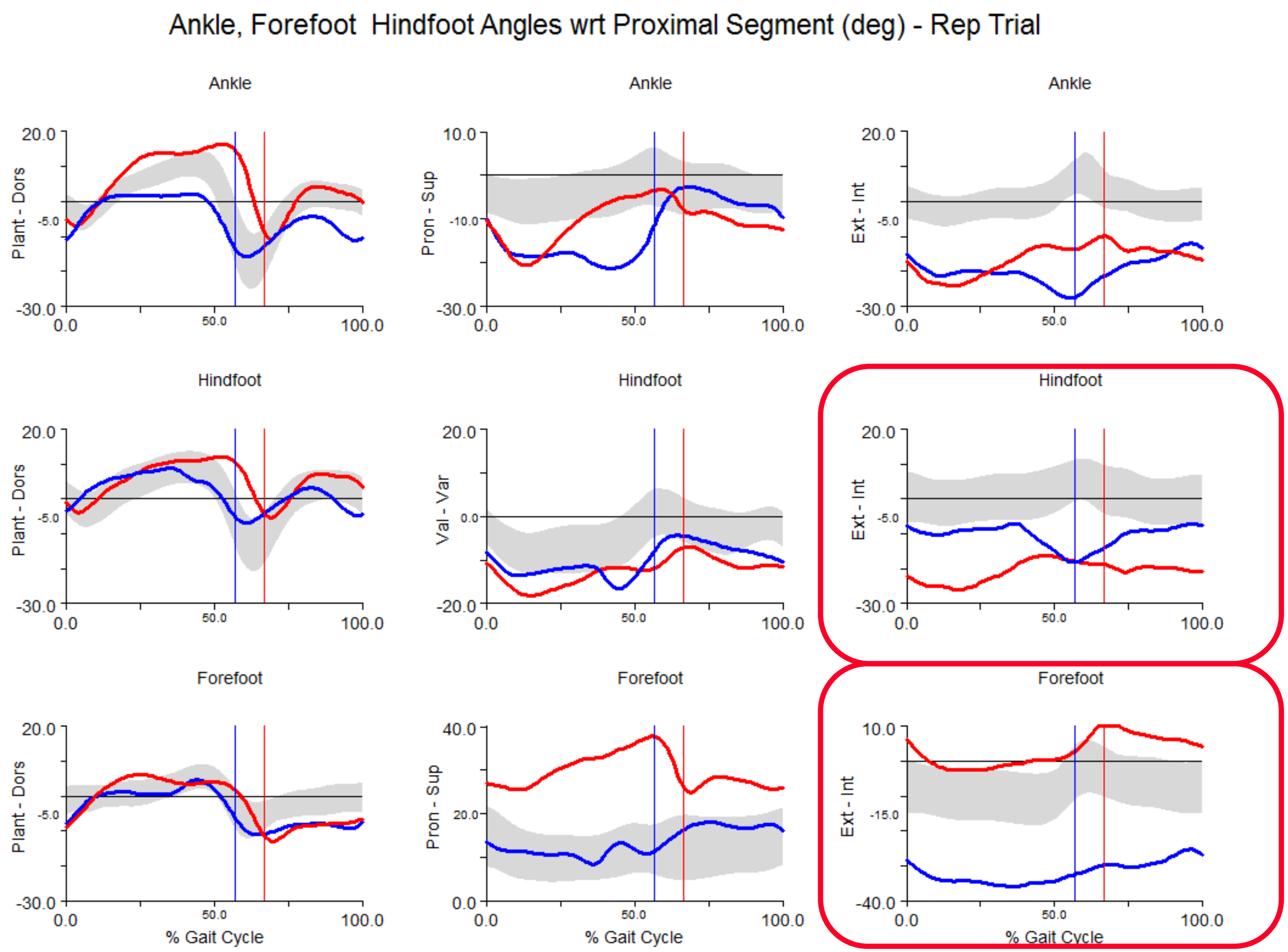
Video


Sagittal Plane Kinetics - Rep Trial (Fixed Scale)
Trunk Tilt
Pelvis Tilt
Foot - Floor Angle
% Stance Phase
Hip Flexion - Extension
Knee Flexion - Extension
Plantar - Dorsiflexion
Hip Moment
Knee Moment
Ankle Moment
Hip Power
Knee Power
Ankle Power
Post - Ant
Ext - Flex
Flex - Ext
Abs - Gen
Toes Up - Down
Plant - Dors
% Gait Cycle
Shriners Gait Lab at Sunny Hill Health Centre -
- 4/9/2013 Barefoot

