Modeling the Thorax

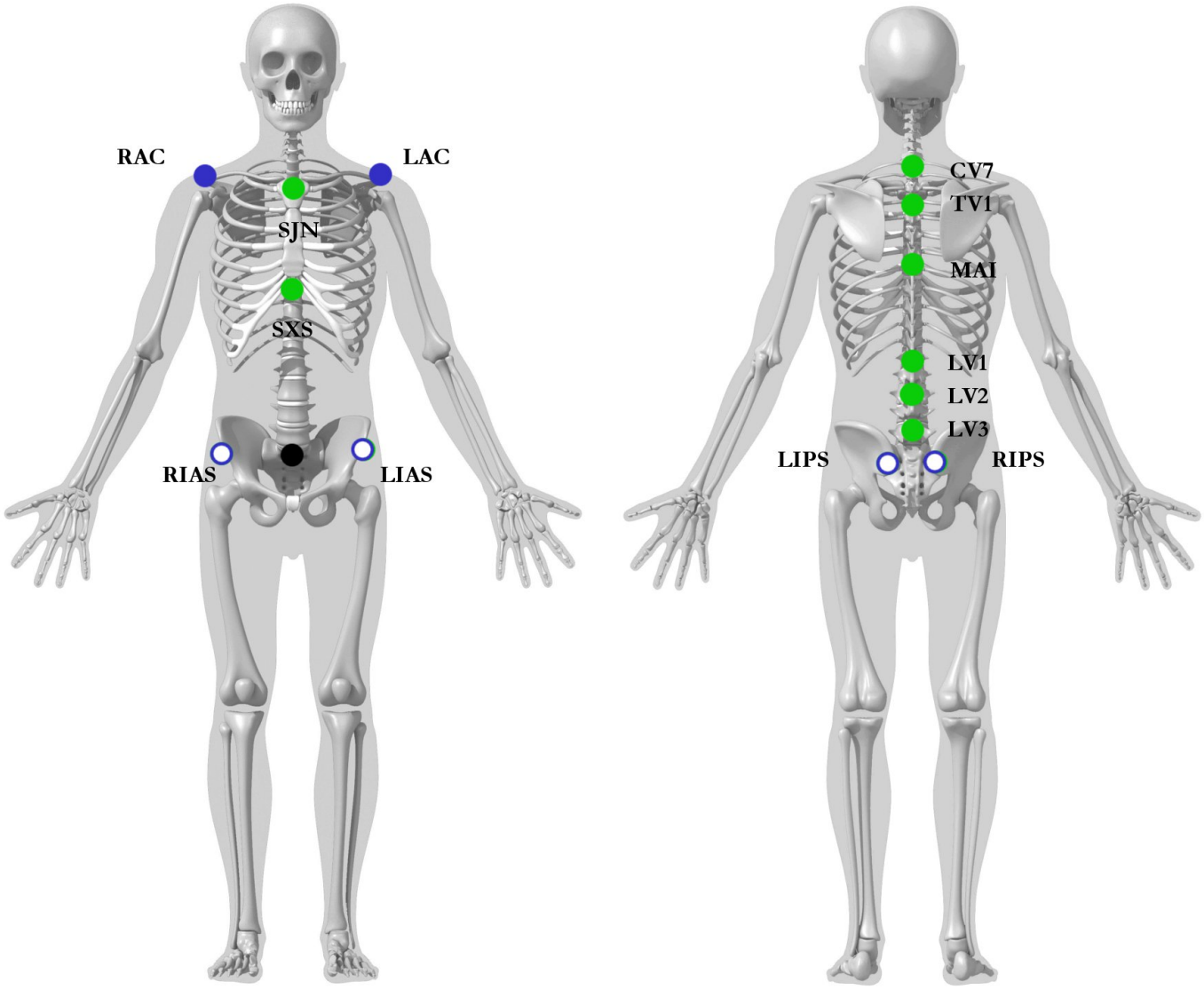
This page covers how to implement two different models of the thorax using Visual3D.

Thorax consistent with ISB recommendation

This tutorial describes how to model the Thorax based on the ISB recommendation.

Wu, G. et al. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human motion - Part II: shoulder, elbow, wrist and hand. Journal of Biomechanics 38, page 981-992, 2005.

Note: Minor changes were made to the recommendation to facilitate its implementation in Visual3D and for consistency with other commonly used coordinate systems. Users are encouraged to adapt these to their own needs and requirements. The following should mainly be used as a starting point, and not as the only way to define the Thorax segment.



Anatomical Landmarks

CV7: Spinal process of the 7th cervical vertebra
TV8: Spinal process of the 8th thoracic vertbebra
IJ: Deepest point of the suprasternal notch (Incisura Jugularis)
PX: Xiphoid process, most caudal point on the sternum

Note: CV7 can be replaced by the second thoracic vertebra (TV2) if required. TV8 can also be replaced either by the tenth (TV10) or twelfth (TV12) thoracic vertebra, or the mid-point between the lowest aspect of the scapula.

Quick Trick: If a lower posterior thorax marker is used, but not require to be placed on a specific anatomical landmark, a quick, consistent and reliable way to place this marker is as followed:

With the subject standing up, ask them to place one of their arms behind their back with their elbow flexed at 90 degree, so that their forearm crosses their spine in a perpendicular manner. Place the

lower posterior thoracic marker on the spine, “2 fingers” above their arm.

Technical Coordinate system Xt, Yt, Zt

Origin: The origin coincident with the mid-point between IJ and CV7.
X_t: The line perpendicular to the plane formed by IJ, CV7, and the midpoint between PX and T8, pointing to the right.
Y_t: The common line perpendicular to the Z_t- and X_t-axis, pointing forwards.
Z_t: The line connecting the midpoint between PX and T8 and the midpoint between IJ and CV7, pointing upward.

