Plug-In Gait Lower Limb Modified

While every effort has been made to ensure the correct implementation of the Plug-In Gait model in Visual3D, some differences may still persist, most likely caused by the different pose estimations used within Nexus and Visual3D.

Introduction

The conventional gait model (CGM) has many variations and can go by many names: Helen Hayes, Vicon Clinical Manager, Newington, and Cleveland Clinic to name a few. We highly recommend reading the Tutorial: Building a Conventional Gait Model prior to going through this tutorial.

Workstation or *Nexus* users will be familiar with the Plug-In Gait variation as Vicon's implementation of the CGM.

In this tutorial, we describe this implementation of Vicon's Plug-In Gait using Visual3D, with the necessary modifications made for marker placement error specific to this dataset. The original tutorial without modifications can be accessed here.

In some trials, clear errors in marker placement can be identified when viewing the model. Here we make the necessary adaptations to the model to compensate.

A video version of this tutorial can be viewed here.

Marker Placement Error

The placement of markers during static and dynamic trials can significantly impact the accuracy of the data that is captured. In this static trial markers were only placed on the lateral sides of each leg, with some being nearly co-linear and some incorrectly aligned with anatomical features.

The closer markers are to being placed co-linearly the more difficult it is to define all six degrees of freedom, this can make the model more sensitive to noise.

In this trial, like many others, markers are only placed on the lateral side of each leg. This is done to avoid markers being knocked off during movement trials, however having markers on the lateral and medial side (at least for static trials) helps to improve our ability to define segment coordinate systems.

The placement of the foot markers, especially the heel, in this trial made it challenging to properly define foot positioning. The Toe_Z landmark was added as a solution to this error.

Modifications Explained

Shank Definition: In this tutorial the RKNE marker was added as the lateral boundary for the right shank definition. This was added to improve alignment of the shank and correct excessive incorrect internal rotation of the tibia that was previously present. In the original tutorial there was a significant

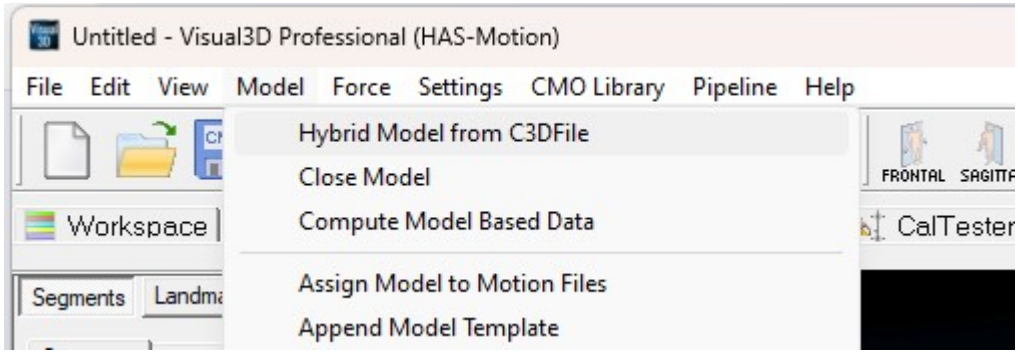
difference in alignment between the shank and thigh segments which is not typically present or anatomically possible, this change in definition was done to correct this error.

Toe Landmark and Definition: The R_Toe_Z landmark was introduced to align the anterior axis of the foot with that of the shank and thigh segments (assuming the subject is standing in alignment). It serves as the distal joint center and the posterior foot alignment. In the original model the foot was defined by the heel and toe markers, both of which were incorrectly placed causing clear error in foot positioning.

Load Static Trial

You can download the sample files here. These sample files were generously provided by Vicon (OMG plc, UK).

Load the static trial:



1. From the **Model** menu, select **Hybrid Model from C3DFile**
2. In the **Select the calibration file for the new model** dialog, select *WalkingStaticLowerBody.c3d*
    1. If using a knee alignment device, select *Sub01_Static_KAD_01.c3d*
3. Click **Open.**

Define Necessary Model Metrics

Create Model Metrics

1. Create Subject Metrics:

1. Click **Subject Data/Metrics** button

2. Select the *Mass* and click the **Modify Selected Item** button
   Name: *Mass*
   Value or Expression: *75*
   NOTE: This value MUST be changed for each subject

3. Select the *Height* and click the **Modify Selected Item** button\\ **Name:** *Height*
   Value or Expression: *1.76*
   NOTE: This value MUST be changed for each subject

4. Click **Add New Item** button

1. **Name:** *MarkerRadius*
   Value or Expression: *0.005*
   NOTE: This value MUST reflect the size of the markers used in YOUR lab

2. **Name:** *Left_Knee_Width //*
   Value or Expression: *//0.105*
   Create the *Right_Knee_Width*
   NOTE: This value MUST be changed for each subject

3. **Name:** *Knee_Width*
   Value or Expression: *(Left_Knee_Width + Right_Knee_Width)/2*

4. **Name:** *Left_Ankle_Width*
   Value or Expression: *0.070*
   Create the *Right_Ankle_Width*
   NOTE: This value MUST be changed for each subject

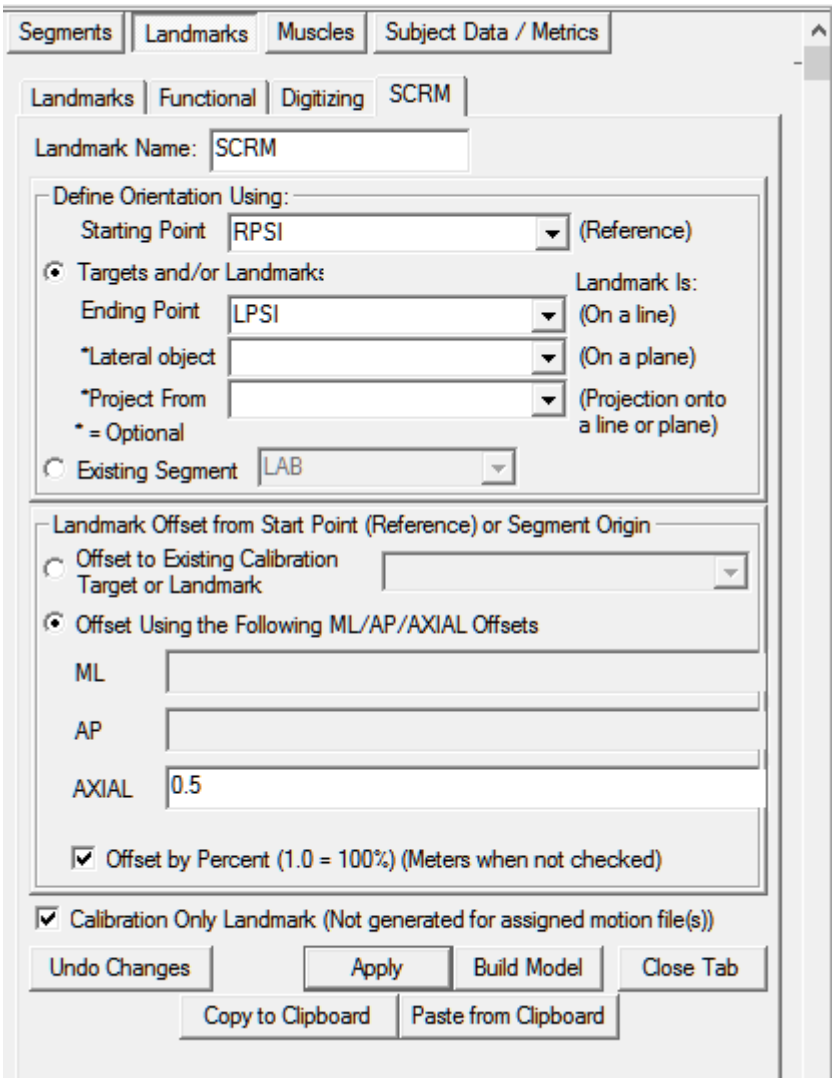
5. **Name:** *Ankle_Width*
   Value or Expression: *(Left_Ankle_Width + Right_Ankle_Width)/2*

