

IORFoot Tutorial Angles

Introduction

The IOR Foot analysis uses joint angles and planar angles to describe the motion of the foot.

The IOR Foot analysis has been described in the paper:

**** Leardini, A., M.G. Benedetti, L. Berti, D. Bettinelli, R. Nativio, and S. Giannini. "Rear-foot, Mid-foot and Fore-foot Motion during the Stance Phase of Gait." *Gait & Posture* 25 (2007): 453-55 ^[1]

**** **Modifications to the IOR Foot Analysis are described in the paper:**

**** Portinaro, N., A. Leardini, A. Panou, V. Monzani, and P. Caravaggi. "Modifying the Rizzoli foot model to improve the diagnosis of pes-planus: application to kinematics of feet in teenagers." *Journal of Foot and Ankle Research* (2014) ^[2]

**** This tutorial describes the original analysis with all modifications from the 2014 paper.

The 2007 paper is described [here](#).

Downloads

Sample data for this tutorial can be downloaded [here](#).

The PPT images shown in this tutorial can be downloaded [here](#).

Modifications

Three modifications were made between the first^[1] and second^[2] papers. These modifications are outlined below.

Mod 1: Hallux

Previously, varus & dorsiflexion at the first metatarso-phalangeal joint were represented by planar angles (F2Pt and F2Ps)^[1].

The 2014 paper creates a hallux segment and calculates the F2Pt and F2Ps angles as joint angles between the Hallux & Metatarsus segments^[2].

Mod 2: Calcaneus

The original paper^[1] only contained one target on the posterior calcaneus. The 2014 modifications^[2] contain two targets on the posterior calcaneus.

The 2007 paper^[1] described the CA target as the:

CA - upper central ridge of the calcaneus posterior surface, i.e. Achilles' tendon attachment The 2014 paper^[2] described the HL target as the:

HL - most distal point of attachment area of the Achilles tendon on the calcaneus The CA^[1] target will be referred to as the FCP (calcaneus proximal - the proximal attachment of the tendon) for the remainder of this tutorial.

The HL^[2] target will be referred to as the FCD (calcaneus distal - FCC^[3] [pg. 162]) for the remainder of this tutorial.

The FCP target will be used to indicate the origin of the calcaneus segment, and the orientation of the FCP/FCD targets will be used to indicate inversion/eversion of the calcaneus (Sha_Cal_Fro Angle). When placing these targets, make sure there is enough distance between them so that your camera system can recognize them as two separate targets.

The FCD target should be removed after the static trial.

Mod 3: MLA Angle

Previously, the MLA angle was calculated using the CA target^[1].

The 2014 paper projects the FCP target onto the ground during the static trial (FCP_proj), and tracks this projection using the calcaneus segment (FCP_proj_track)^[2].

Target Placement

The following text contains a detailed explanation of how to palpate the necessary bony landmarks:

Serge van Sint Jan "Color Atlas of Skeletal Landmark Definitions: Guidelines for Reproducible Manual and Virtual Palpations" 2007 - Churchill Livingstone^[3]

Foot Targets



CA^[1] (FCP)^[3] : p. 162 = Proximal posterior Surface of Calcaneus. * **HL^[2] (FCD)^[3]** : p. 162 = Distal attachment of the Achilles' tendon. * **ST^[1] (FST)^[3]** : p.164 = Sustentaculum Tali of Calcaneus. **PT^[1] (FPT)^[3]** : p.171 = Lateral apex of the peroneal tubercle. **TN^[1] (FNT)^[3]** : p.165 = Medial apex of the tuberosity navicular. **FMH^[1] (FM1)^[3]** : p.173 = Head of 1st Metatarsus. **SMH^[1] (FM2)^[3]** : p.173 = Head of 2nd Metatarsus. **VMH^[1] (FM5)^[3]** : p.173 = Head of 5th Metatarsus. **VMB^[1] (FMT)^[3]** : p.172

= Tuberosity of 5th Metatarsal **PM**^[1] (**PD6**)^[3] : p.175 = Proximal Distal Phalanx. ** **FMB**^[1] = Base of First Metatarsal. *** **SMB**^[1] = Base of Second Metatarsal. *** * Serge Van Sint Jan describes palpation for the FCC landmark (which should be the FCD), and the FCP landmark should be placed proximal to this landmark.