Video

Video

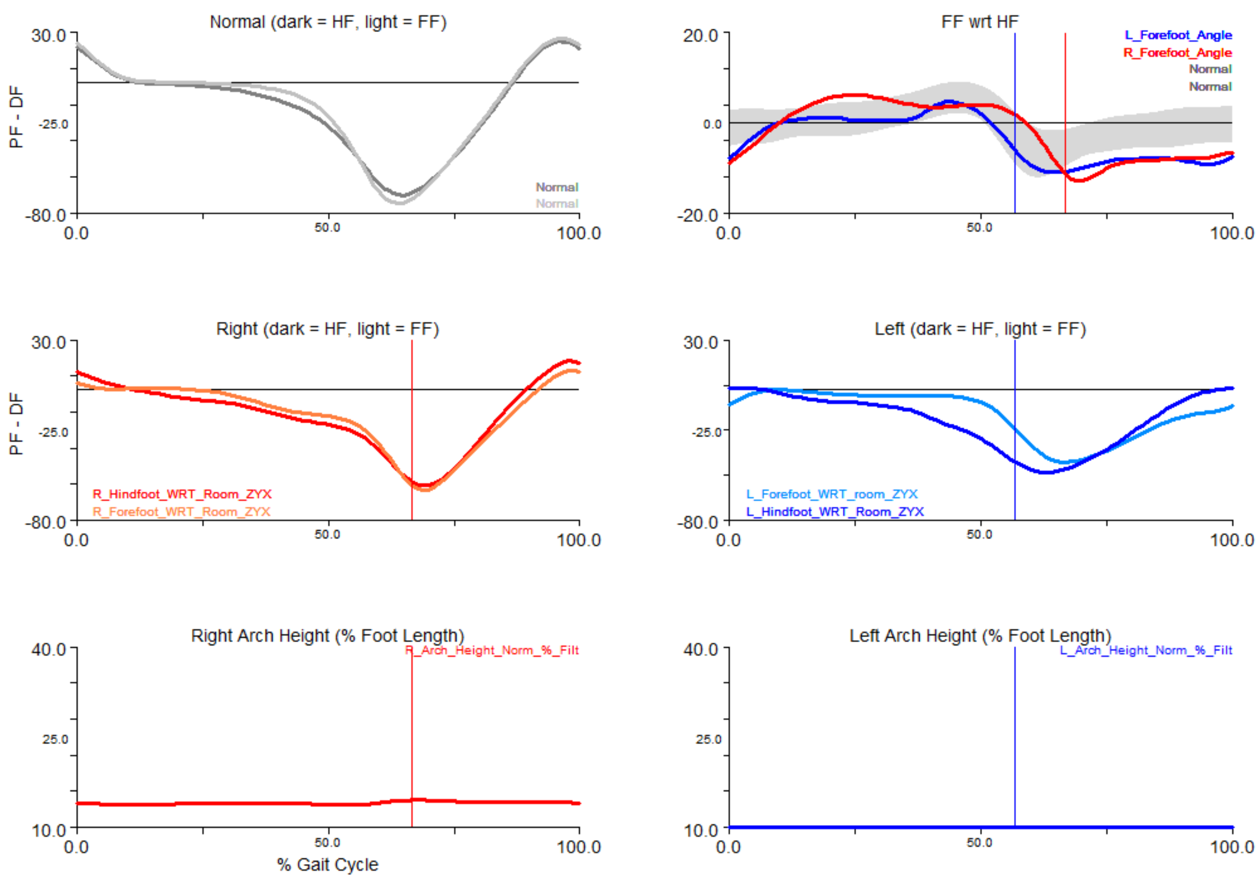
Foot Kinematics



Shriners Gait Lab at Sunny Hill Health Centre - 4/9/2013 Barefoot

