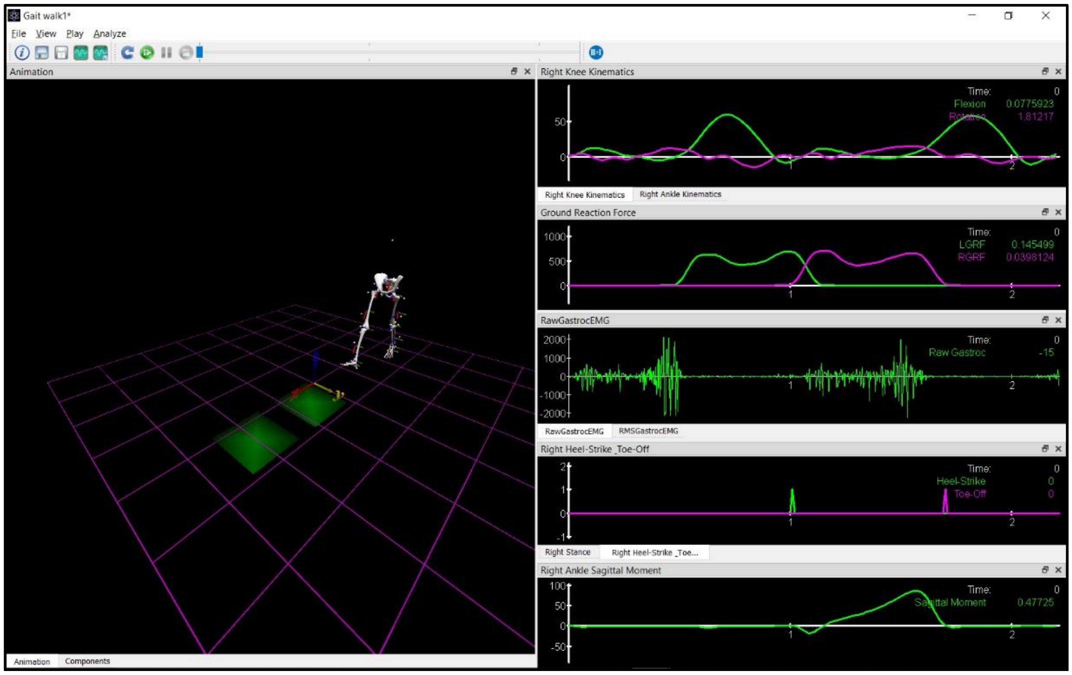
The MotionMonitor xGen Software Guide: Biomechanical Variables and Sample Calculations

This document provides examples for how to define some of the most common biomechanical variables in The MotionMonitor xGen. These examples were defined using sample data from the Activity 'Gait Walk 1' found with the 'Sample Scholastic Files' user in version 3.38.02 or later. Each example includes a description for the data, screen captures of the variable expression and the formula for the expression.



When selecting to define a variable relative to another variable, it's important to consider whether the desire is to just have the original value reported in the orientation of the 'relative to' Axes or if the position and movement for the 'relative to' Axes should be taken into account. The former is what we refer to as a ***non-position or directional/offset vector*** and the latter is referred to as a ***position vector.***

For instance, when reporting the position of the ankle you would want to take the position of the reference frame into account so that the position being examined is relative to and in the orientation of the 'relative to' Axes. Whereas, when examining the force at a joint, the value is just being reported in the orientation (X, Y & Z directions) of the 'relative to' Axes.

The MotionMonitor xGen has different Axes operators for these conditions, relpos() and reldir(), respectively. When using the drop-list for defining biomechanical variables from a Subject or from other hardware devices, the proper operator is selected, as you will see in the examples to follow. However, careful consideration should be made that the proper operator is selected for custom user-defined variables.

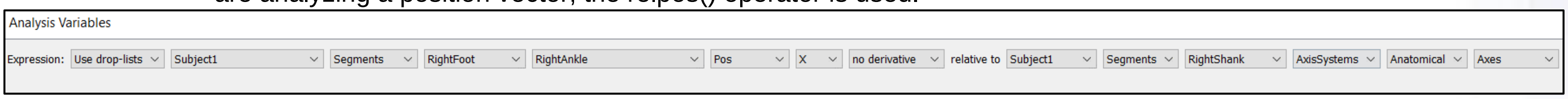
For more details on any of the data types and operators used in this guide, please reference The MotionMonitor xGen – Elements software manual.