** Serge Van Sint Jan describes palpation for the mediolateral borders of this landmark (PM6/PL6), the target should be placed at the midpoint.

*** There is no reference for this landmark in Serge Van Sint Jan text, please see the IOR Foot paper for further clarification

Shank Targets

HF ^[1] (FAX) ^[3] : p.154 = Apex of the styloid process	
TT ^[1] (TTC) ^[3] : p.144 = Tibial tuberosity	
LM ^[1] (FAL) ^[3] : p.158 = Apex of the Lateral malleolus	
MM ^[1] (TAM) ^[3] : p.148 = Apex of the Medial malleolus	

Segment Definition

Hallux (Hal)

Segment Definition:		
The FMH target is defined as the origin of Hal segment. The A/P (X) axis is defined from the FMH to PM target. The sagittal axis (Z axis) is along the plane defined by the FMH, FM, and VMH targets.		
The Hal segment is a modification ^[2] to the original analysis ^[1]		
Joint Angles:		
* F2Pt ^[1] / Y component of the Met-Hal Angle ^[2]		
* F2Ps ^[1] / Z component of the Met-Hal Angle ^[2]		
Planar Angles:		
* No planar angles		
Hallux Landmarks		

1. Create RHal_Vert: Click Landmarks button Click Add New Landmark button Create Landmark: RHal_Vert // <HTML><p></HTML> Landmark Name: RHal_Vert <HTML></p></HTML> <HTML><p></HTML> Define Orientation Using: Starting Point: //RFMH Ending Point: RPM Lateral Object: RVMH										Offset Using the Following ML/AP/AXIAL Offsets: X: 0.0 Y: -DISTANCE(RFMH,RPM) Z: 0.0 Do NOT Check: Offset by Percent (1.0 = 100%) Do NOT Check: Calibration Only Landmark									
Hallux Definition																			
1. Create RHal Segment: In the Segments tab, select <i>RHal</i> in the Segment Name box. Select Kinematic Only Click on the Create Segment button. In the RHal tab, enter these values:	Define Proximal Joint and Radius Lateral: None Joint: RFMH Medial: None Radius: 0.1 Define Distal Joint and Radius Lateral: None Joint: RPM Medial: None Radius: 0.1 Extra Target to Define Orientation Location: Lateral RHal_Vert Select Tracking Targets: RHal_Vert, RFMH, RPM	Click on Build Model. Click on Close Tab before proceeding.	2. Modify the Segment Coordinate System: Define the Segment Orientation as:	A/P Axis: -Z Distal to Proximal: -X	The image to the right (and all other images in this tutorial) show a mediolateral view of the segment coordinate system after it has been modified.														

Metatarsus (Met)

Segment Definition:

The FM2 landmark is projected onto the plane defined by the FM1, FM5, and SMB landmarks. The line from the SMB to FM2 projection are used to define the X axis (A/P) axis of the Met segment. The sagittal axis (Z axis) is along the plane defined by the FM1, FM5, and SMB targets.

The FMB target is not used to define the segment, but it will be used to track the segment (in addition to the other targets).