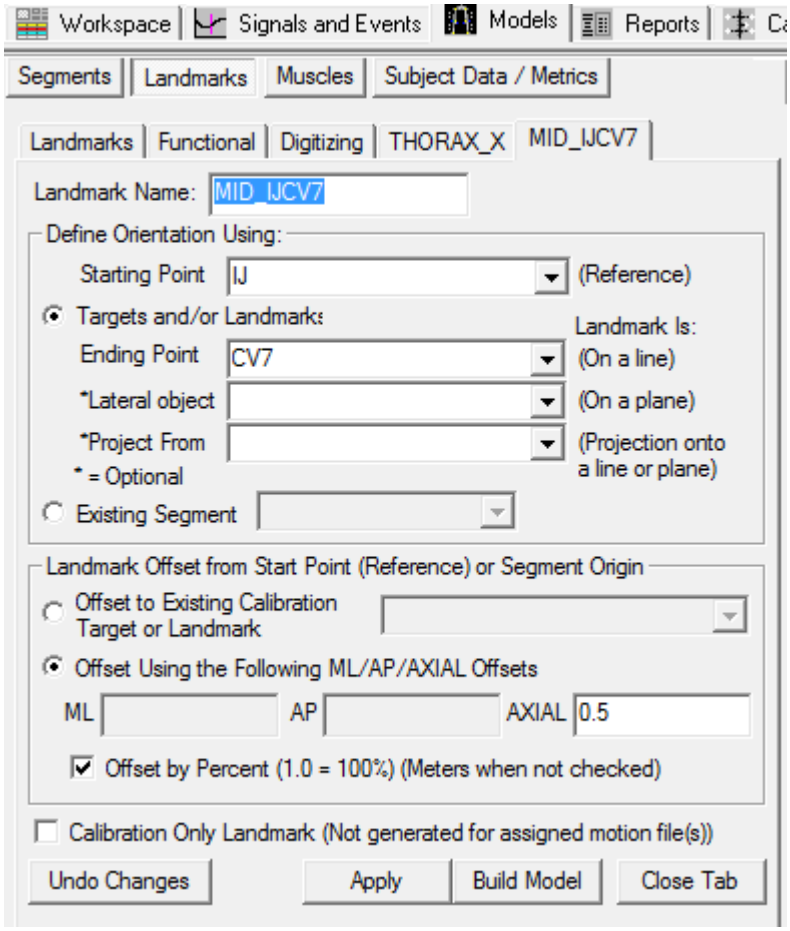
Visual3D Model Construction

The file *Thorax_Static.c3d* can be downloaded for this tutorial. Alternatively, you can also use your own data, with a similar markerset.

Landmarks need to be created for: midpoint of IJ and CV7 (**MID_IJCV7**), midpoint of PX and TV8 (**MID_PXTV8**) and THORAX_X.

To create the midpoint of IJ and the CV7 landmark **MID_IJCV7**:

1. Click on the **Landmarks** TAB
2. Click on **Add New Landmark** tab
3. In the **Landmark Name** box, enter *MID_IJCV7*
4. In the **Starting Point** box, enter *IJ*
5. In the **Ending Point** box, enter *CV7*
6. From the **Offset Using the Following AP/ML/Axial Offsets** box, in the **AXIAL** enter *0.5*
7. Check the **Offset by Percent (1.0=100%) (Meters when not checked)**
8. Click **Apply.**

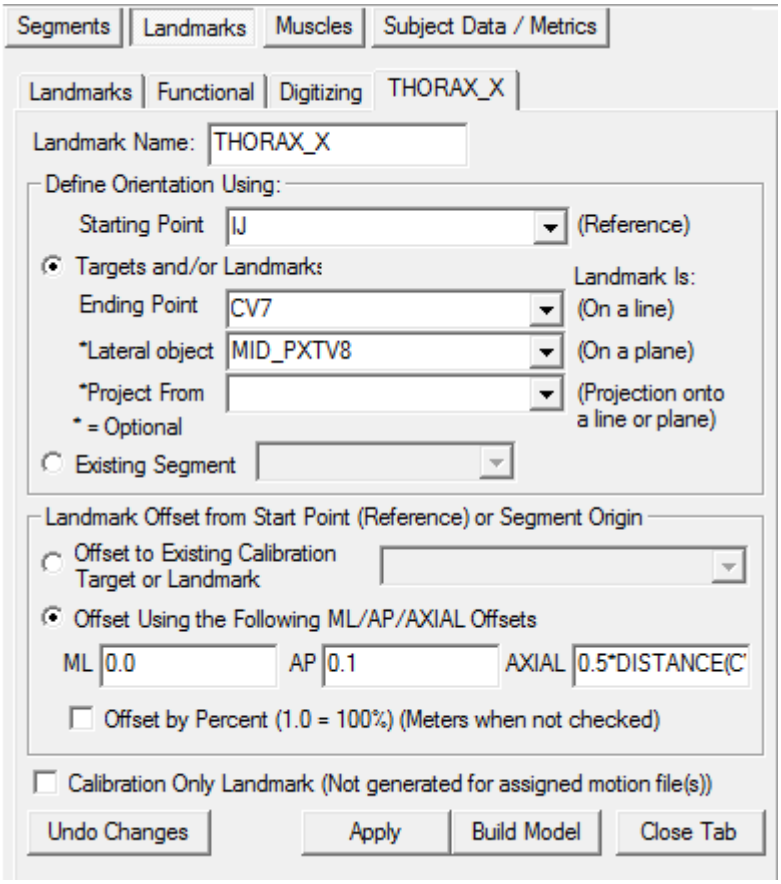


To create the midpoint of PX and the TV8 landmark **MID_PXTV8**:

1. Click on **Add New Landmark** tab
2. In the **Landmark Name** box, enter *MID_PXTV8*
3. In the **Starting Point** box, enter *PX*
4. In the **Ending Point** box, enter *TV8*
5. From the **Offset Using the Following AP/ML/Axial Offsets** box, in the **AXIAL** enter *0.5*
6. Check the **Offset by Percent (1.0=100%) (Meters when not checked)**
7. Click **Apply.**

To create the lateral Thorax landmark used to define the medio-lateral axis **THORAX_X**:

1. Click on **Add New Landmark** tab
2. In the **Landmark Name** box, enter *THORAX_X*
3. In the **Starting Point** box, enter *IJ*
4. In the **Ending Point** box, enter *CV7*
5. In the **Lateral object** box, enter *MID_PXTV8*
6. From the **Offset Using the Following ML/AP/Axial Offsets** box, in the **AP** enter *0.1* **AXIAL** enter *0.5*DISTANCE(IJ,CV7)*
7. Click **Apply.**

