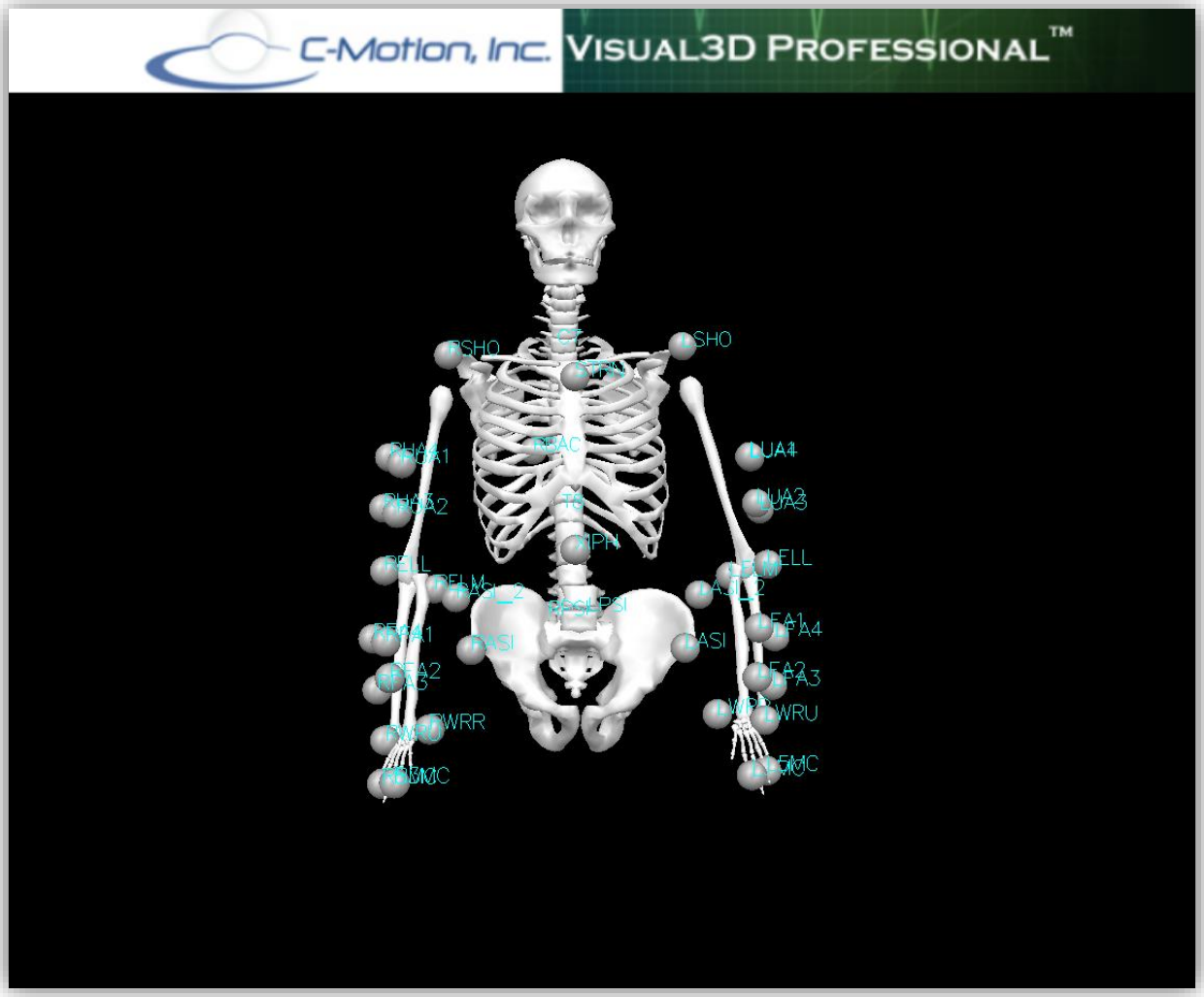
Custom upper extremity model in Visual 3D

Based on International Society of Biomechanics Recommendations [1]



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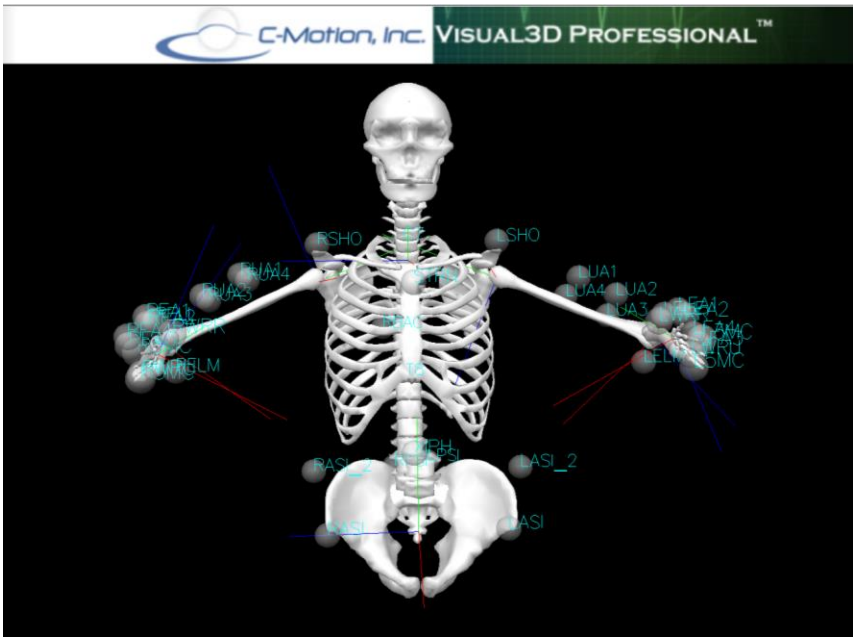
List of Markers