Pelvis Segment

Pelvis with 4 Targets

For an alternative pelvis definition with 3 targets see the original tutorial.

Pelvis with 4 Targets - Landmarks

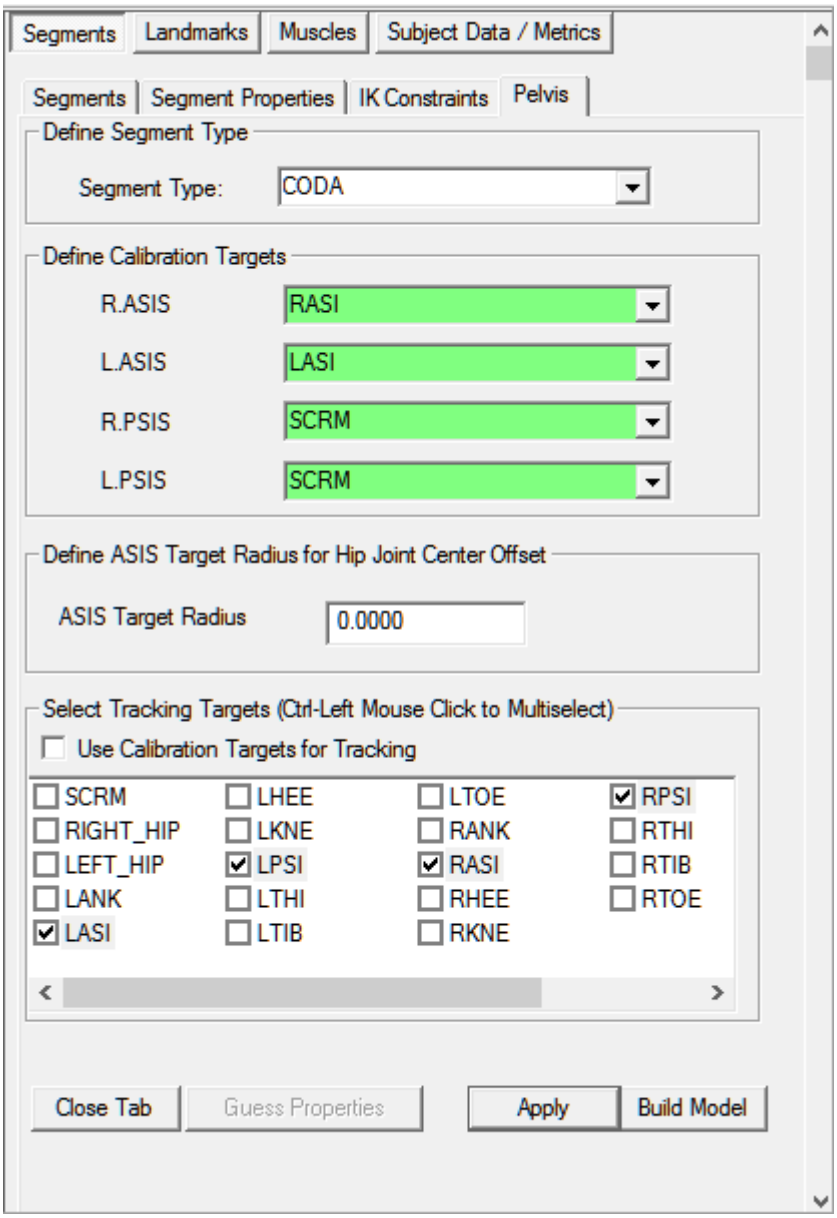


1. Create SCRM:

1. Click **Landmarks** button
2. Click **Add New Landmark** button
3. Create Landmark: SCRM

   Landmark Name: SCRM
   Define Orientation Using:
   Starting Point: *RPSI*
   Ending Point: *LPSI*
   Offset Using the Following **ML/AP/AXIAL** Offsets:
   AXIAL: *0.5*
   Check: *Offset by Percent (1.0 = 100%)*
   Check: *Calibration Only Landmark*

Pelvis with 4 Targets - Definition



2. Create Pelvis Segment:

1. In the **Segments** tab, select *Pelvis* in the Segment Name box.
2. Select **CODA** in the Segment Type box.
3. Click on the **Create Segment** button.
4. In the **Pelvis** tab, enter these values:

Define Calibration Targets
R.ASIS: *RASI* **L.ASIS:** *LASI*
R.PSIS: *SCRM* **L.PSIS:** *SCRM*
Define ASIS Target Radius for Hip Joint Center Offset
ASIS Target Radius: *MarkerRadius*
Select Tracking Targets:
LASI, *LPSI*, *RASI*, *RPSI*

5. Click on **Build Model.**
6. Click on **Close Tab** before proceeding.

Hip Joint Center

The CODA pelvis automatically creates hip joint centers using the Bell and Brand regression equations. The PiG model uses the Davis regression equations.

The directions below walk you through the necessary steps to create the RHJC and LHJC using the Davis regression equations. Please note, some metrics can be manually entered OR target data can be used to estimate these values.