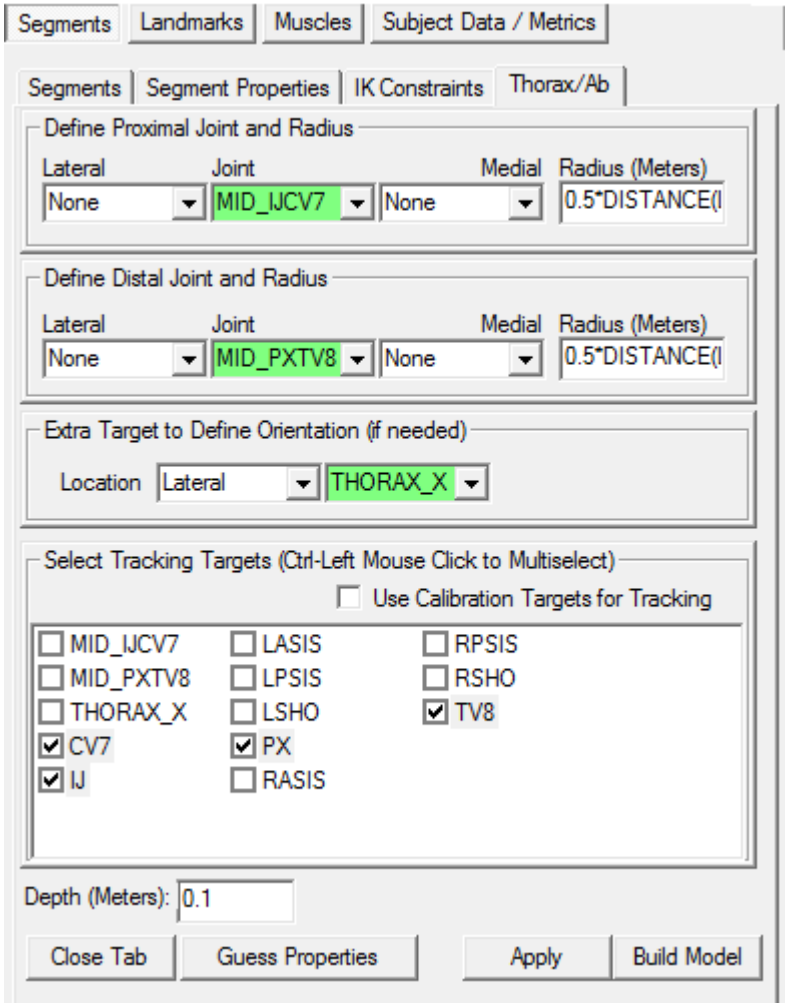


We have now created all the needed landmarks for the Thorax/Ab segment. To create the Thorax/Ab segment in Visual 3D:

1. Click on **Segments** tab
2. From the **Segment Name** box, select *Thorax/Ab.*
3. From the **Segment Type** box, select *Visual 3D.*
4. Click **Create.**

A dialog will open that will allow us to define the segment. The Z axis, pointing upwards, is the predominant axis. This is defined as the direction from the midpoint of the PX and TV8 to the midpoint of IJ and CV7. The proximal and distal ends of the segment must be defined. The origin is the MID_IJCV7.

1. In the **Define Proximal Joint and Radius** section, select *MID_IJCV7* for the **Joint.**
2. In the **Proximal Radius** box, enter *0.5*distance(LSHO,RSHO)*.
3. In the **Define Distal Joint and Radius** section, select *MID_PXTV8* for the **Joint.**
4. In the **Distal Radius** box, enter *0.5*distance(LSHO,RSHO)*
5. In the **Extra Target to Define Orientation** section, select *Lateral* for the **Location.** and *THORAX_X* for the marker.
6. In the **Select Tracking Targets**, click on *CV7*, *IJ*, *PX*, and *TV8*
7. In **Depth**, enter *0.14*
8. Click on **Build Model**

