<u>The MotionMonitor xGen Software Guide:</u> 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.

Analysis Va	ariables																	
Expression:	Use drop-lists $ \smallsetminus $	Subject1	\sim	Segments	\sim	RightFoot	\sim	RightAnkle	~	Pos	\sim	X	\sim	no derivative	\sim	relative to	World	\sim

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.

Analysis Variables														
Expression: Use drop-lists	Subject1 ~	Segments V	RightFoot ~	RightAnkle ~	Pos	× X ×	no derivative $\ \ \lor$ relative t	Subject1 ~	Segments ~	RightShank ~	AxisSystems $ \smallsetminus $	Anatomical $ \smallsetminus $	Axes	~

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.

Analys	sis Variak	oles						
Type:	Scalar	~	Name:	X1	Expression:	Use formula	~	disp(Subject1.Segments.RightFoot.RightAnkle.Pos.X, InitialTime)
							2.5	

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.

Analys	is <mark>V</mark> arial	oles						
Type:	Time	~	Name:	RightHeelStrikeTime	Expression:	Use formula	~	tmax(RightHeelStrike,InitialTime,FinalTime,0.01)

tmax(RightHeelStrike,InitialTime,FinalTime,0.01)

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

Analysis Variables			
Type: Scalar 🗸 Name:	X1 Expression:	Use formula $~~ \lor$	attime(disp(Subject1.Segments.RightFoot.RightAnkle.Pos.X, InitialTime),RightHeelStrikeTime)

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

<u>Orientation</u>

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

Analysis V	/ariables									
Expression:	Use drop-lists \lor	Subject1	~	Segments 🗸 🗸	RightFoot	~	Angles	~	Flexion	~
Expression:	Use drop-lists V	Subject1	~	Segments V	RightFoot	~	Angles	~	Flexion	~

Subject1.Segments.RightFoot.Angles.Flexion

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

Analysis Variables Expression: Use drop-lists v Subject1 v Segments v RightFoot v AxisSystems v Anatomical v Axes v Ori v Eul v ZYX v Z v relative to World v

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

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

Subject1	~	Segments	\sim	RightFoot	\sim	AxisSystems	~	Anatomical	×	Axes	~	Ori	~ E	ul 1	/ Z	YX V	z	~ 1	relative to	Subject1	\sim	Segments	~	RightShank	~	AxisSystems	~	Anatomical	~	Axes	\sim
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rel(Subject1.Segments.RightFoot.AxisSystems.Anatomical.Axes, Subject1.Segments.RightShank.AxisSystems.Anatomical.Axes).Ori.EuI.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**.

,							_	~~														
Expression:	Use drop-lists 🗸 🗸	Subject1	\sim	Segments	\sim	RightFoot	\sim	AxisSystems	\sim	Anatomical	\sim	Axes	\sim	Ori	\sim	Mat	\sim	M11	v r	relative to	World	~

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**.

Analysis Variables																					
Expression: Use drop-lists 🗸	Subject1	\sim	Segments	\sim	RightFoot	~	AxisSystems	~	Anatomical	~	Axes	\sim	Ori	\sim	Quat	~	Q0	∨ r	relative to	World	\sim

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.

Analysis Var	riables													
Expression:	Use drop-lists \vee	Subject1 ~	Segments	~	RightFoot	~	AxisSystems	~	AxisSystem1 ∨	GSAngleSets	~	GSAngleSet1 $$	Flexion	~

Linear Velocity and Acceleration

Analysis Variables

nalysis Variables

on: Use drop-lists 🗸 Subject1

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.

Expression:	Use drop-lists \smallsetminus	Subject1 \vee	Segments \sim	RightFoot \sim	RightAnkle \vee	Pos \checkmark	x ~	1st derivative $~ \lor$	relative to	World	~

(A) = (A) + (A)	diff(Subie	ect1.Seaments	RightFoot.	RightAnkle.	Pos.X)
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For the **Velocity of a point reported relative to another segment**, simply select the 1st derivative for the position variable.

		diff(re	ldir(Subje	ect1.Segr	nents.	RightFoot.F	RightAnk	le.Pos,					
		Subject ¹ .S	Segments.	RightSha	nk.Ax	isŠystems./	Anatomi	cal.Axe	s).X)				
		,	0	0					, ,				
	Similarly	Linear A	coloratio	n can be	o dofin	od by soloc	ting the	2nd dori	vativo	for the p	ocition v	variable	<u> </u>
	Similariy	, Lineal A	cceleratic		uenn	eu by selec	ung une	z uen	valive		Janon	variable	<u>,</u>
Analysis V	ariables												
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Angular Velocity and Acceleration

✓ Segments ✓ RightFoot ✓ AxisSystems

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.