Foot Kinematics

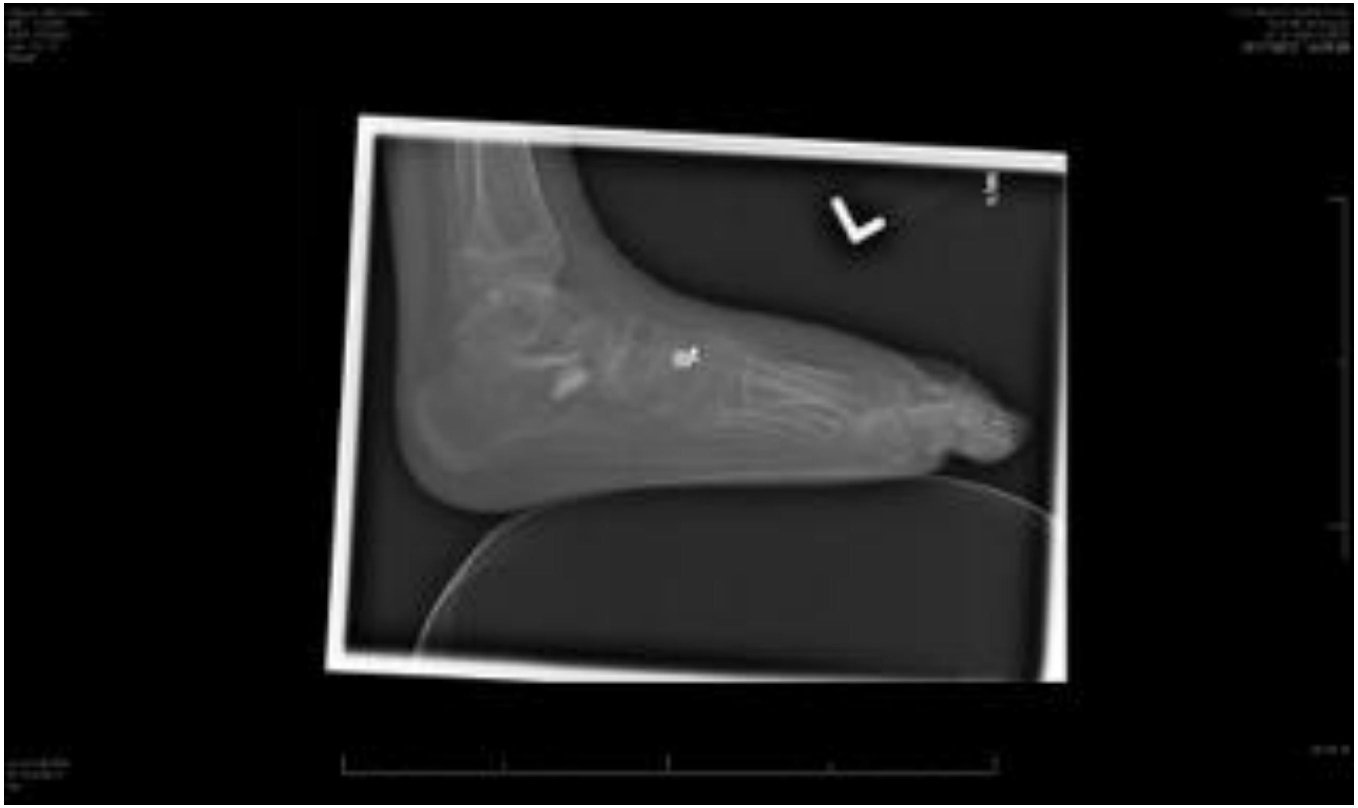
Forefoot & Hindfoot Angles - Sagittal Plane - Rep Trial (deg)