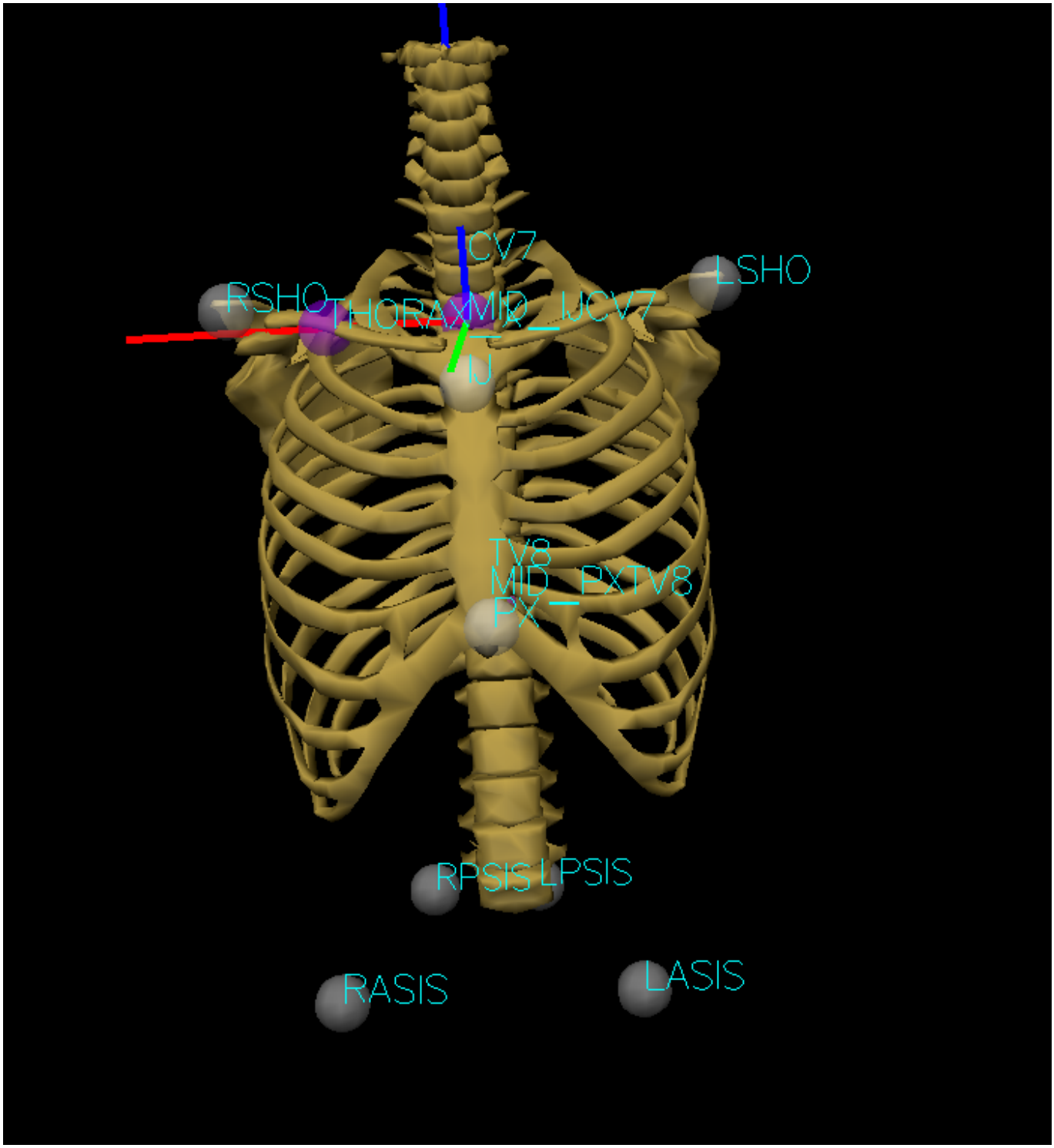


Scaling the thorax's graphic

You should now see a thorax segment on your standing model. The thorax graphic is not oriented or scaled correctly. If you do not see the thorax segment after clicking Build Model, double check the values you entered in the last step. We now need to rotate the thorax graphic to the correct orientation. To orient the thorax skeleton graphic.

1. Click on the **Segment Properties** TAB
2. Click on **Rotate Scale/Graphic Model** tab
3. Rotate the scale/graphic 180 in vertical rotation.
4. Click on Scale button
5. Change the scale for all three (width, depth and height) to 180
6. Click on the Move button
7. Change the Move Up/Down to 65
8. Click on **Ok**
9. Click on **Apply**

Note: The scaling and position (move) values are specific to this tutorial's dataset. The values may vary if using your own dataset.



ISB's exact coordinate system

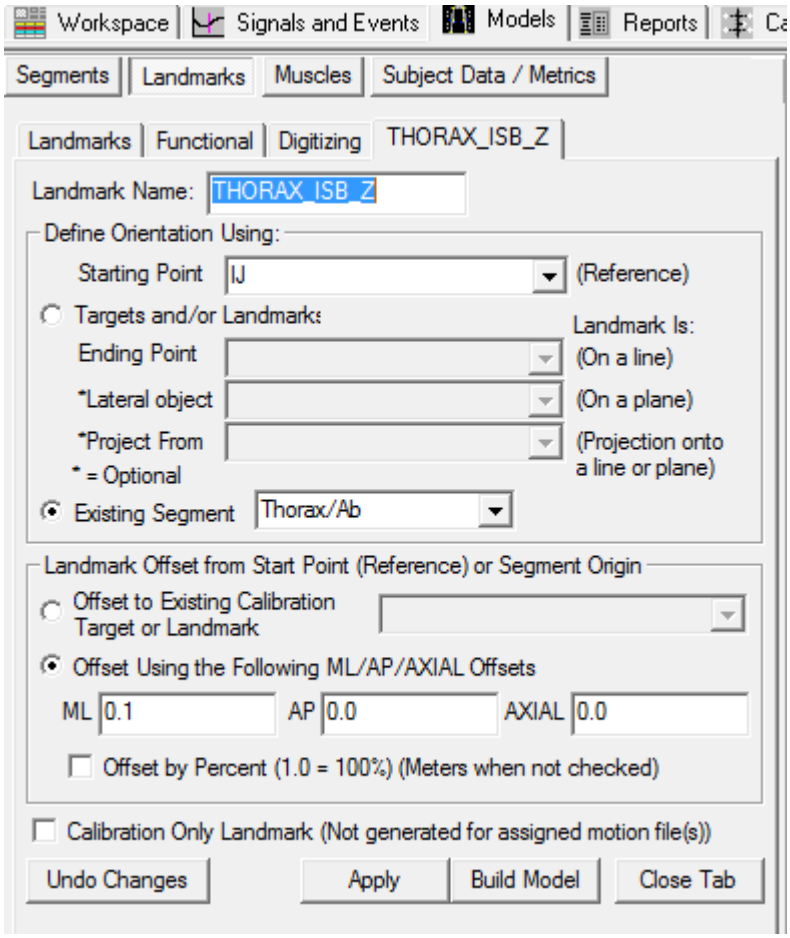
Once the above Thorax segment has been created, it is very easy to create another Thorax segment to the ISB's exact specifications.

Two additional landmarks have to be created, THORAX_ISB_Z and THORAX_ISB_Y:

To create the **THORAX_ISB_Z** landmark:

1. Click on the **Landmarks** TAB
2. Click on **Add New Landmark** tab

3. In the **Landmark Name** box, enter *THORAX_ISB_Z*
4. In the **Starting Point** box, enter *IJ*
5. In the **Existing Segment** box, select *Thorax/Ab*
6. From the **Offset Using the Following AP/ML/Axial Offsets** box, in the **ML** enter *0.1*
7. Click **Apply.**



To create the **THORAX_ISB_Y** landmark:

1. Click on the **Landmarks** TAB
2. Click on **Add New Landmark** tab
3. In the **Landmark Name** box, enter *THORAX_ISB_Y*
4. In the **Starting Point** box, enter *IJ*
5. In the **Existing Segment** box, select *Thorax/Ab*
6. From the **Offset Using the Following AP/ML/Axial Offsets** box, in the **AXIAL** enter *0.1*
7. Click **Apply.**