Joint Angles:

- * Mid-Met Angle
- * Cal-Met Angle
- * F2Pt^[1] / Y component of the Met-Hal Angle^[2]
- * F2Ps^[1] / Z component of the Met-Hal Angle^[2]

Planar Angles:

- * S2F is projected onto the plane of the Met segment
- * S2V is projected onto the plane of the Met segment

[illegible]

1. Create RMet Segment: • In the Segments tab, select RMet in the Segment Name box. • Select Kinematic Only • Click on the Create Segment button. • In the RMet tab, enter these values:	Define Proximal Joint and Radius Lateral: None Joint: RSMB Medial: None Radius: 0.1 Define Distal Joint and Radius Lateral: None Joint: RMET_DIST Medial: None Radius: 0.1 Extra Target to Define Orientation Location: Medial RFMH Select Tracking Targets: RFMB, RFMH, RSMB, RSMH, RVMH	• Click on Build Model. • Click on Close Tab before proceeding.	2. Modify the Segment Coordinate System: • Define the Segment Orientation as:	A/P Axis: +Y Distal to Proximal: -X	The image to the right (and all other images in this tutorial) show a mediolateral view of the segment coordinate system after it has been modified.
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Mid-foot (Mid)

Segment Definition: The midpoint between the TN and VMB targets is used to define the origin of the Mid segment. The A/P (X) axis is defined along the line from this midpoint to the SMB target. The sagittal (Z) axis is along the plane defined by the ID, TN and SMB targets. Joint Angles: * Cal-Mid Angle * Mid-Met Angle Planar Angles: * Not used for planar angles.					
Mid-foot Landmarks					

1. Create RID Joint Center: - Click Landmarks button - Click Add New Landmark button - Create Landmark: <i>RID</i>		Landmark Name: <i>RID</i> Define Orientation Using: Starting Point: <i>RTN</i> Ending Point: <i>RVMB</i>		- Offset Using the Following AXIAL Offset: <i>0.5</i> Check: <i>Offset by Percent (1.0 = 100%)</i> Check: <i>Calibration Only Landmark</i>		☐					
Mid-foot Definition											
1. Create RMid Segment: - In the Segments tab, select <i>RMid</i> in the Segment Name box. - Select Kinematic Only. - Click on the Create Segment button. - In the RMid tab, enter these values:		Define Proximal Joint and Radius Lateral: <i>None</i> Joint: <i>RID</i> Medial: <i>None</i> Radius: <i>0.1</i> Define Distal Joint and Radius Lateral: <i>None</i> Joint: <i>RSMB</i> Medial: <i>None</i> Radius: <i>0.1</i> Extra Target to Define Orientation Location: <i>Medial RTN</i> Select Tracking Targets: <i>RSMB, RTN, RVMB</i>		- Click on Build Model. - Click on Close Tab before proceeding.		2. Modify the Segment Coordinate System: Define the Segment Orientation as:		A/P Axis: <i>+Y</i> Distal to Proximal: <i>-X</i>		☐	

Calcaneus (Cal)

Segment Definition: The origin is at the FCP target. The A/P (X) axis is along the line from the FCP to midpoint of the ST and PT targets (IC landmark). The sagittal (Z) axis is along the plane defined by the FCP, ST and TN targets. Joint Angles: * Sha-Cal Angle * Cal-Mid Angle Z rotation & Y Rotation* * Cal-Met Angle * The 2014 paper ^[2] modified the definition of inversion/eversion for the calcaneus segment relative to the shank segment. This is now calculated as the Sha_Cal_Fro angle which is a four point planar angle. Planar Angles: * No planar angles		☐	
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Calcaneus Landmarks									
1. Create RIC Joint Center: - Click Landmarks button - Click Add New Landmark button - Create Landmark: <i>RIC</i>		Landmark Name: <i>RIC</i> Define Orientation Using: Starting Point: <i>RST</i> Ending Point: <i>RPT</i>		- Offset Using the Following AXIAL Offset: <i>0.5</i> Check: <i>Offset by Percent (1.0 = 100%)</i> Check: <i>Calibration Only Landmark</i>					
Calcaneus Definition									
1. Create RCal Segment: - In the Segments tab, select <i>RCal</i> in the Segment Name box. - Select Kinematic Only - Click on the Create Segment button. - In the RCal tab, enter these values:		Define Proximal Joint and Radius Lateral: <i>None</i> Joint: <i>RFCP</i> Medial: <i>None</i> Radius: <i>0.1</i> Define Distal Joint and Radius Lateral: <i>None</i> Joint: <i>RIC</i> Medial: <i>None</i> Radius: <i>0.1</i> Extra Target to Define Orientation Location: <i>Medial</i> <i>RST</i> Select Tracking Targets: <i>RFCP, RPT, RST</i>		2. Modify the Segment Coordinate System: - Click on Build Model. - Click on Close Tab before proceeding. - Define the Segment Orientation as:		A/P Axis: +Y Distal to Proximal: -X			