Shriners Gait Lab at Sunny Hill Health Centre - - 4/9/2013 Barefoot

Post Op

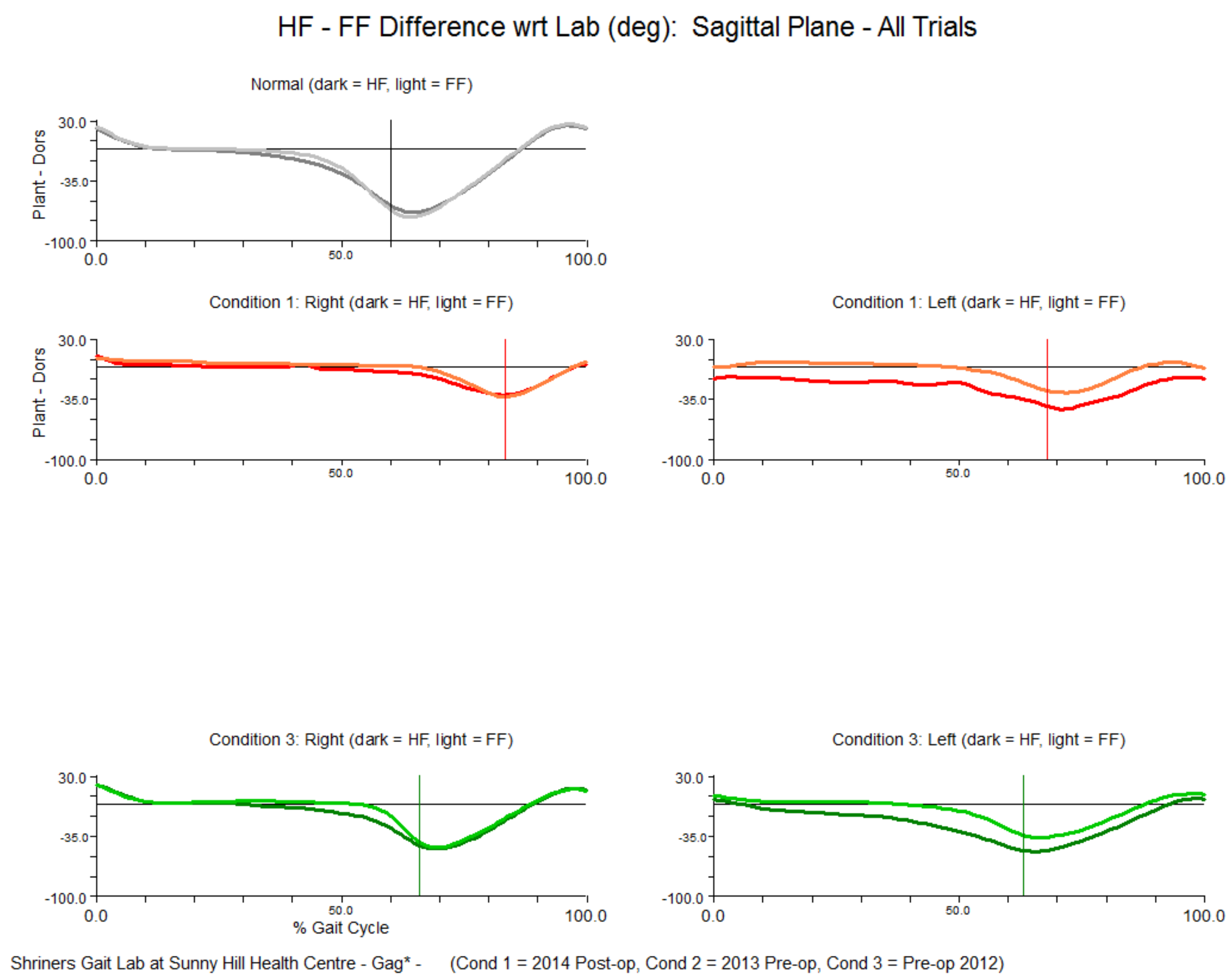
Post-Op Xray



Post Op

Post Op

Kinematics


HF - FF Difference wrt Lab (deg): Sagittal Plane - All Trials
Normal (dark = HF, light = FF)
Condition 1: Right (dark = HF, light = FF)
Condition 1: Left (dark = HF, light = FF)
Condition 3: Right (dark = HF, light = FF)
Condition 3: Left (dark = HF, light = FF)
Plant - Dors
30.0
-35.0
-100.0
0.0
50.0
100.0
% Gait Cycle
Shriners Gait Lab at Sunny Hill Health Centre - Gag* - (Cond 1 = 2014 Post-op, Cond 2 = 2013 Pre-op, Cond 3 = Pre-op 2012)