Position and displacement variables

Position in the X-axis direction of the World coordinate system for the ankle position, as tracked by the foot segment, is defined below. The 'Type' drop-list could be changed from Scalar to Vector in order to define a vector variable type to be used in subsequent analyses.

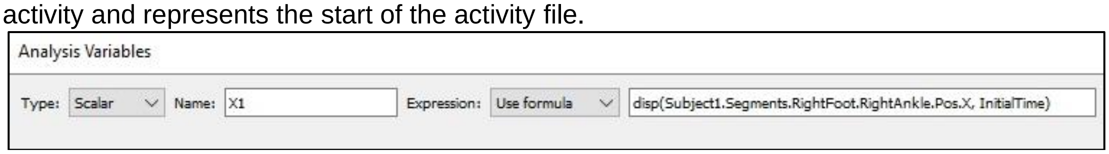
Subject1.Segments.RightFoot.RightAnkle.Pos.X

The **Position** of the ankle, as tracked by the foot segment, can be reported relative to another segment. If the Shank is selected for the 'relative to' reference frame, the ankle position as tracked by the foot will be reported relative to the position and orientation of the shank's reference frame, as it was defined in the Segment parameters panel for the Subject in the Setup Component dialog. As we are analyzing a position vector, the relpos() operator is used.



relpos(Subject1.Segments.RightFoot.RightAnkle.Pos,Subject1.Segments.RightShank.AxisSystems.Anatomical.Axes).X

The **Displacement** of the ankle position previously described above is defined below. Displacement is the change in value, position in this instance, for a variable from a specified time. The time specified below is InitialTime, which is a Time variable that automatically gets generated within each activity and represents the start of the activity file.



disp(Subject1.Segments.RightFoot.RightAnkle.Pos.X, InitialTime)

Additional displacement calculations…

The displacement variable described above can also be evaluated at a particular time by use of an At Time operator. First, we must generate a 'Time' variable for the time of interest. There was only 1 right heel strike on the force plate in the 'Gait Walk 1' activity, so we can use the Max Time (tmax) operator to determine the time where 'RightHeelStrike', a Boolean variable, became True.

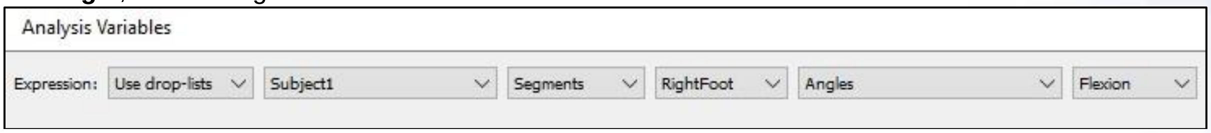
tmax(RightHeelStrike,InitialTime,FinalTime,0.01)

The attime() operator is then used to determine the displacement between the InitialTime and RightHeelStrikeTime events.

attime(disp(Subject1.Segments.RightFoot.RightAnkle.Pos.X, InitialTime),RightHeelStrikeTime)

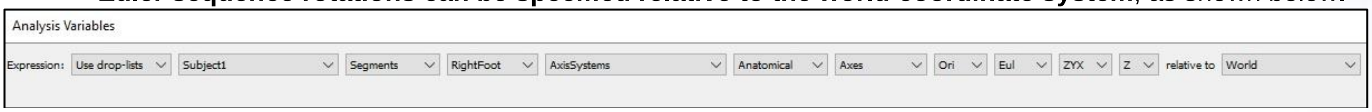
Orientation

Selecting elements from the 'Angles' drop-list for a segment will report the **Orthopaedic, 2D projection angle**, for that segment.