Marker Name	Segment / Joint	Location	Tracking only
STRN	Trunk	Suprasternal notch	
XIPH	Trunk	Xiphoid process	
C7	Trunk	7th cervical vertebra	
T8	Trunk	8th thoracic vertebra	
RASI	Pelvis	Right anterior superior iliac crest	
RPSI	Pelvis	Right posterior superior iliac crest	
RPSI_2	Pelvis	Right iliac crest	X
LASI	Pelvis	Left anterior superior iliac crest	
LPSI	Pelvis	Left posterior superior iliac crest	
LASI_2	Pelvis	Left iliac crest	X
RSHO	Right Humerus	Right acromion process	
RUP1	Right Humerus	Upper arm cluster	X
RUP2	Right Humerus	Upper arm cluster	X
RUP3	Right Humerus	Upper arm cluster	X
RUP4	Right Humerus	Upper arm cluster	X
RELL	Right Elbow joint	Lateral epicondyle	
RELM	Right Elbow joint	Medial epicondyle	
RFR1	Right Forearm	Forearm cluster	X
RFR2	Right Forearm	Forearm cluster	X
RFR3	Right Forearm	Forearm cluster	X
RFR4	Right Forearm	Forearm cluster	X
RWRR	Right Wrist	Most caudal-lateral point on radial styloid	
RWRU	Right Wrist	Most caudal-medial point on ulnar styloid	
R3MC	Right Hand	3rd metacarpal head	
R5MC	Right Hand	5th metacarpal head	
LSHO	Left Humerus	Left acromion process	
LUP1	Left Humerus	Upper arm cluster	X
LUP2	Left Humerus	Upper arm cluster	X
LUP3	Left Humerus	Upper arm cluster	X
LUP4	Left Humerus	Upper arm cluster	X
LELL	Left Elbow joint	Lateral epicondyle	
LELM	Left Elbow joint	Medial epicondyle	
LFR1	Left Forearm	Forearm cluster	X
LFR2	Left Forearm	Forearm cluster	X
LFR3	Left Forearm	Forearm cluster	X
LFR4	Left Forearm	Forearm cluster	X
LWRR	Left Wrist	Most caudal-lateral point on radial styloid	
LWRU	Left Wrist	Most caudal-medial point on ulnar styloid	
L3MC	Left Hand	3rd metacarpal head	
L5MC	Left Hand	5th metacarpal head	

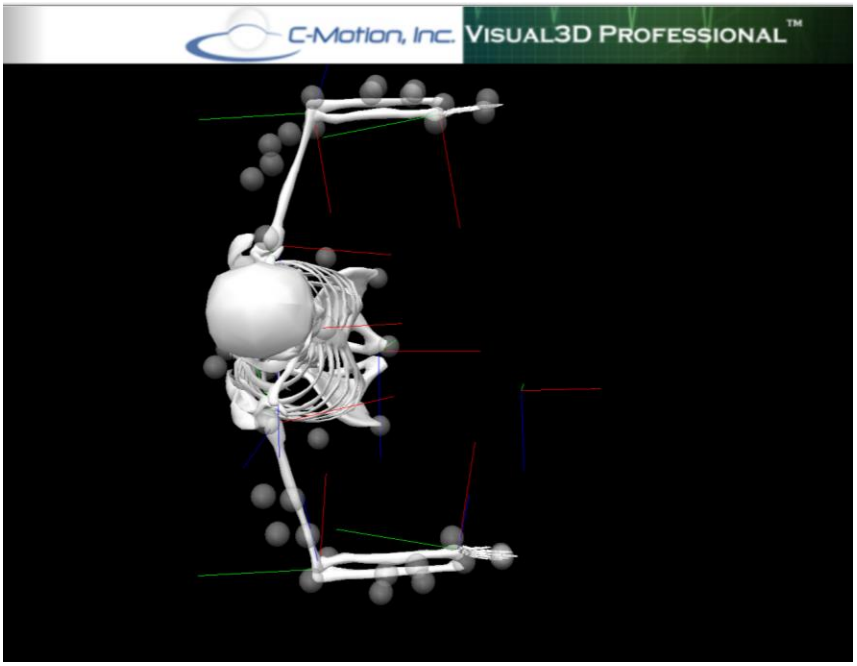
Static Posture

For the static posture, the arms are abducted, the elbows are flexed to 90 degrees and the hands are in a neural position. The coordinate system for this model is Y up, X forward, Z right.