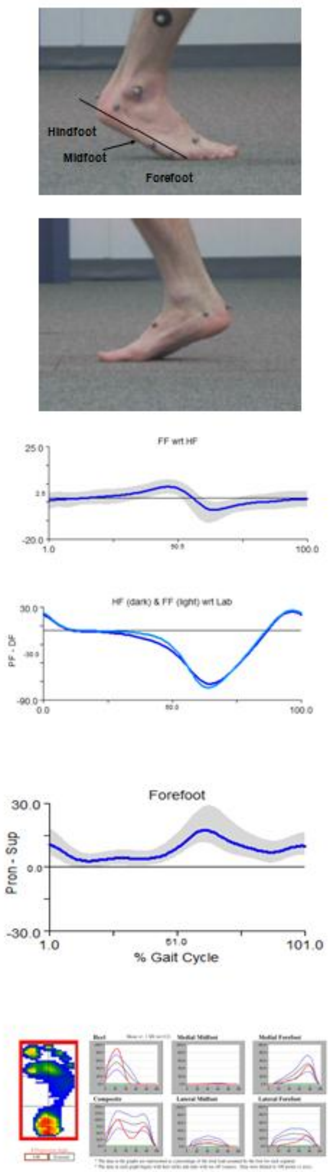
Conclusion

- By using the mSHCGFM, it is now possible to quantify the presence and severity of MFB in children in the sagittal plane and monitor the progression over time.

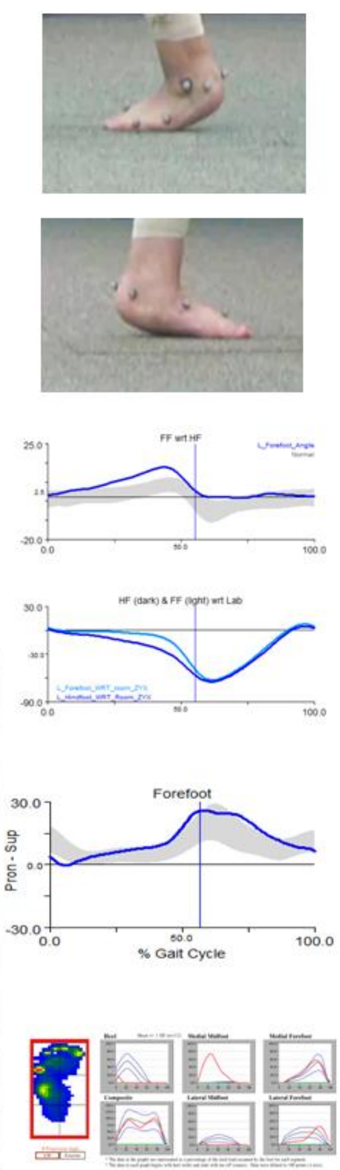
Future Directions

- Examine forefoot and hindfoot motion in coronal and transverse planes
- Application to Clubfoot