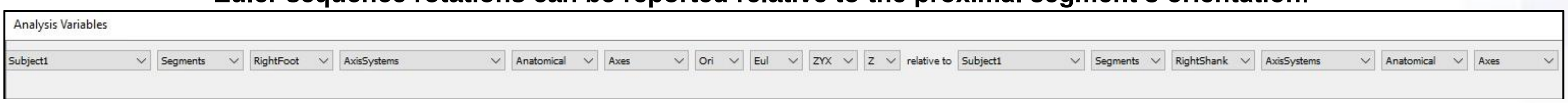
Subject1.Segments.RightFoot.Angles.Flexion

Euler sequence rotations can be specified relative to the world coordinate system, as shown below**.**



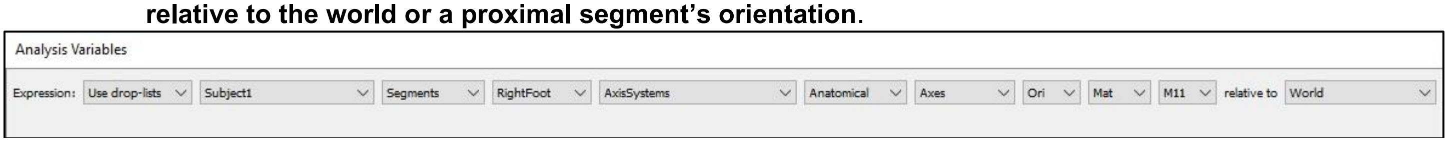
Subject1.Segments.RightFoot.AxisSystems.Anatomical.Axes.Ori.Eul.ZYX.Z

Euler sequence rotations can be reported relative to the proximal segment's orientation.



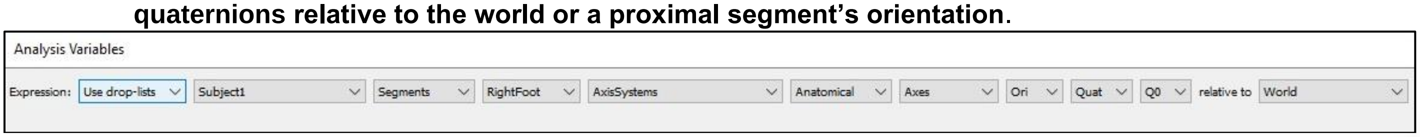
rel(Subject1.Segments.RightFoot.AxisSystems.Anatomical.Axes, Subject1.Segments.RightShank.AxisSystems.Anatomical.Axes).Ori.Eul.ZYX.Z

As done with Euler sequences, variables can be defined for orientation data from the **rotation matrix relative to the world or a proximal segment's orientation**.



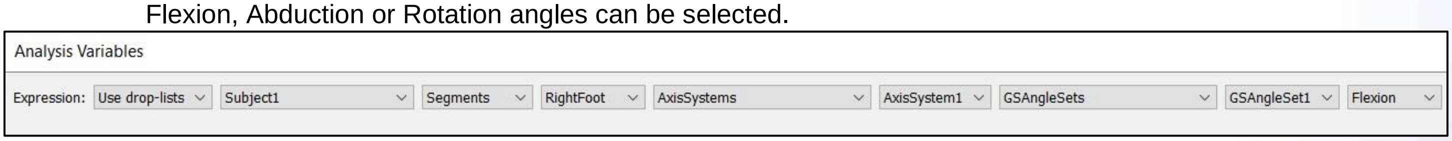
Subject1.Segments.RightFoot.AxisSystems.Anatomical.Axes.Ori.Mat.M11

As done with Euler sequence and the rotation matrix, variables can be defined for orientation data from the **quaternions relative to the world or a proximal segment's orientation**.



Subject1.Segments.RightFoot.AxisSystems.Anatomical.Axes.Ori.Quat.Q0

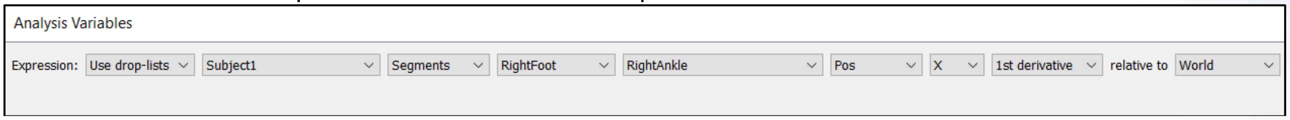
Grood & Suntay Angles can be defined as shown below, when additional Axis Systems have been defined for a Subject's segment and a reference segment Axes was selected for the Grood-Suntay Angle Set. Flexion, Abduction or Rotation angles can be selected.