Create Model Metrics for Hip Joint Center

1. Create Subject Metrics:

1. Click **Subject Data/Metrics** button
2. Click **Add New Item** button
    1. **Name:** *Left_Leg_Length*
    (A) **Value or Expression:** *0.940*
    OR:
    (B) **Value or Expression:** *DISTANCE(LASI,LANK)*
    Create the *Right_Leg_Length*
    NOTE: If you specify an explicit value (ex. 0.940), this value MUST be changed for each subject

    2. **Name:** *Leg_Length*
    Value or Expression: *(Left_Leg_Length + Right_Leg_Length)/2*

    3. **Name:** *C*
    Value or Expression: *0.115*Leg_Length - 0.0153*

    4. **Name:** *theta*
    Value or Expression: *28.4*PI/180.0*

    5. **Name:** *beta*
    Value or Expression: *18.0*PI/180.0*

    6. **Name:** *Xdis*
    (A) **Value or Expression:** *0.750*
    OR:
    (B) **Value or Expression:** *0.1288*Leg_Length - 0.04856*
    NOTE: If you specify an explicit value (ex. 0.750), this value MUST be changed for each subject

    7. **Name:** *HJC_ML*
    Value or Expression: *(C * sin(theta) -0.5 * ASIS_distance)*

    8. **Name:** *HJC_AP*
    Value or Expression: *(-Xdis-MarkerRadius) * cos(beta)+ C * cos(theta) * sin(beta)*

9. **Name:** *HJC_AX*
   Value or Expression: *(-Xdis-MarkerRadius) * sin(beta)- C * cos(theta) * cos(beta)*

Helen Hayes Hip Landmarks

1. Create RHIP:

1. Click **Landmarks** button
2. Click **Add New Landmark** button
3. Create Landmark: *RHIP*

   Landmark Name: *RHIP*
   Define Orientation Using:
   Click **Existing Segment:** *Pelvis*
   Offset Using the Following **ML/AP/AXIAL** Offsets:
   X: *-HJC_ML* **Y:** *HJC_AP* **Z:** *HJC_AX*
   Do NOT Check: *Offset by Percent (1.0 = 100%)*
   Do NOT Check: *Calibration Only Landmark*

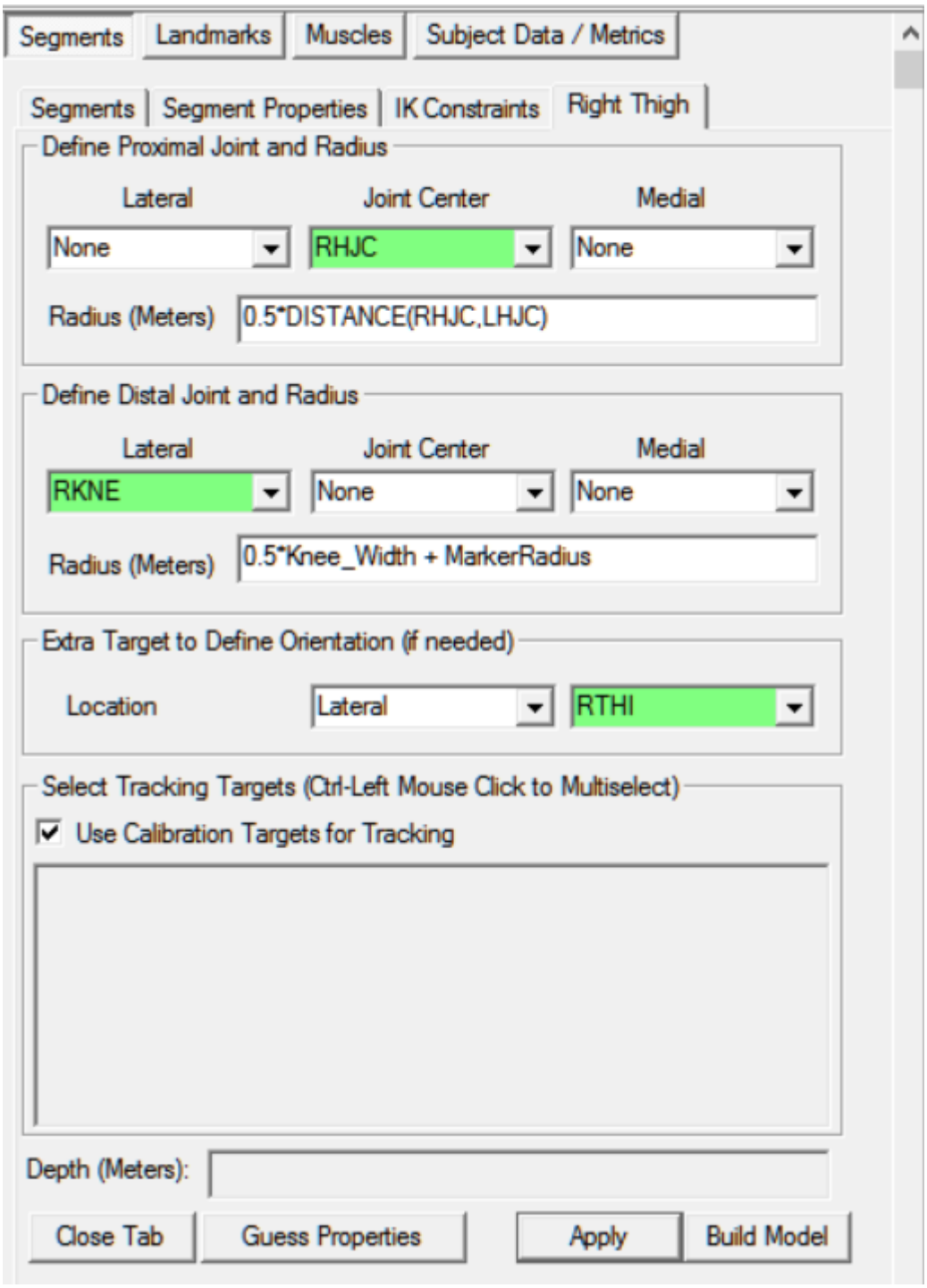
---

2. Create LHIP:

1. Click **Landmarks** button
2. Click **Add New Landmark** button
3. Create Landmark: *LHIP*

   Landmark Name: *LHIP*
   Define Orientation Using:
   Click **Existing Segment:** *Pelvis*
   Offset Using the Following **ML/AP/AXIAL** Offsets:
   X: *HJC_ML* **Y:** *HJC_AP* **Z:** *HJC_AX*
   Do NOT Check: *Offset by Percent (1.0 = 100%)*
   Do NOT Check: *Calibration Only Landmark*