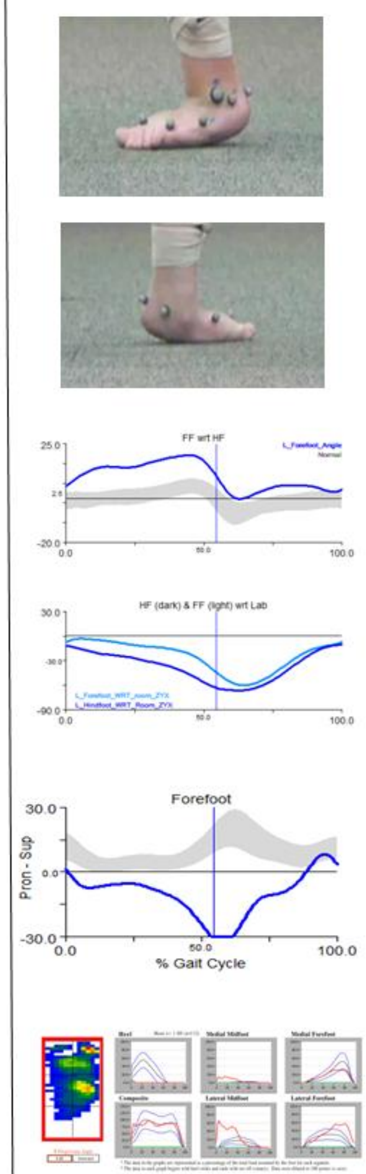
Normal



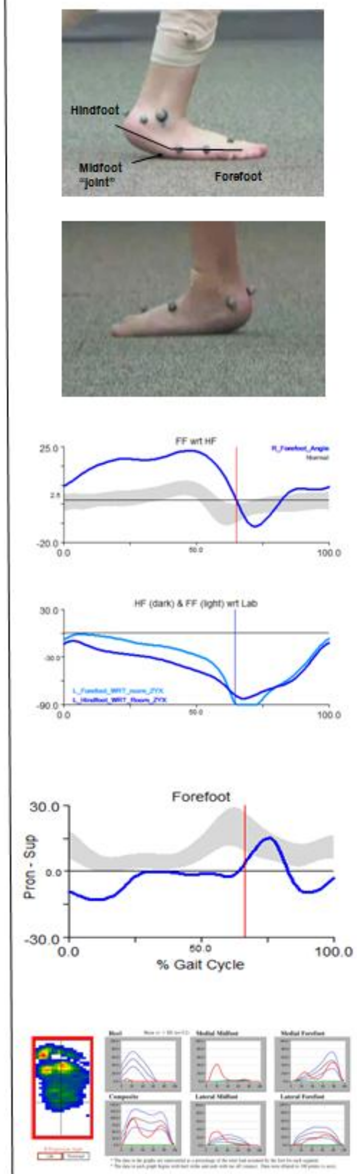
Lateral Column MFB



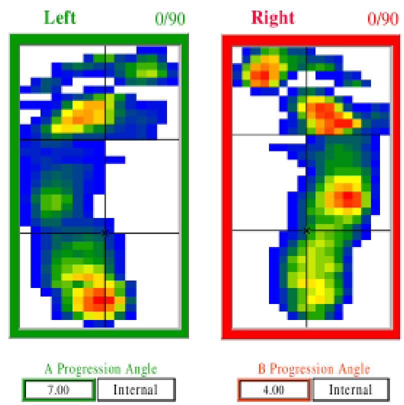
Medial Column MFB

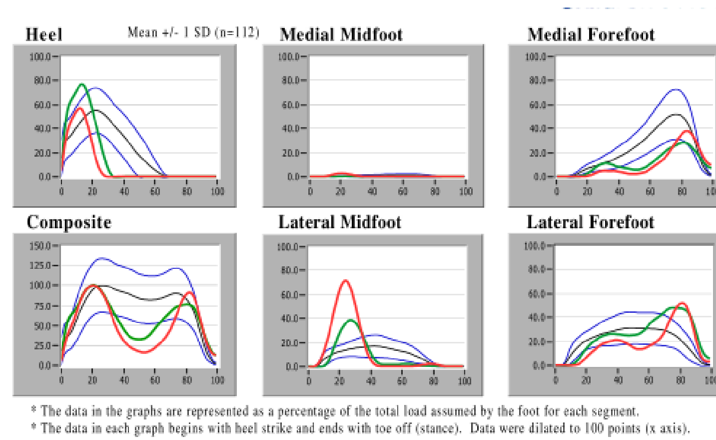


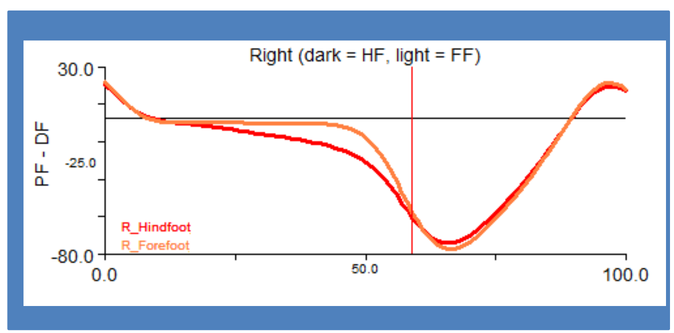
Double-Column MFB

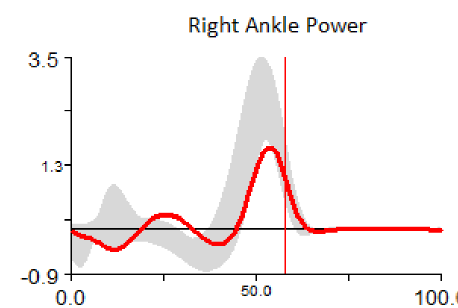


Application to Clubfoot









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- Maurer, Jessica D, Valerie Ward, Tanja a Mayson, Karen R Davies, Christine M Alvarez, Richard D Beauchamp, and Alec H Black. 2014. “Classification of Midfoot Break Using Multi-Segment Foot Kinematics and Pedobarography.” *Gait & Posture* 39 (1) (January 19): 1–6. doi:10.1016/j.gaitpost.2013.08.015. http://www.ncbi.nlm.nih.gov/pubmed/24001869.

Thank You