Analysis Variables			
Expression: Use drop-lists v Subject1 v Se	Segments V RightFoot V AxisSystems V	Anatomical V Axes V Ori V X V angular velocity V relative to World	~

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

V Anatomical V Axes V Ori V X V angular velocity V relative to Subject1 V Segments V RightShank V AxisSystems V Anatomical V Axes

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

Anal	ables
Expre	se drop-lists v Subject 1 v Segments v RightFoot v AxisSystems v Anatomical v Axes v Ori v X v angular acceleration v relative to World v

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

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	Force and Moment Defining the Force at a joint relative to the World axes can be done as seen below.
	Expression: Use drop-lists v Subject1 v Segments v RightFoot v RightAnkle v Force v X v relative to World v
	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 <i>non-position or directional/offset type value</i> , the reldir() operator is used.
Analysis Variables	
Expression: Use drop-list	s v Subject V Segments v RightFoot v RightAnkle v Force v X v relative to Subject V Segments v RightShank v AxisSystems v Anatomical v Axes v
	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.
Analysis Varia	bles
Type: Scalar	V Name: X1 Expression: Use formula V reldir(Subject1.Segments.RightFoot.RightAnkle.Force/Subject1.Mass, Subject1.Segments.RightShank.AxisSystems.Anatomical.Axes).X
	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.

Analysis	Variables															
Expression:	Use drop-lists $$	Subject1	\sim	Segments	\sim	RightFoot	\sim	RightAnkle	\sim	Moment	\sim	x	\sim	relative to	World	\sim

Subject1.Segments.RightFoot.RightAnkle.Moment.X

Expression: Use drop-lists Subject1. Segments RightFoot RightAnkle Power Longitudinal Subject1. Segments RightFoot. RightAnkle. Power Longitudinal Linear Momentum In the world reference frame can be selected as seen below. Analysis Variables Expression: Use drop-lists Subject1. Segments RightFoot LinMom X relative to World Subject1. Segments RightFoot LinMom X relative to World Vord Vord <th>100000 A.00000</th> <th>'ariables</th> <th></th>	100000 A.00000	'ariables										
Subject1.Segments.RightFoot.RightAnkle.Power.Longitudinal Linear Momentum The Linear Momentum in the world reference frame can be selected as seen below. Analysis Variables Expression: Use drop-lists is subject1 Subject1.Segments.RightFoot LinMom 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.	Expression:	Use drop-lists	∨ Subject1	~	Segments	~	RightFoot	∨ RightA	nkle	V Power	V	gitudinal V
The Linear Momentum in the world reference frame can be selected as seen below. Analysis Variables Expression: Use drop-lists Subject1. Segments RightFoot LinMom Subject1. Segments. Segments Segments. Segments Segments. Segments Segments. Seg	Linear	Momentu	Subject	1.Segmer	nts.Right	tFoo	t.Right	Ankle.Po	ower.Long	itudinal		
Expression: Use drop-lists Subject1 Segments RightFoot LinMom X relative to World 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.	The Lin Analysis Va	ear Mom ariables	entum in t	the world	referen	ce f	rame c	an be s	elected as	seen belo	Ν.	
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.	Expression:	Use drop-lists $$	Subject1	✓ Seg	gments \vee	RightF	Foot V	LinMom	~	X V relative	to World	~
Defining the Linear Momentum of the foot relative to another segment's reference frame is shown below. As we are analyzing a <i>non-position or directional/offset type value</i> , the reldir() operator is used.				Subjec	t1.Segm	nents	s.Righti	=oot.Lin	Mom.X			
	Defining shown b is used.	the Line below. As	ear Momen s we are ar	n tum of th nalyzing a	e foot r non-pos	elati sitior	ive to a	nother ectional/	segment offset type	s reference value, the	e frame reldir() o	is perator
	Eukiaett		amonto y BightEo	at y linMam		vv	v rolativo	cubicct1	Comment	BightChank y	AvicEustome	Anatomical
			Cubicati	reldir(Sub	bject1.Se	egm hank	ents.Ri	ghtFoot	LinMom, Anatomica	Avos) X		

Analysis Variables								
Expression: Use drop-lists V	Subject1 V	Segments V F	RightFoot 🗸	AngMom 🗸	x ~	relative to	World	~

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.

Analysis valiables																				
Expression: Use drop-lists	 ✓ Subject1 	~	Segments	~	RightFoot	AngMom	~	x	~	relative to	Subject1	~	Segments \lor	RightShank \lor	AxisSystems	\sim	Anatomical	~	Axes	~

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.

Analysis Variables												
Expression: Use drop-lists \lor	Subject1	\sim	Segments	\sim	RightFoot	\sim	Energy	\sim	Rotational	\sim	Longitudinal	\sim

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.

Analysis Variables					
Expression: Use drop-lists 🗸	Subject1 V	Segments \lor	RightFoot 🗸 🗸	MOI 🗸	Longitudinal $$

Subject1.Segments.RightFoot.MOI.Longitudinal