Virtual Foot (Foo)

Segment Definition: The origin is at the FCP target. The A/P (X) axis is along the line from the FCP to RFT_DIST landmark. The sagittal (Z) axis is along the plane defined by the FCP, FMH and VMH targets. This foot segment should be set to “kinematic only” since the origin is not at the point of rotation (the mid point of the RIMM & RLM targets. The IORFoot analysis does not calculate kinetics, so no kinetic foot segment is described in this model. To create gait events, you will need a kinetic foot segment. An example of a kinetic foot segment is created in the sample download files for this tutorial.	
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Foot Landmarks										
1. Create RFT_DIST: - Click Landmarks button - Click Add New Landmark button - Create Landmark: <i>RFT_DIST</i>	Landmark Name: <i>RFT_DIST</i>	Define Orientation Using: Starting Point: <i>RCA</i> Ending Point: <i>RFMH</i> Lateral Object: <i>RVMH</i> Project From: <i>RSMH</i>	Do NOT Check: <i>Offset by Percent (1.0 = 100%)</i> Check: <i>Calibration Only Landmark</i>							
Foot Definition										
1. Create Right Virtual Foot Segment: - In the Segments tab, select <i>Right Virtual Foot</i> in the Segment Name box. - Select Kinematic Only - Click on the Create Segment button. - In the Right Virtual Foot tab, enter these values:	Define Proximal Joint and Radius Lateral: <i>None</i> Joint: <i>RFCP</i> Medial: <i>None</i> Radius: $0.5 * \text{DISTANCE}(RST, RPT)$	Define Distal Joint and Radius Lateral: <i>None</i> Joint: <i>RFT_DIST</i> Medial: <i>None</i> Radius: $0.5 * \text{DISTANCE}(RFMH, RVMH)$	Extra Target to Define Orientation Location: <i>Medial RFMH</i>	Select Tracking Targets: <i>RFCP, RFMH, RVMH</i>	- Click on Build Model. - Click on Close Tab before proceeding.	2. Modify the Segment Coordinate System: Define the Segment Orientation as:	A/P Axis: +Y Distal to Proximal: -X			

Shank (Sha)

Shank Landmarks										
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1. Create RIM: • Click Landmarks button • Click Add New Landmark button • Create Landmark: <i>RIM</i>	Landmark Name: <i>RIM</i> Define Orientation Using: Starting Point: <i>RLM</i> Ending Point: <i>RMM</i>	• Offset Using the Following AXIAL Offset: <i>0.5</i> • Check: <i>Offset by Percent (1.0 = 100%)</i> • Check: <i>Calibration Only Landmark</i>	2. Create RSK_PROX: • Click Landmarks button • Click Add New Landmark button • Create Landmark: <i>RSK_PROX</i>	Landmark Name: <i>RSK_PROX</i> Define Orientation Using: Starting Point: <i>RIM</i> Ending Point: <i>RLM</i> Lateral Object: <i>RHF</i> Project From: <i>RTT</i>	• Do NOT Check: <i>Offset by Percent (1.0 = 100%)</i> • Check: <i>Calibration Only Landmark</i>	
Shank Definition						
1. Create Right Shank Segment: • In the Segments tab, select <i>Right Shank</i> in the Segment Name box. • Click on the Create Segment button. • In the Right Shank tab, enter these values:	Define Proximal Joint and Radius Lateral: <i>None</i> Joint: <i>RSK_PROX</i> Medial: <i>None</i> Radius: <i>DISTANCE(RSK_PROX,RHF)</i> Define Distal Joint and Radius Lateral: <i>None</i> Joint: <i>RIM</i> Medial: <i>None</i> Radius: <i>0.5*DISTANCE(RLM,RMM)</i> Extra Target to Define Orientation Location: <i>Lateral</i> <i>RLM</i> Select Tracking Targets: <i>RHF, RLM, RMM, RTT</i>	• Click on Build Model. • Click on Close Tab before proceeding.	2. Modify the Segment Coordinate System: • Define the Segment Orientation as:	A/P Axis: <i>+X</i> Distal to Proximal: <i>+Y</i>		