Linear Velocity and Acceleration

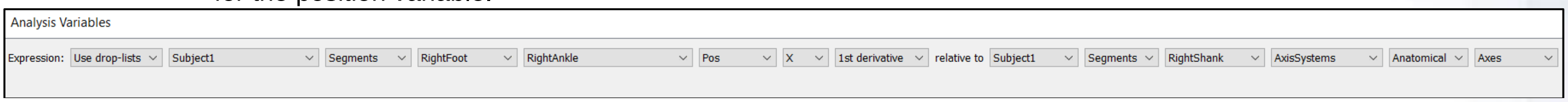
For defining linear velocity and acceleration, the derivatives of Position variables are taken.

Liner Velocity for a point relative to world can be defined as shown below. Simply select the 1st derivative for the position variable from the drop-list.



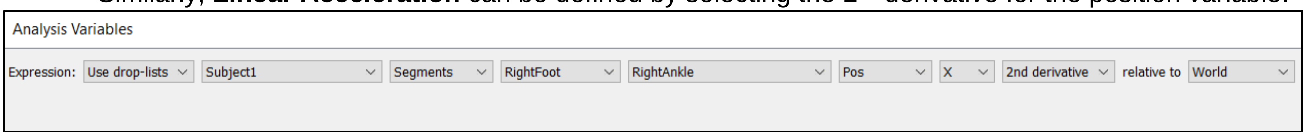
diff(Subject1.Segments.RightFoot.RightAnkle.Pos.X)

For the **Velocity of a point reported relative to another segment**, simply select the 1st derivative for the position variable.



diff(reldir(Subject1.Segments.RightFoot.RightAnkle.Pos, Subject1.Segments.RightShank.AxisSystems.Anatomical.Axes).X)

Similarly, **Linear Acceleration** can be defined by selecting the 2nd derivative for the position variable.

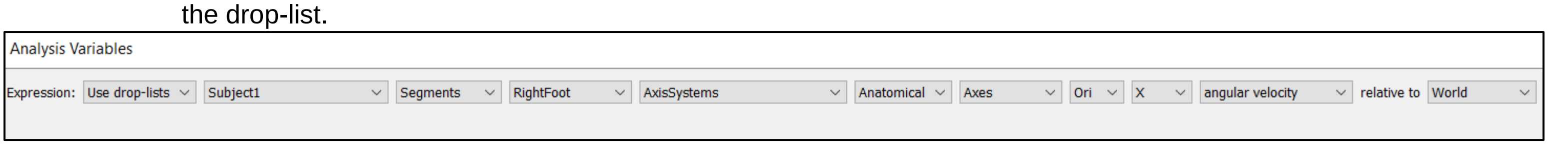


diff2(Subject1.Segments.RightFoot.RightAnkle.Pos.X)

Angular Velocity and Acceleration

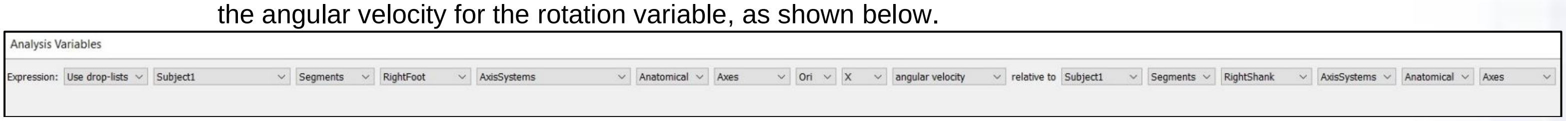
Angular velocity and acceleration can be derived from Rotation variables.

Angular Velocity for a Rotation relative to world can be defined as seen below. Simply select the Magnitude, X, Y or Z components following the Orientation drop-list selection and then angular velocity from the drop-list.



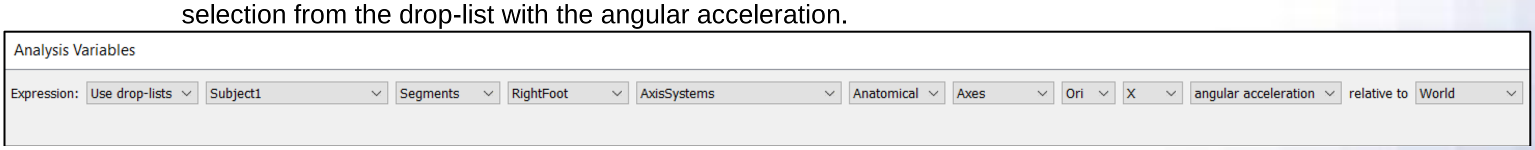
angvel(Subject1.Segments.RightFoot.AxisSystems.Anatomical.Axes.Ori).X