Once these two landmarks have been created,

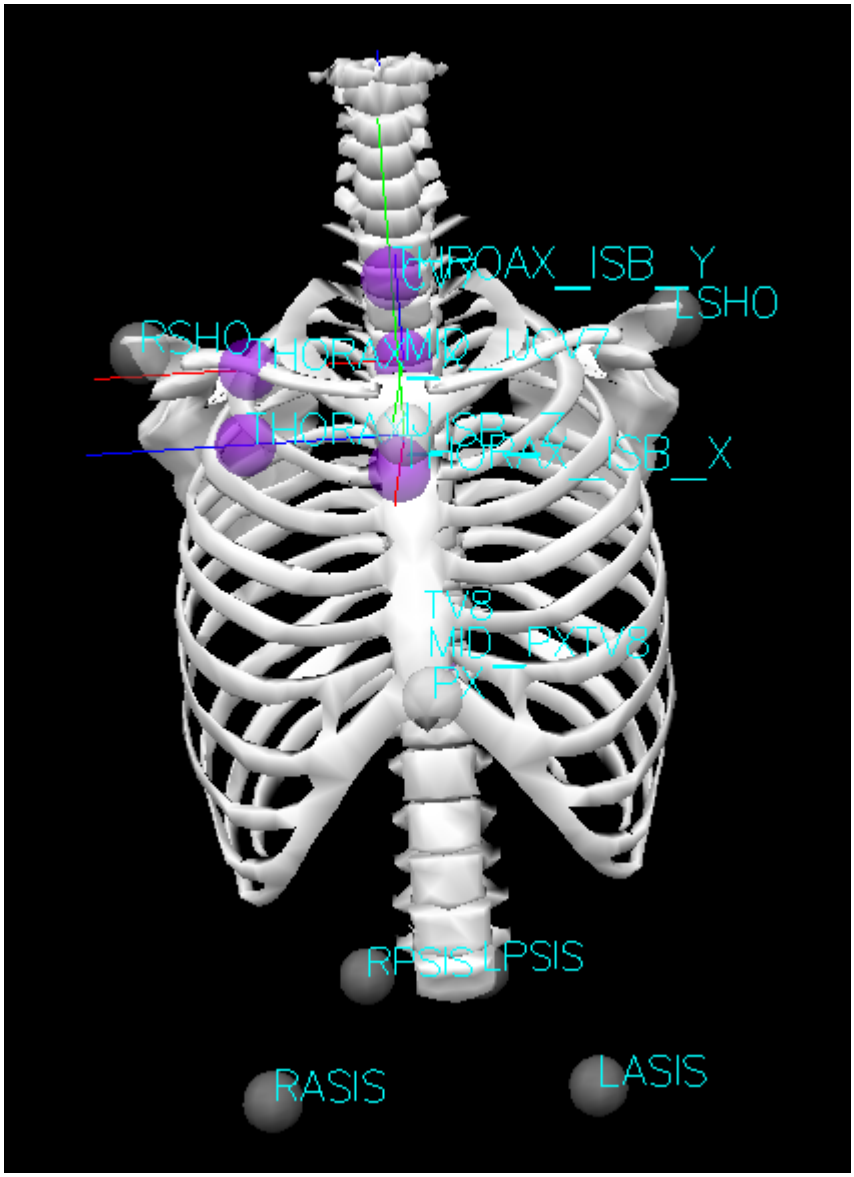
1. In the **Define Proximal Joint and Radius** section, select *IJ* for the **Joint.**
2. In the **Proximal Radius** box, enter *0.5*distance(LSHO,RSHO)*.
3. In the **Define Distal Joint and Radius** section, select *THORAX_ISB_Y* for the **Joint.**
4. In the **Distal Radius** box, enter *0.5*distance(LSHO,RSHO)*
5. In the **Extra Target to Define Orientation** section, select *Lateral* for the **Location.** and *THORAX_ISB_Z* for the marker.
6. In the **Select Tracking Targets**, click on *CV7*, *IJ*, *PX*, and *TV8*

7. In **Depth**, enter *0.14*

1. Go to the Segment Properties tab
2. Select **THORAX_ISB** in the *Segment Name* list
3. For *Segment Mass*, enter **0.1**.
4. For *Segment Geometry*, select **Cone** from the list
5. Click **Apply**
6. Click on **Build Model**

In the Segment Properties tab, select THORAX_ISB from the Segment Name box.

1. Click on **Modify Segment Coordinate System**
2. For the *A/P Axis*, select **-X**
3. For the *Distal to Proximal* axis, select **-Y**
4. Click **OK**



RAB Thorax Model

Model based on the upper extremity model developed by Dr. George Rab, Kyria Petuskey, and Anita Bagley from Shriners Hospital for Children, Northern California. Refer to their paper “A Method for Determination of Upper Extremity Kinematics” Gait & Posture 15 (2002) 113-119 for the exact model specifics (Download here). Another article using the Rab upper body model can be downloaded here.

The Thorax/Ab segment is constructed from virtual landmarks on the lateral superior borders of the Iliac Crest and virtual landmarks at the shoulder joint centers.

Iliac Crest Landmarks

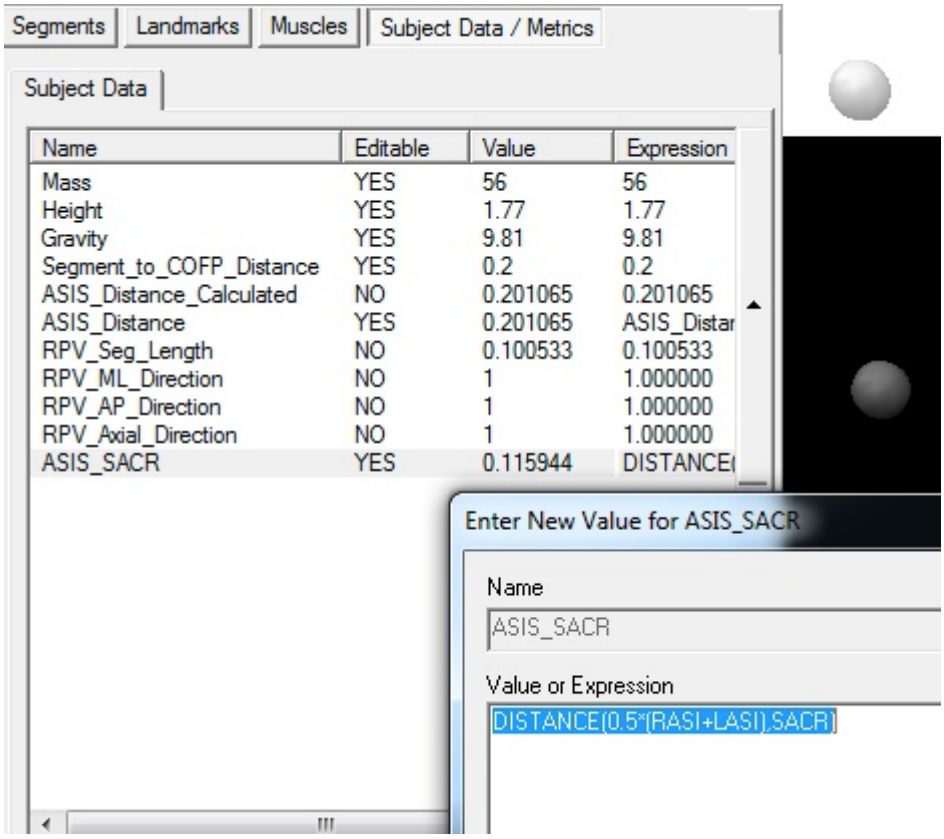
The Iliac Crest Landmarks were estimated using the Terry Database published as:

Kepple TM, Sommer HJ, Siegel KL, Standhope SJ (1998) A three-dimensional musculoskeletal database for the lower extremities. Journal of Biomechanics 31, pp 77-80 This landmark was not part of the original Terry Database, but we estimated the position from the database that can be downloaded Here.

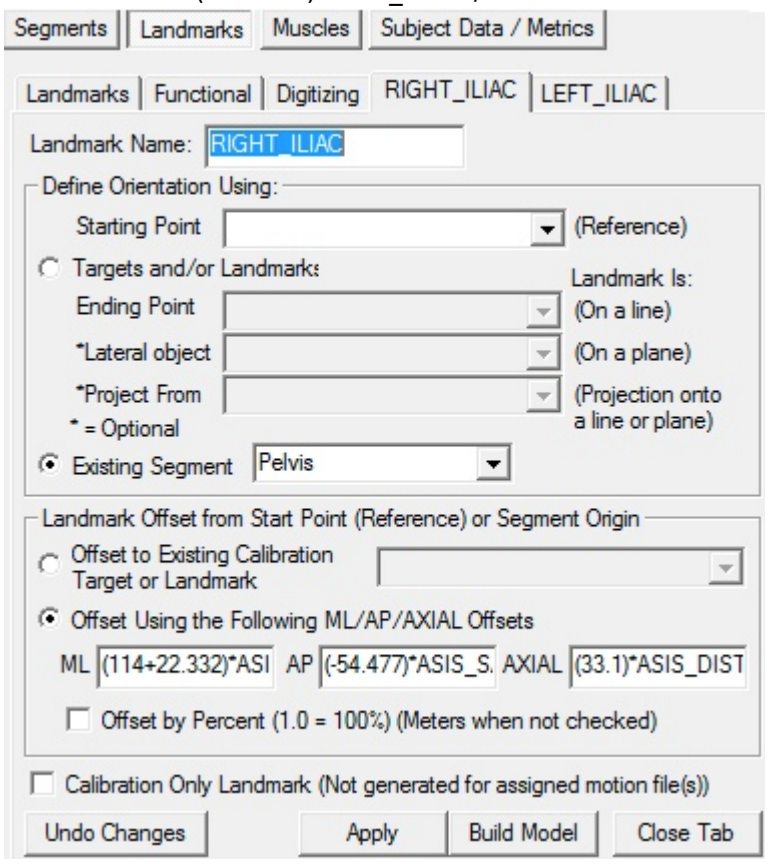
The medial/lateral and superior/inferior location of the **RIGHT_ILIAC** and **LEFT_ILIAC** landmarks were defined as the most lateral point on the superior tubercle of the Iliac crest (landmarks 39 & 40 of the Terry Pelvis dataset)

The anterior/posterior location of the **RIGHT_ILIAC** and **LEFT_ILIAC** landmarks were defined as the lateral surface of the Right ilium at midpoint between most lateral point on superior tubercle of the Iliac crest and origin of the Gluteus Medius posterior fibers {landmarks 43 & 44 of the Terry Pelvis dataset)

The location of Terry Landmark 39 is (22.332 , -54.477 , 29.705) The location of Terry Landmark 40 is (-251.082 , -49.732 , 36.540) These values were averaged for creating the landmark. From the Terry dataset the distance between the ASIS landmarks (Terry landmarks 1&2) is approximately 228 which is defined as the x-axis of the pelvis. The x-component of the **RIGHT_ILIAC** landmark in Pelvis coordinates is (114+22.7)*ASIS_DISTANCE/228 The z-component of the **RIGHT_ILIAC** landmark in Pelvis coordinates is (33.1)*ASIS_DISTANCE/228 From the Terry dataset the perpendicular distance from the x-axis to the mid-point of the PSIS landmarks (Terry landmarks 3&4) is approximately 143.5 In Visual3D create a Subject/Model Metric to compute this distance as the distance from the SACR marker to the mid-point of the RASI and LASI markers.



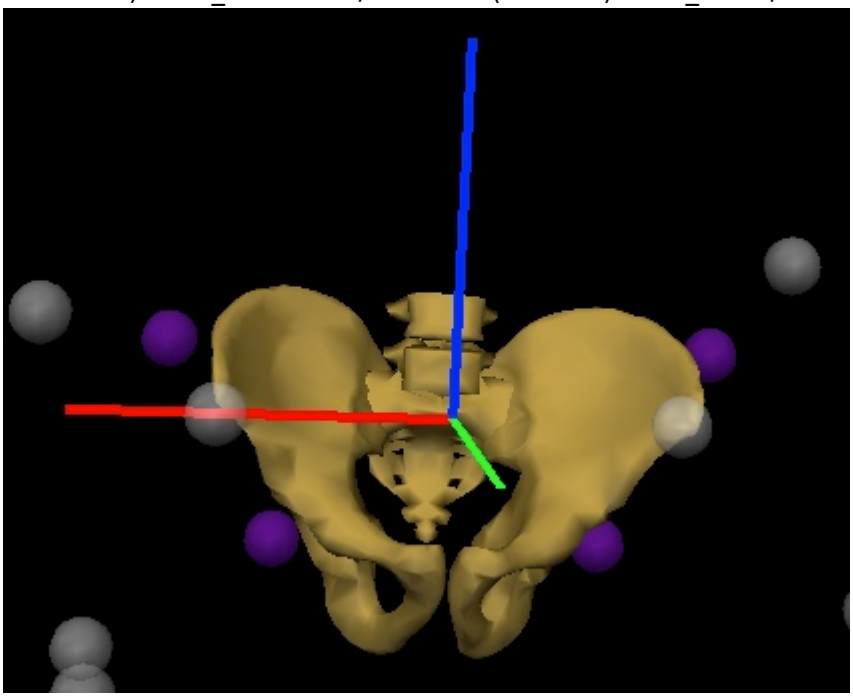
The y-component of the **RIGHT_ILIAC** landmark in Pelvis coordinates is (-54.477)*ASIS_SACR/143.5 Create the **RIGHT_ILIAC** Landmark using these values as. In Summary:



The RIGHT_ILIAC landmark is defined as:

Existing Segment= Pelvis ML= (114+22.332)*ASIS_DISTANCE/228 AP= (-54.477)*ASIS_SACR/143.5 AXIAL= (33.1)*ASIS_DISTANCE/228
The LEFT_ILIAC landmark is assumed to be located symmetrically and defined as:

Existing Segment= Pelvis ML= -(114+22.332)*ASIS_DISTANCE/228 AP= (-54.477)*ASIS_SACR/143.5 AXIAL= (33.1)*ASIS_DISTANCE/228



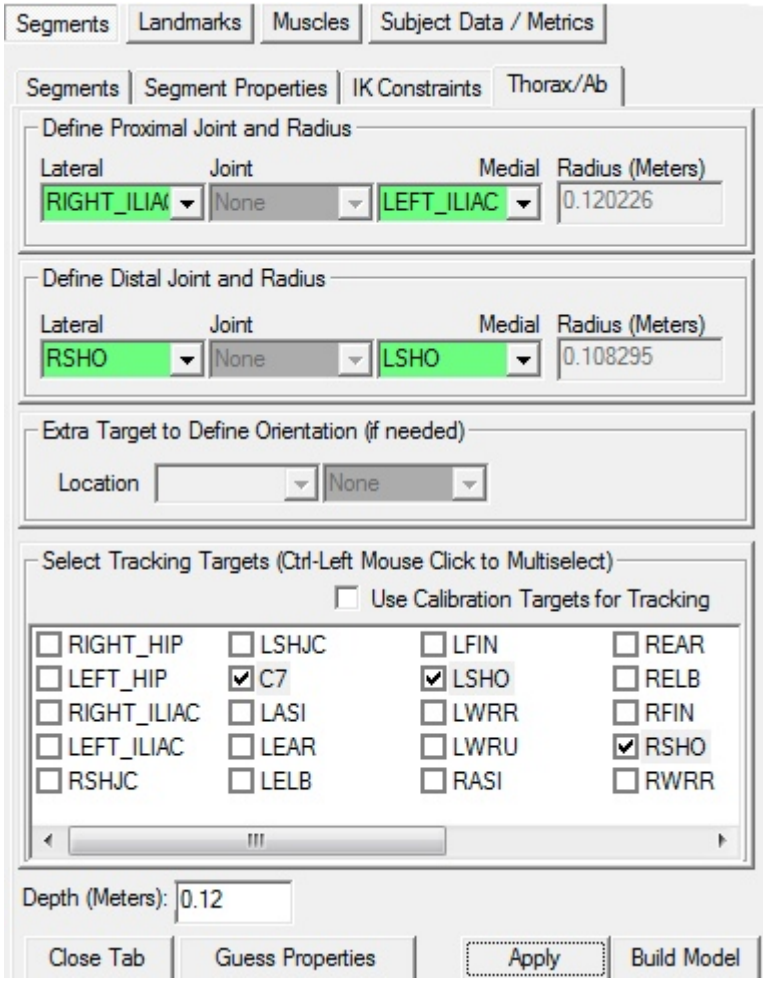
Construct the segment

We have now created all the needed landmarks for the thorax/ab segment. To create the thorax/ab segment in Visual 3D:

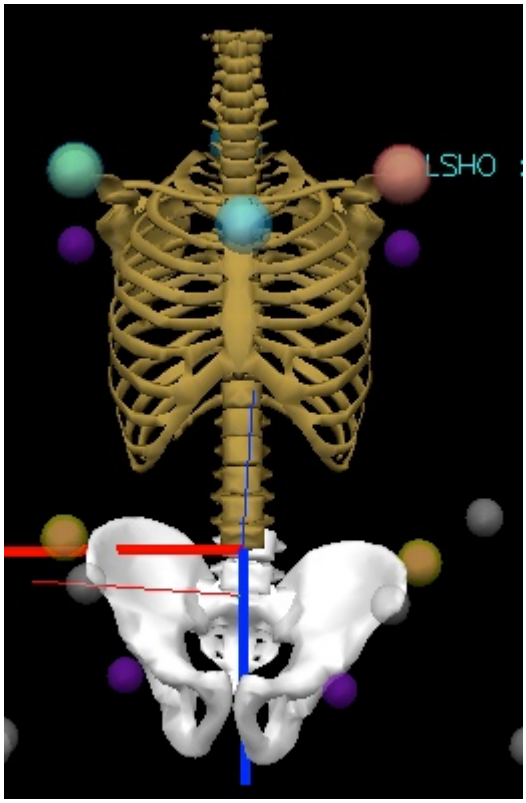
1. Click on **Segments** tab
2. From the **Segment Name** box, select *Thorax/Ab.*
3. From the **Segment Type** box, select *Visual 3D.*
4. Click **Create.**

A dialog will open that will allow us to define the segment.