Sagittal Planar Angles

The **F2G**, **S2G**, and **V2G** angles are planar angles relative to the ground.

The **MLA** angle is the angle between the Medial Longitudinal Arch/Navicular drop.

F2G S2G and V2G Landmarks

The F2G, S2G and V2G angles are calculated in the plane orthogonal to the ground. These landmarks will need to be projected onto the ground. To project landmarks onto the ground, the Lab_O, Lab_X and Lab_Y landmarks will need to be created to identify the plane of the ground.

[illegible]

F2G Angle

F2G Angle - 3D angle of the first metatarsus relative to the ground					
F2G Definition					
1. Create RF2G planar angle: - Define Resulting Signal Name: <i>RF2G</i> - Calculate a 4 point angle between the following targets:		1 - <i>TARGET::ORIGINAL::RFMB</i> 2 - <i>TARGET::ORIGINAL::RFMH</i> 3 - <i>TARGET::ORIGINAL::RFMH_proj</i> 4 - <i>TARGET::ORIGINAL::RFMB_proj</i> Angle Direction: <i>Right Hand Rule</i> 3D Space: <i>Always 0 to 180 degrees</i>			2. Create LF2G planar angle: When defining the left signal, use same definitions as for the right angle

S2G Angle

S2G Angle - 3D angle of the second metatarsus relative to the ground				
S2G Definition				
1. Create RS2G planar angle: - Define Resulting Signal Name: <i>RS2G</i> - Calculate a 4 point angle between the following targets:		1 - <i>TARGET::ORIGINAL::RSMB</i> 2 - <i>TARGET::ORIGINAL::RSMH</i> 3 - <i>TARGET::ORIGINAL::RSMH_proj</i> 4 - <i>TARGET::ORIGINAL::RSMB_proj</i> Angle Direction: <i>Right Hand Rule</i> 3D Space: <i>Always 0 to 180 degrees</i>		
				2. Create LS2G planar angle: When defining the left signal, use same definitions as for the right angle

V2G Angle

V2G Angle - 3D angle of the fifth metatarsus relative to the ground	
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MLA Angle

<https://has-motion.com/wiki/>
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MLA Definition					
1. Create RMLA planar angle: • Define Resulting Signal Name: RMLA • Calculate a 3 point angle between the following targets:	1 - LANDMARK::ORIGINAL::RFCP_track 2 - TARGET::ORIGINAL::RST 3 - TARGET::ORIGINAL::RFMH Angle Direction: Right Hand Rule Use Range: -180 to 180 degrees Projected onto Plane: XY Note: The reference segment will need to be changed to RMF within the text option. Command text should have the internal name (e.g. RMF) and not the display name "Right Virtual Foot". https://www.c-motion.com/v3dwiki/index.php?title=Segment_Default_Names			2. Create LMLA planar angle: • When defining the left signal, use same definitions as for the right angle	Note: The reference segment will need to be changed to Left Virtual Foot within the text option.