For the **Angular velocity of the foot segment reported relative to another segment**, simply select the angular velocity for the rotation variable, as shown below.



angvel(rel(Subject1.Segments.RightFoot.AxisSystems.Anatomical.Axes, Subject1.Segments.RightShank.AxisSystems.Anatomical.Axes).Ori).X

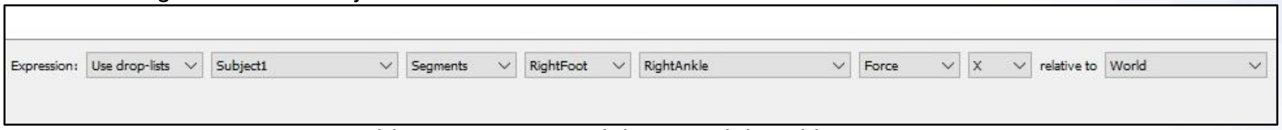
The same variables can be defined for **Angular Acceleration**, by replacing the angular velocity selection from the drop-list with the angular acceleration.



angacc(Subject1.Segments.RightFoot.AxisSystems.Anatomical.Axes.Ori).X

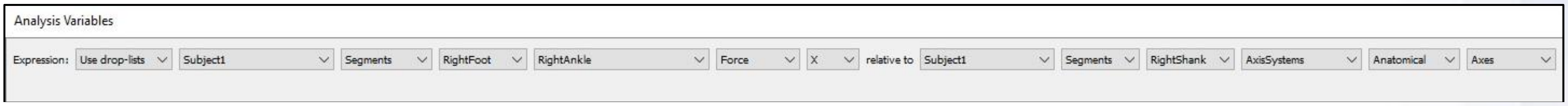
Force and Moment

Defining the **Force** at a joint relative to the World axes can be done as seen below.



Subject1.Segments.RightFoot.RightAnkle.Force.X

To define the **Force at joint in the reference frame of another segment's axes** see the expression below. As we are analyzing a *non-position or directional/offset type value*, the reldir() operator is used.

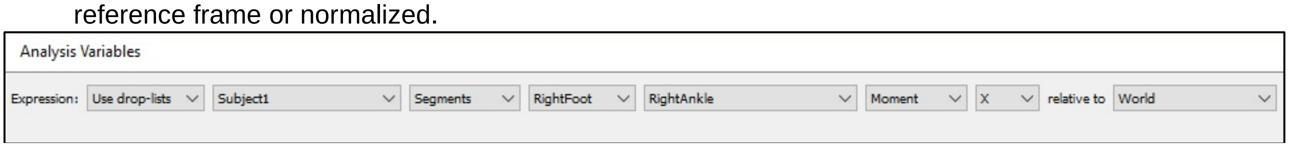


reldir(Subject1.Segments.RightFoot.RightAnkle.Force, Subject1.Segments.RightShank.AxisSystems.Anatomical.Axes).X

Force reported in the Shank segment's reference frame and normalized to body mass. The force vector could be directly divided by the mass of the subject, as seen below, or the entire expression could be placed in parentheses and divided by the mass of the subject.

reldir(Subject1.Segments.RightFoot.RightAnkle.Force/Subject1.Mass, Subject1.Segments.RightShank.AxisSystems.Anatomical.Axes).X

Similarly, the **Moment** data at a joint could be defined relative to the World axes, another segment's reference frame or normalized.



Subject1.Segments.RightFoot.RightAnkle.Moment.X

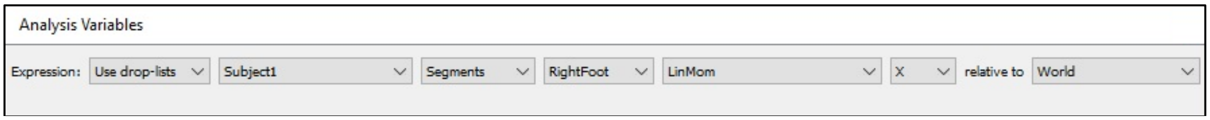
Power

The **Power** for a joint can be selected as seen below.