Thigh Segment



1. Create Right Thigh Segment:

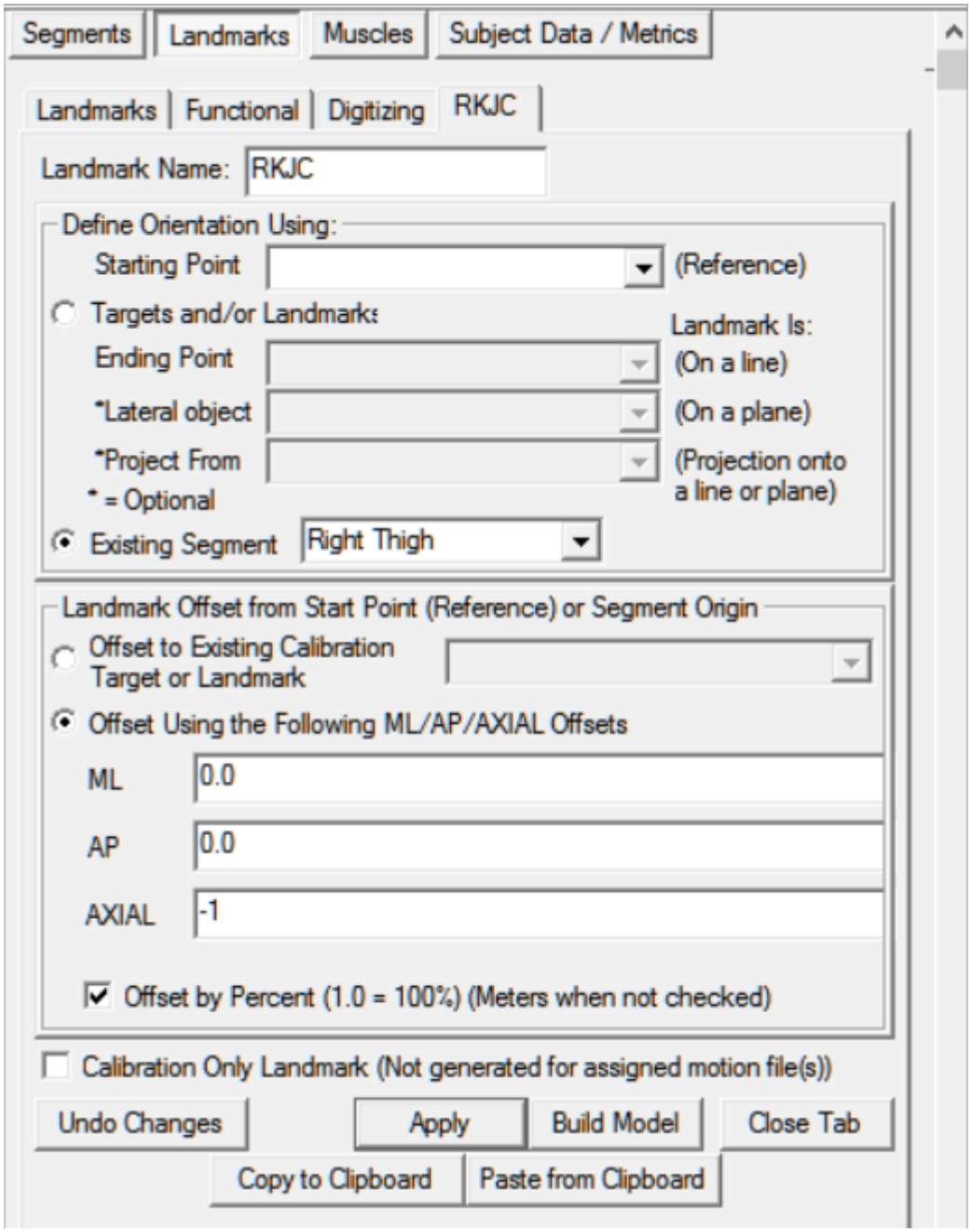
1. In the **Segments** tab, select *Right Thigh* in the Segment Name box.
2. Click on the **Create Segment** button.
3. In the **Right Thigh** tab, enter these values:

Define Proximal Joint and Radius
Lateral: *None* **Joint:** *RHJC* **Medial:** *None*
Radius: *0.5*DISTANCE(RHJC,LHJC)*
Define Distal Joint and Radius
Lateral: *RKNE* **Joint:** *None* **Medial:** *None*
Radius: *0.5*Knee_Width + MarkerRadius*
Extra Target to Define Orientation

Location: *Lateral RTHI*
Select Tracking Targets:
Check: *Use Calibration Targets for Tracking*