Transverse Planar Angles

S2F Angle

S2F Angle – Angle between the first and second metatarsus projected on to the transverse plane of the Met segment					
S2F Definition					
1. Create RS2F planar angle: • Define Resulting Signal Name: RS2F • Calculate a 4 point angle between the following targets:	1 - TARGET::ORIGINAL::RSMH 2 - TARGET::ORIGINAL::RSMB 3 - TARGET::ORIGINAL::RFMB 4 - TARGET::ORIGINAL::RFMH Angle Direction: Right Hand Rule Use Range: -180 to 180 degrees Projected onto Plane: XZ Note: The reference segment will need to be changed to RMet within the text option.			2. Create LS2F planar angle: • When defining the left signal, use same definitions except set:	Angle Direction: Left Hand Rule Note: The reference segment will need to be changed to LMet within the text option.

S2V Angle

S2V Angle – Angle between the fifth and second metatarsus projected on to the transverse plane of the Met segment					
S2V Definition					

1. Create RSha_Cal_Fro planar angle: - Define Resulting Signal Name: <i>RSha_Cal_Fro</i> - Calculate a 4 point angle between the following targets:	1 - LANDMARK::ORIGINAL::RSK_PROX_TRACK 2 - LANDMARK::ORIGINAL::RSK_DIST_TRACK 3 - LANDMARK::ORIGINAL::RFCD_TRACK 4 - TARGET::ORIGINAL::RFCP Angle Direction: <i>Left Hand Rule</i> Use Range: <i>-180 to 180 degrees</i> Projected onto Plane: <i>YZ</i> Note: The reference segment will need to be changed to RSK within the text option.	✖ When defining the left signal, use same definitions except set:	Angle Direction: <i>Right Hand Rule</i> Note: The reference segment will need to be changed to LSK within the text option.
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Joint Angles

Joint Angle definitions for the:

- Sha_Foo_Angle
- Sha_Cal_Angle
- Cal_Mid_Angle
- Mid_Met_Angle
- Cal_Met_Angle
- Met_Hal_Angle

The Met_Hal_Angle calculations are used to replace the F2Ps & F2Pt planar angles from the 2007 paper^[1].

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References

1. ↑ [1.00](#) [1.01](#) [1.02](#) [1.03](#) [1.04](#) [1.05](#) [1.06](#) [1.07](#) [1.08](#) [1.09](#) [1.10](#) [1.11](#) [1.12](#) [1.13](#) [1.14](#) [1.15](#) [1.16](#) [1.17](#) [1.18](#) [1.19](#) [1.20](#) [1.21](#) [1.22](#) [1.23](#) [1.24](#) [1.25](#) [1.26](#) [1.27](#) [1.28](#)
Leardini, A., M.G. Benedetti, L. Berti, D. Bettinelli, R. Natio, and S. Giannini. "Rear-foot, Mid-foot and Fore-foot Motion during the Stance Phase of Gait." *Gait & Posture* 25 (2007): 453-55
2. ↑ [2.00](#) [2.01](#) [2.02](#) [2.03](#) [2.04](#) [2.05](#) [2.06](#) [2.07](#) [2.08](#) [2.09](#) [2.10](#) [2.11](#) [2.12](#) [2.13](#)
Portinaro, N., A. Leardini, A. Panou, V. Monzani, and P. Caravaggi. "Modifying the Rizzoli foot model to improve the diagnosis of pes-planus: application to kinematics of feet in teenagers." *Journal of Foot and Ankle Research* (2014)

3. [↑](#) [3.00](#) [3.01](#) [3.02](#) [3.03](#) [3.04](#) [3.05](#) [3.06](#) [3.07](#) [3.08](#) [3.09](#) [3.10](#) [3.11](#) [3.12](#) [3.13](#) [3.14](#) [3.15](#) Serge van Sint Jan “Color Atlas of Skeletal Landmark Definitions: Guidelines for Reproducible Manual and Virtual Palpations” 2007 - Churchill Livingstone

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