Subject1.Segments.RightFoot.RightAnkle.Power.Longitudinal

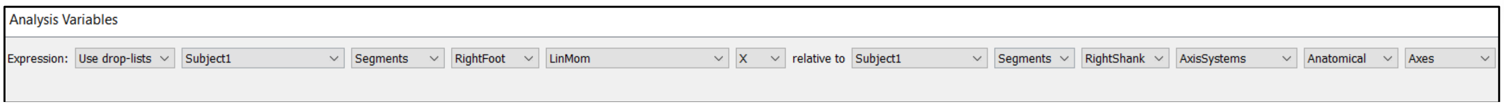
Linear Momentum

The **Linear Momentum in the world reference frame** can be selected as seen below.



Subject1.Segments.RightFoot.LinMom.X

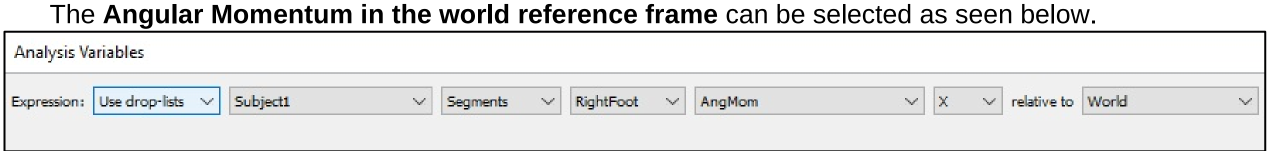
Defining the **Linear Momentum of the foot relative to another segment's reference frame** is shown below. As we are analyzing a *non-position or directional/offset type value*, the reldir() operator is used.



reldir(Subject1.Segments.RightFoot.LinMom, Subject1.Segments.RightShank.AxisSystems.Anatomical.Axes).X

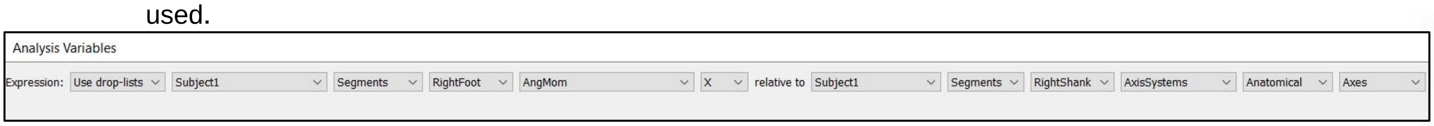
Angular Momentum

The **Angular Momentum in the world reference frame** can be selected as seen below.



Subject1.Segments.RightFoot.AngMom.X

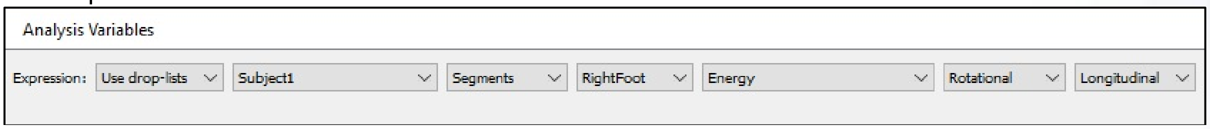
Defining the **Angular Momentum of the foot relative to another segment's axes** can be seen below. As we are analyzing a *non-position or directional/offset type value*, the reldir() operator is used.



reldir(Subject1.Segments.RightFoot.AngMom, Subject1.Segments.RightShank.AxisSystems.Anatomical.Axes).X

Energetics

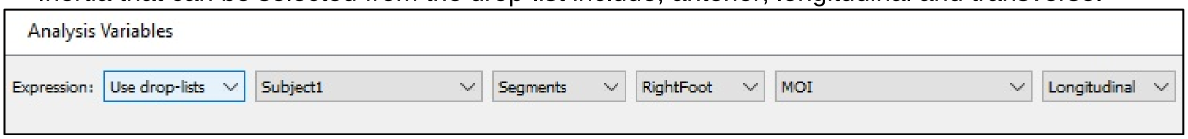
Segment **Energy** can be selected as seen below. Potential, Total and the components of Rotational and Translational energetics (anterior, longitudinal, transverse and total) may be selected from the drop-lists.



Subject1.Segments.RightFoot.Energy.Rotational.Longitudinal

Moment of Inertia

Moment of Inertia for a segment can be selected as seen below. Components for the Moment of Inertia that can be selected from the drop-list include, anterior, longitudinal and transverse.



Subject1.Segments.RightFoot.MOI.Longitudinal