4. Click on **Build Model.**
5. Click on **Close Tab** before proceeding.

Shank Segment

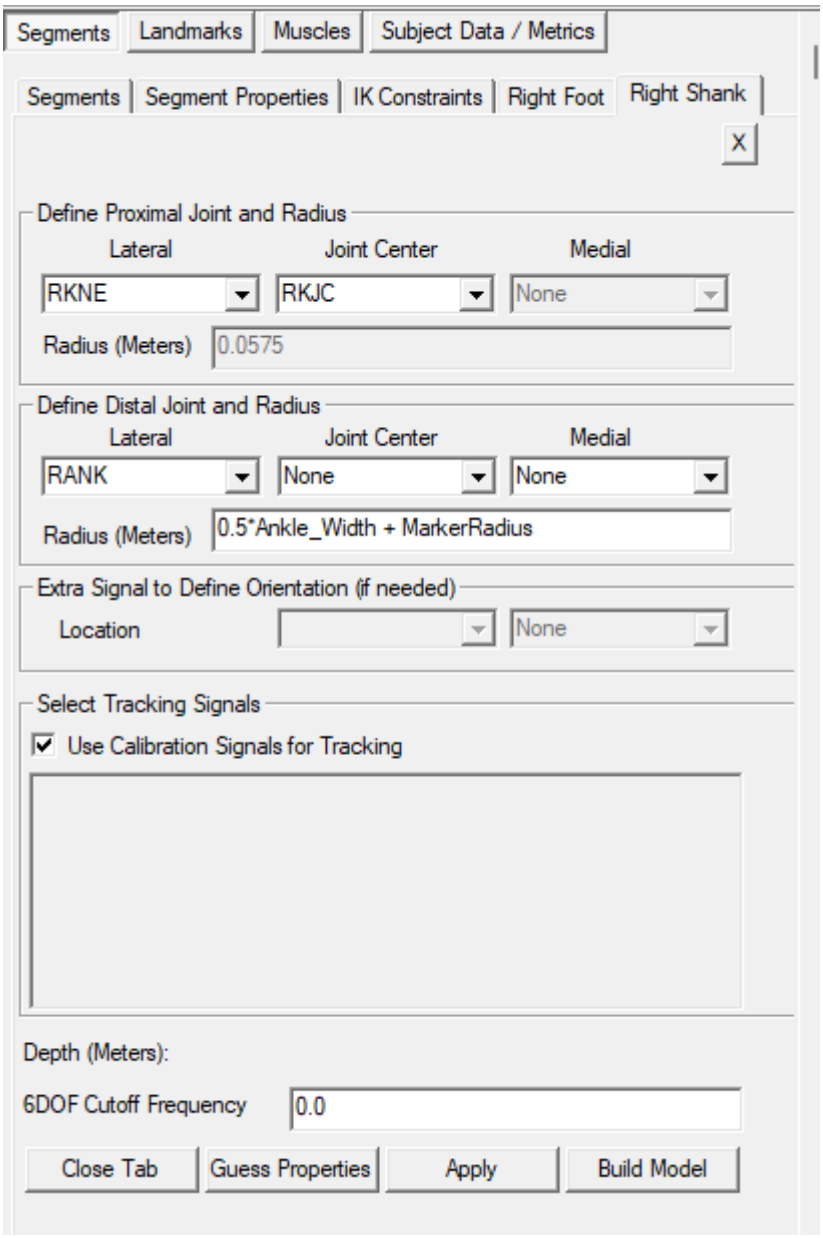


Shank Landmarks

1. Create RKJC:

1. Click **Landmarks** button
2. Click **Add New Landmark** button
3. Create Landmark: *RKJC*

Landmark Name: *RKJC*
Define Orientation Using:
Click **Existing Segment:** *Right Thigh*
Offset Using the Following **ML/AP/AXIAL** Offsets:
ML: *0.0* **AP:** *0.0* **AXIAL:** *-1.0*
Check: *Offset by Percent (1.0 = 100%)*
Do NOT Check: *Calibration Only Landmark*



Shank Definition

1. Create Right Shank Segment:

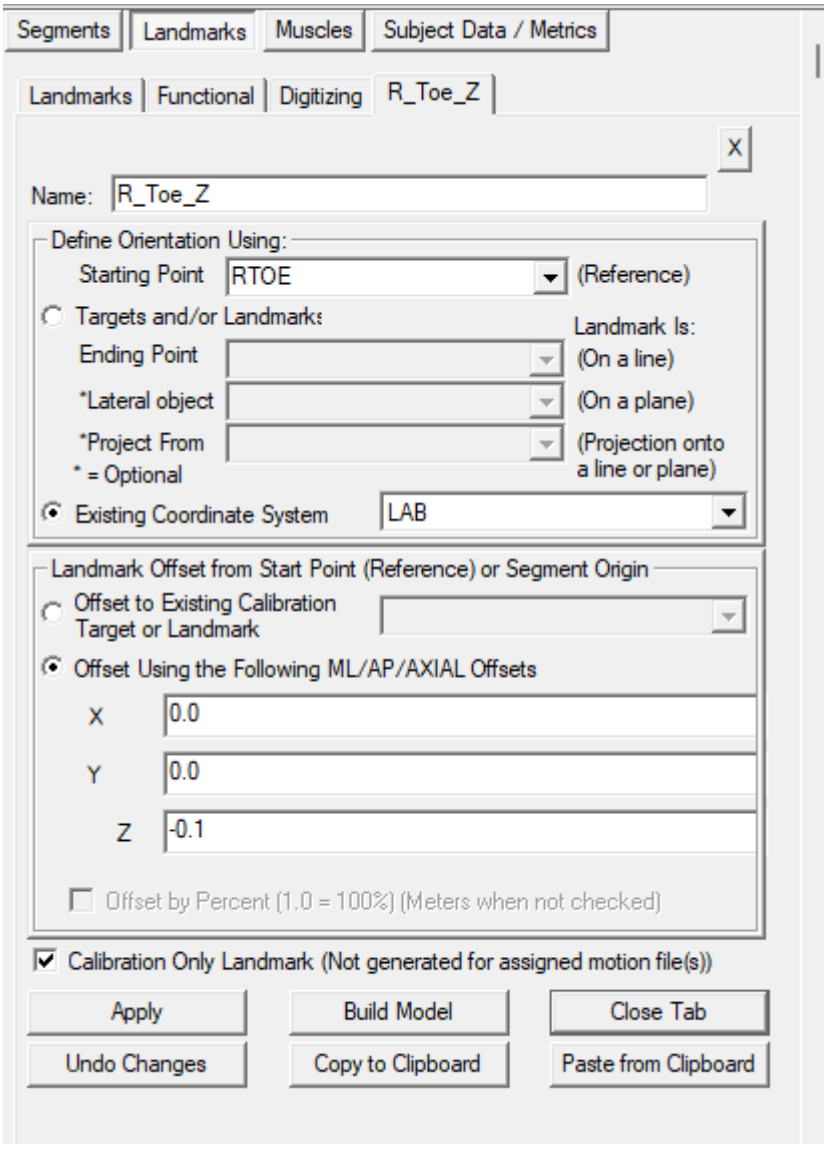
1. In the **Segments** tab, select *Right Shank* in the Segment Name box.
2. Click on the **Create Segment** button.
3. In the **Right Shank** tab, enter these values:

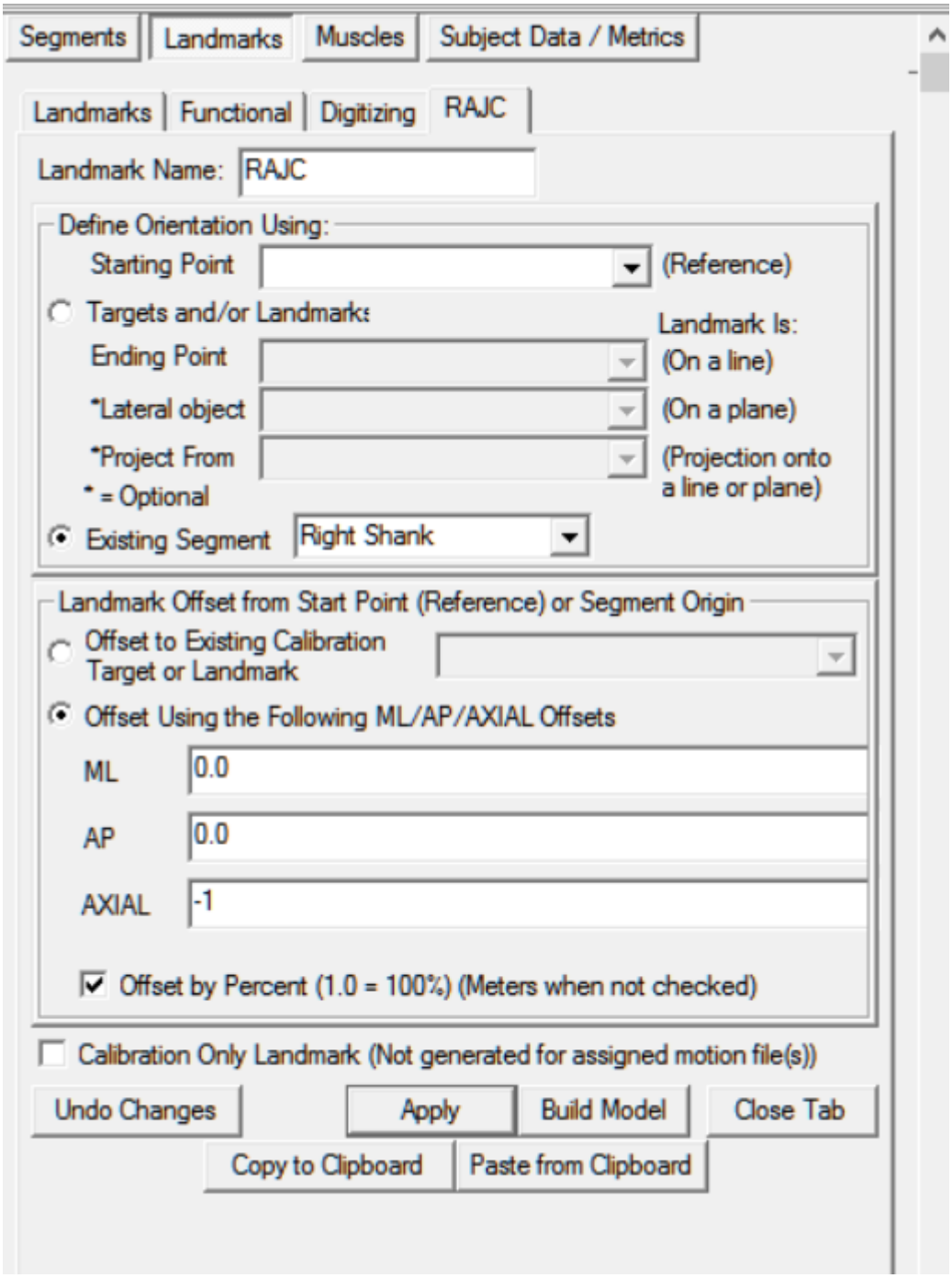
   Define Proximal Joint and Radius
   Lateral: *RKNE* **Joint:** *RKJC* **Medial:** *None*
   Define Distal Joint and Radius
   Lateral: *RANK* **Joint:** *None* **Medial:** *None*
   Radius: *0.5*Ankle_Width + MarkerRadius*
   Select Tracking Targets:
   Check: *Use Calibration Targets for Tracking*

4. Click on **Build Model.**
5. Click on **Close Tab** before proceeding.

Foot Segment

Foot Landmarks





1. Create RAJC:

1. Click **Landmarks** button
2. Click **Add New Landmark** button
3. Create Landmark: *RAJC*

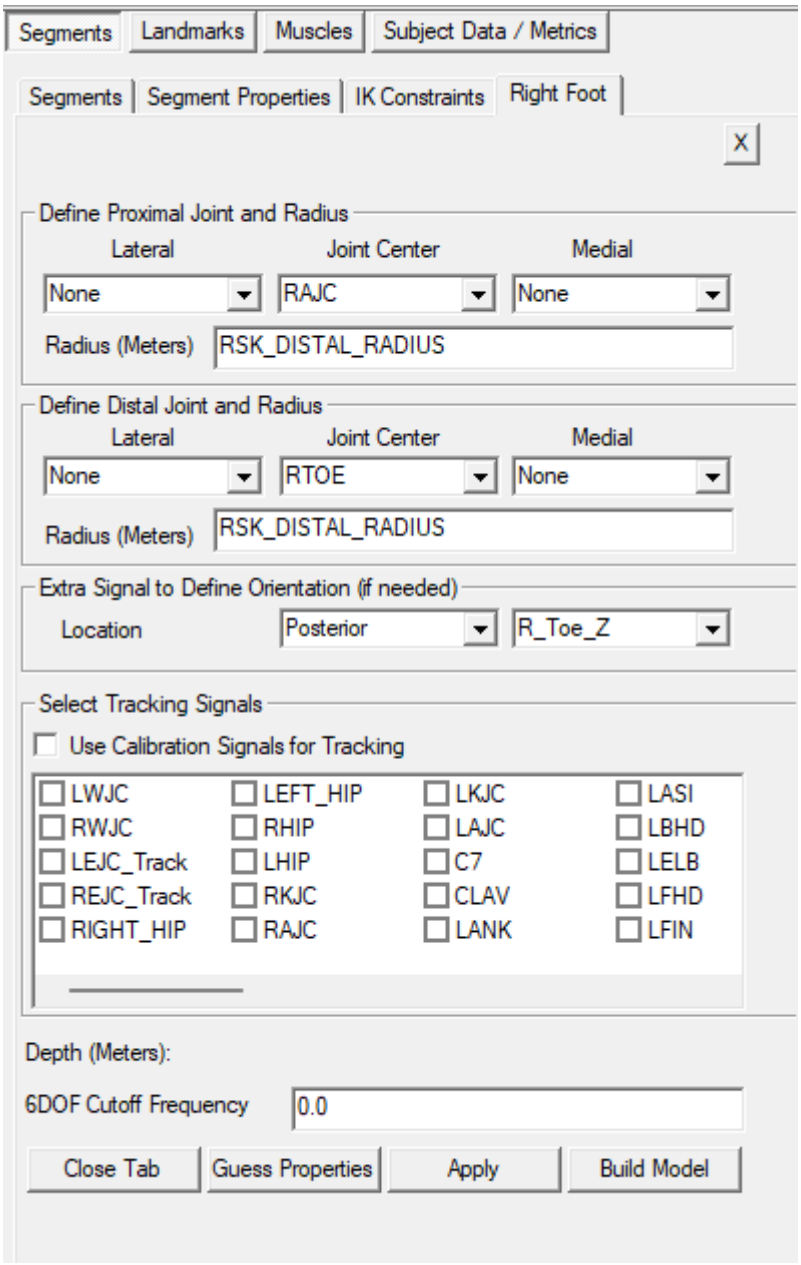
Landmark Name: *RAJC*
Define Orientation Using:
Click **Existing Segment:** *Right Shank*
Offset Using the Following **ML/AP/AXIAL** Offsets:
ML: *0.0* **AP:** *0.0* **AXIAL:** *-1.0*
Check: *Offset by Percent (1.0 = 100%)*
Do NOT Check: *Calibration Only Landmark*

2. Create R_TOE_Z:

1. Click **Landmarks** button
2. Click **Add New Landmark** button
3. Create Landmark: *R_TOE_Z*

   Landmark Name: *R_TOE_Z*
   Define Orientation Using:
   Click **Starting Point and Existing Segment:** *RTOE and LAB*
   Offset Using the Following **ML/AP/AXIAL** Offsets:
   ML: *0.0* **AP:** *0.0* **AXIAL:** *-0.1*
   Do Not Check: *Offset by Percent (1.0 = 100%)*
   Check: *Calibration Only Landmark*