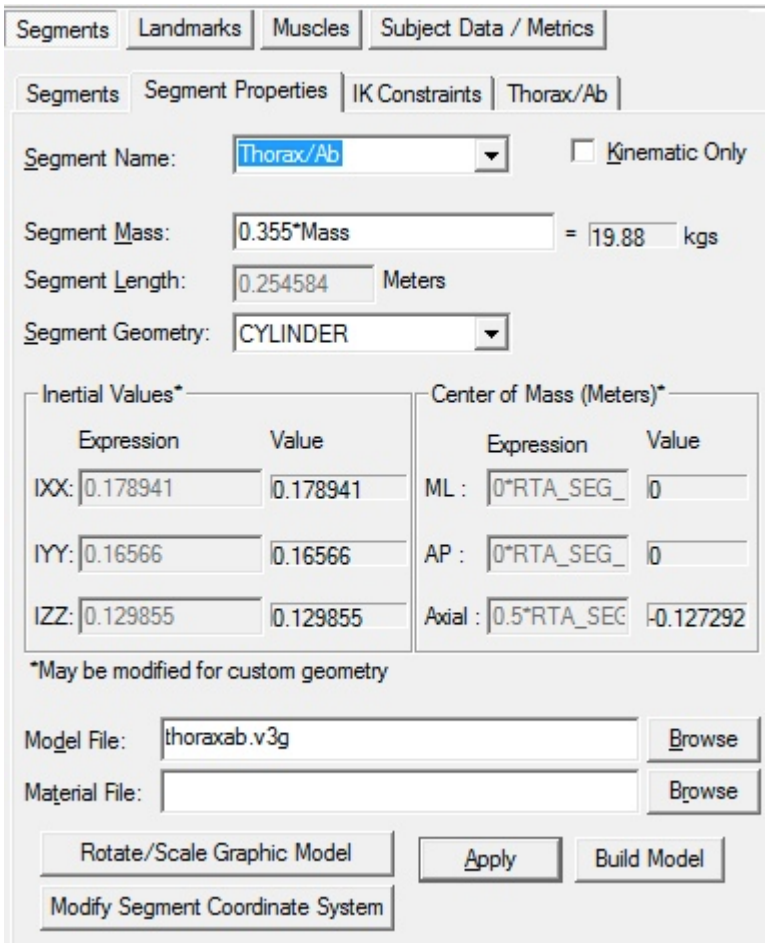
1. In the **Define Proximal Joint and Radius** section, select *RIGHT_ILIAC* for the **Lateral.** and select *LEFT_ILIAC* for the **Medial.**
2. In the **Define Distal Joint and Radius** section, select *RSHO* for the **Lateral.** and select *LSHO* for the **Medial.**
3. In the **Select Tracking Targets**, click on *C7*, *STRN*, *LSHO*, *RSHO*
4. In the **Depth (Meters):** box, enter *0.12*
5. Click on **Build Model**



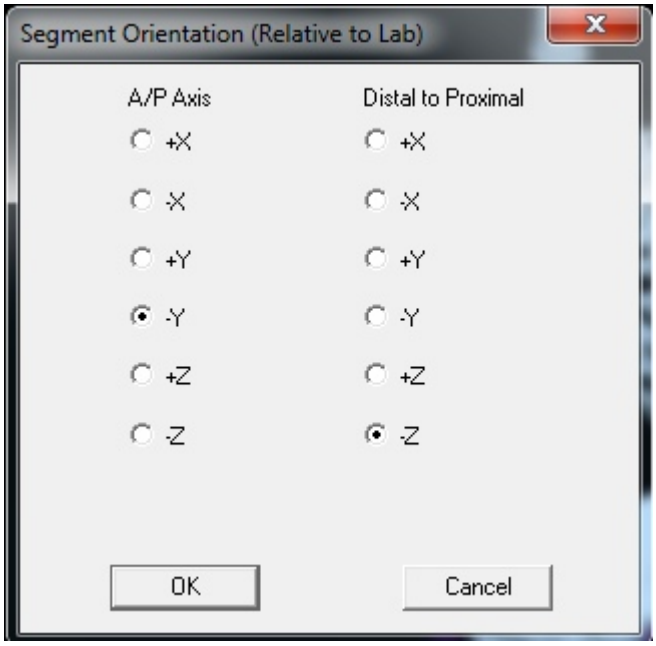
You should now see a thorax segment on your standing model. If you do not see the thorax segment after clicking Build Model, double check the values you entered in the last step.



Note that the Z-axis of the segment (Blue Line) is pointing down, so we must fix that.



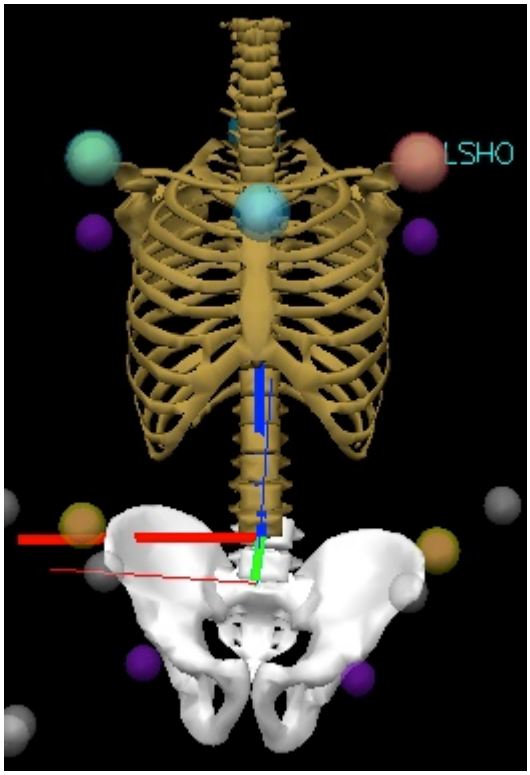
Switch to the segment properties tab, select the Thorax/Ab segment in the combo box, and select Modify Segment Coordinate System.



Select the AP direction to be -Y and the AXIAL direction to be -Z

This may seem a little strange at first because it is certainly an option to create the segment with the Acromion at the proximal end and the Iliac Crest at the distal end.

Placing the proximal end of the thorax/ab segment at the pelvis essentially places two proximal ends together (e.g. the Thorax/Ab and Pelvis), but now the distal end of the Thorax/Ab segment is at the shoulders, which allows the creation of shoulder and neck joints (e.g. the arms and head are considered distal segments of the body).



References

ISB Thorax: Wu, Ge, et al. “ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: shoulder, elbow, wrist and hand.” Journal of biomechanics 38.5 (2005): 981-992.

RAB Thorax: Rab, George, Kyria Petuskey, and Anita Bagley. “A method for determination of upper extremity kinematics.” Gait & posture 15.2 (2002): 113-119.