Foot Definition



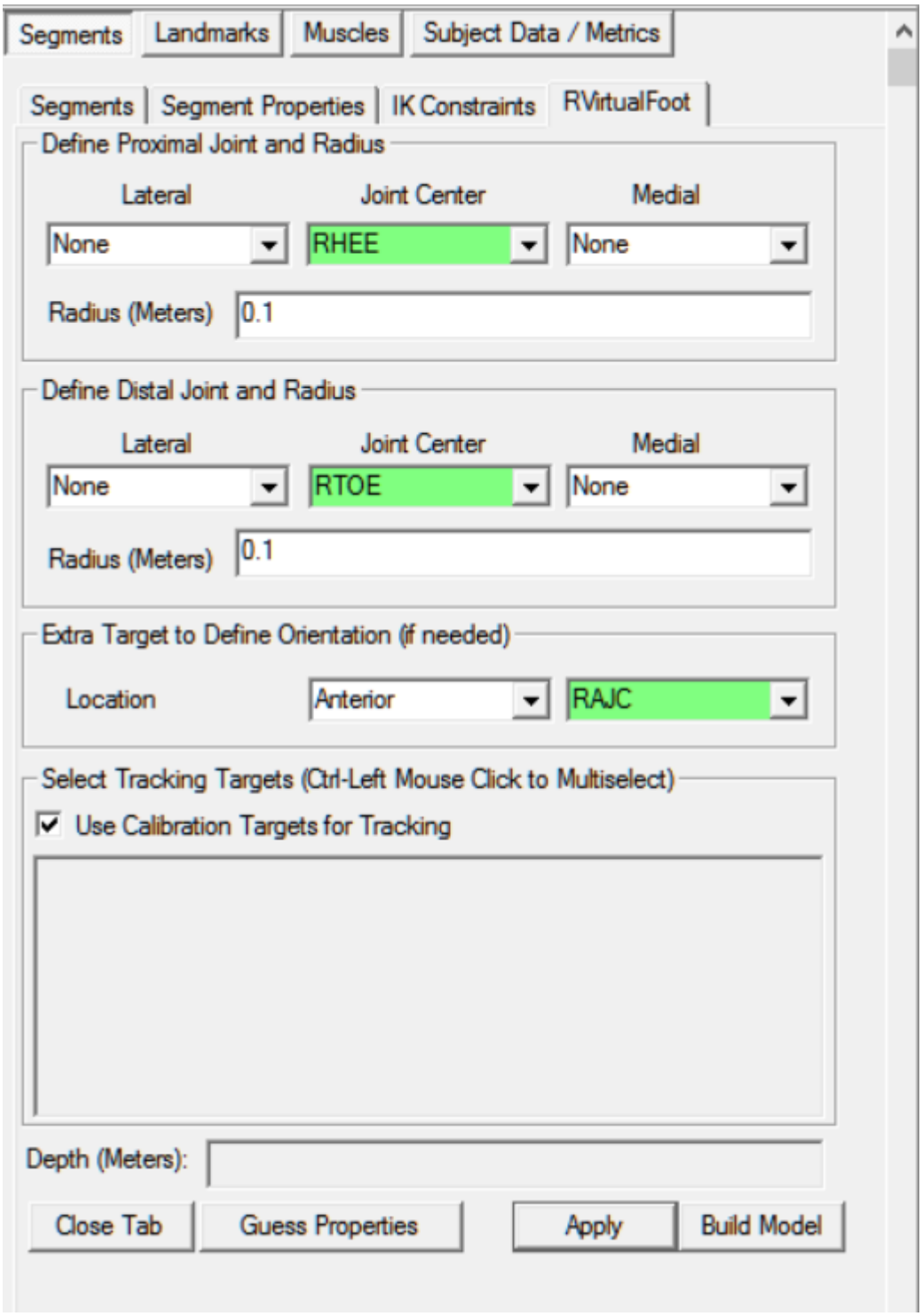
1. Create Right Foot Segment:

1. In the **Segments** tab, select *Right Foot* in the Segment Name box.
2. Click on the **Create Segment** button.
3. In the **Right Foot** tab, enter these values:

   Define Proximal Joint and Radius
   Lateral: *None* **Joint:** *RAJC* **Medial:** *None*
   Radius: *RSK_DISTAL_RADIUS*
   Define Distal Joint and Radius
   Lateral: *None* **Joint:** *RTOE* **Medial:** *None*
   Radius: *RSK_DISTAL_RADIUS*
   Extra Target to Define Orientation
   Location: *Posterior* *R_Toe_Z*
   Select Tracking Targets:
   Select: *RHEE, RMT5, and RTOE*

4. Click on **Build Model.**
5. Click on **Close Tab** before proceeding.

Virtual Foot Segment



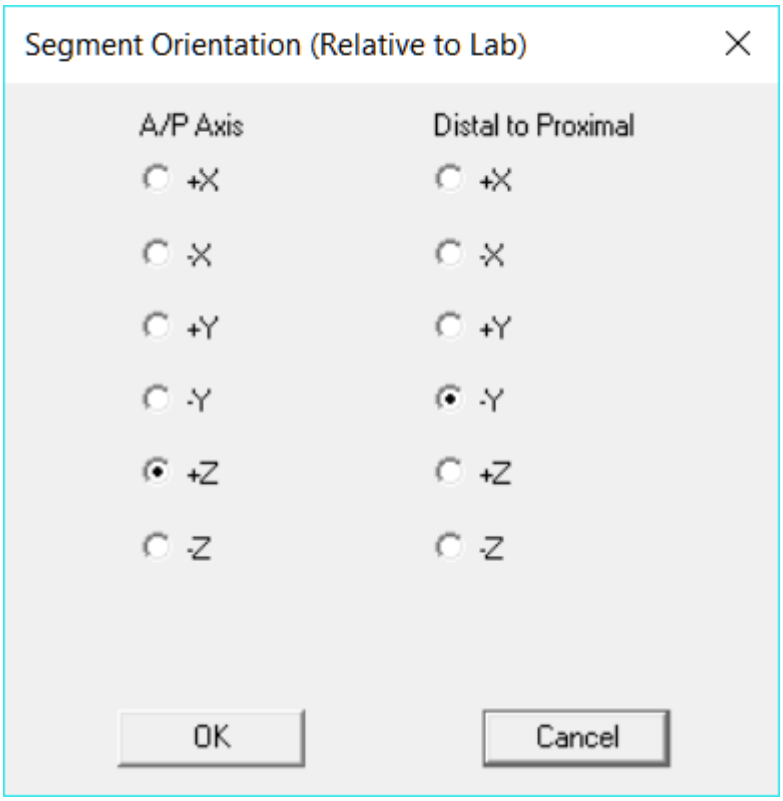
1. Create RVirtualFoot Segment:

1. In the **Segments** tab, type *RVirtualFoot* in the Segment Name box.
2. Check **Kinematic Only**.
3. Click on the **Create Segment** button.
4. In the **RVirtualFoot** tab, enter these values:

Define Proximal Joint and Radius
Lateral: *None* **Joint:** *RHEE* **Medial:** *None*
Radius: *0.1*
Define Distal Joint and Radius
Lateral: *None* **Joint:** *RTOE* **Medial:** *None*

Radius: *0.1*
Extra Target to Define Orientation
Location: *Anterior RAJC*
Select Tracking Targets:
Check: *Use Calibration Targets for Tracking*

5. Click on **Build Model.**
6. Click on **Close Tab** before proceeding.



2. Modify the Segment Coordinate System:

1. Define the Segment Orientation as:
A/P Axis: *+Z*
Distal to Proximal: *-Y*

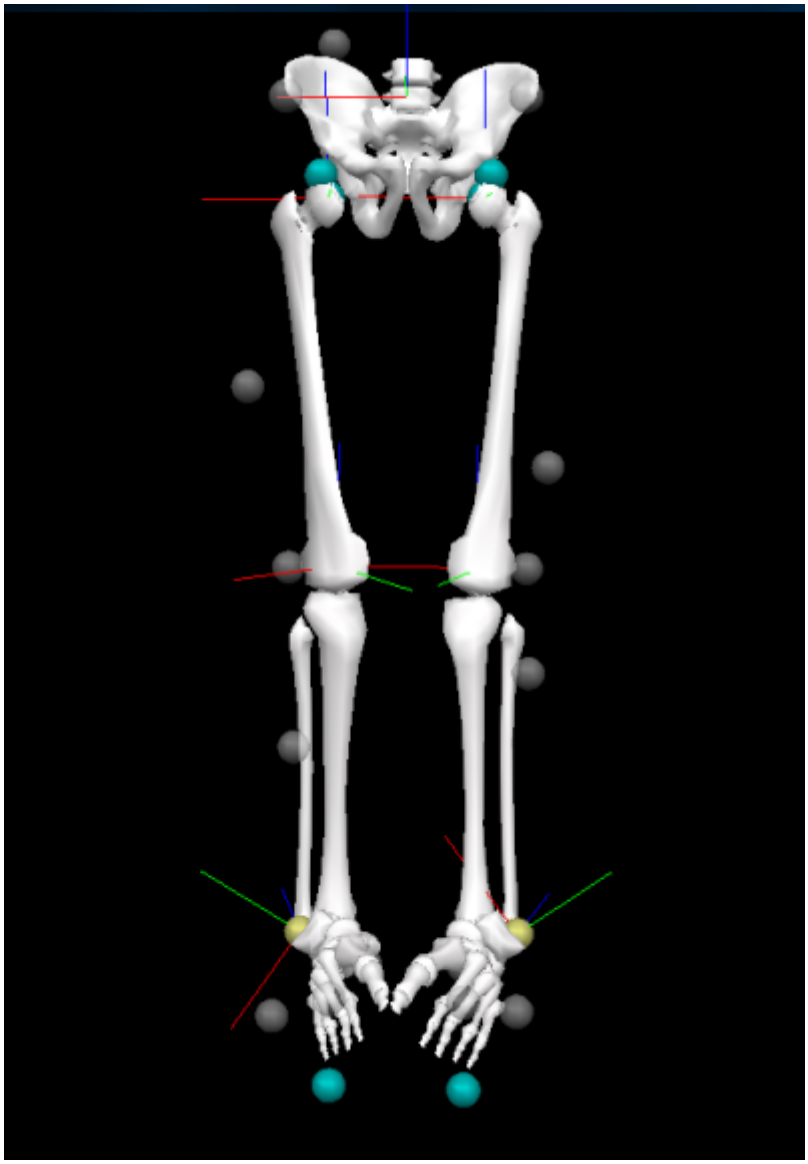
Left Side Model

To build the left side of the model start by copying and reflecting the appropriate landmarks that were created for the right side. Do the same for the thigh, shank and foot segments.

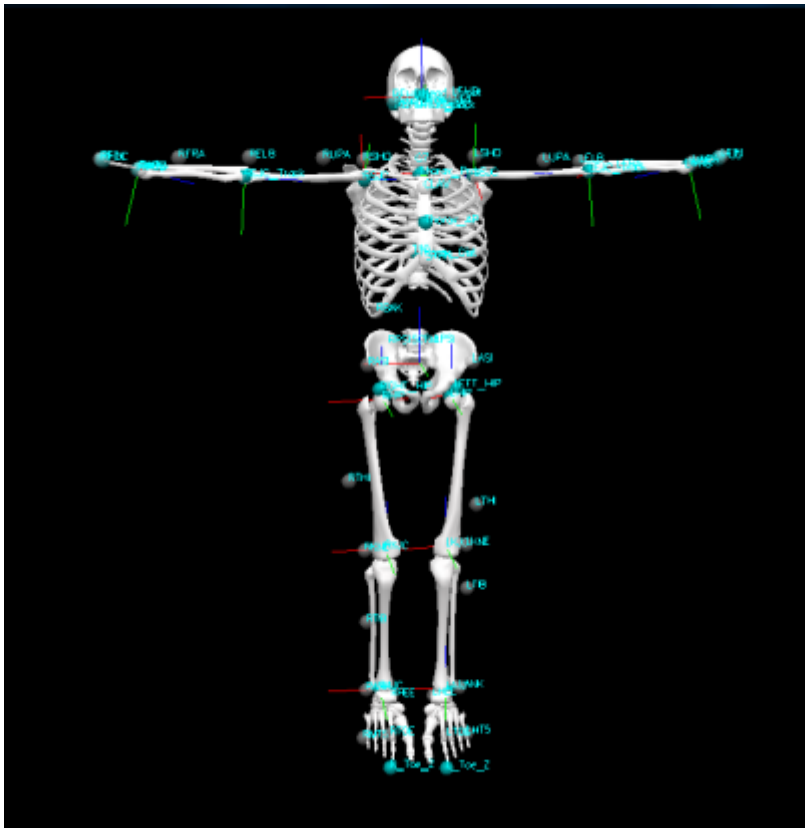
Impact of Modifications

The images below show the original model, before modifications, compared to the modified model. Significant errors in tibial rotation and foot orientation can be seen in the original that are corrected for in the updated model.

Original:



Modified:



As a result of the modifications made in this tutorial the updated model shows improved alignment between the thigh, shank, and foot segments as well as a more neutral (less supinated) foot position.