FRONT VIEW:



TOP DOWN VIEW:



Joint Center: Shoulder

The shoulder joint center is defined according to [2]. To determine the joint center location, the circumference of the shoulder, around the acromion and axilla was measured for each subject. From this approximated circular measurement, the radius of the shoulder was calculated:

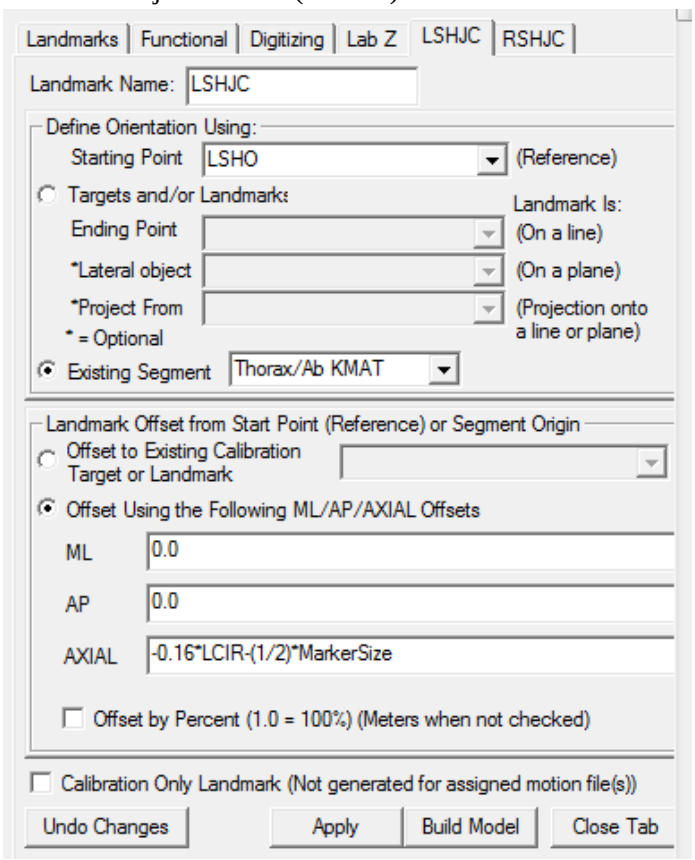
$$r = \frac{CIR}{2\pi} = 0.16 \cdot CIR$$

The joint center, SHJC, was then located inferiorly from the acromion marker, SHO, in the local coordinate system of the trunk, at the measured distance, r:

$$SHJC = SHO - r\ \hat{y}$$

The circumference of each arm was entered as a subject metric. RCIR = right circumference in meters, LCIR = left circumference in meters. Here, we also subtract half the height of the marker.

Left shoulder joint center (LSHJC)

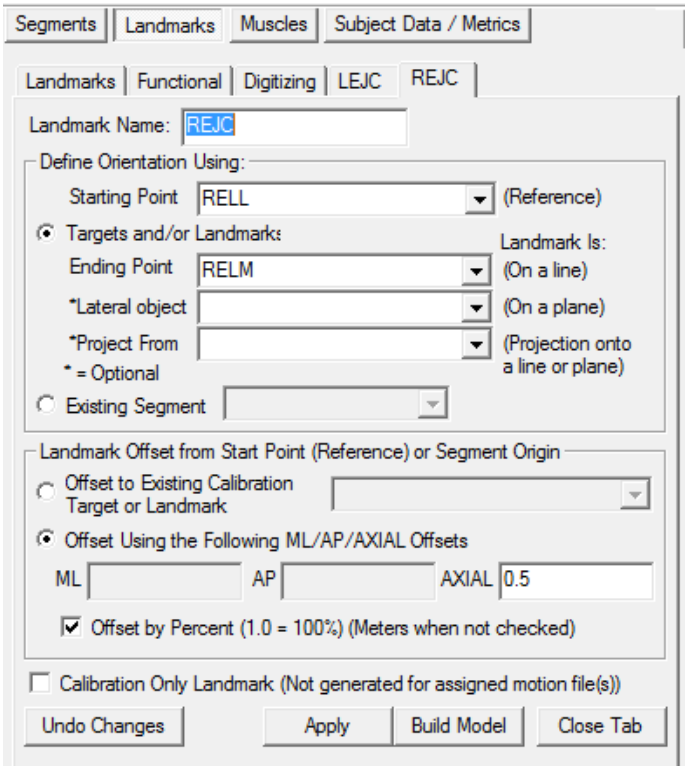


Joint Center: Elbow

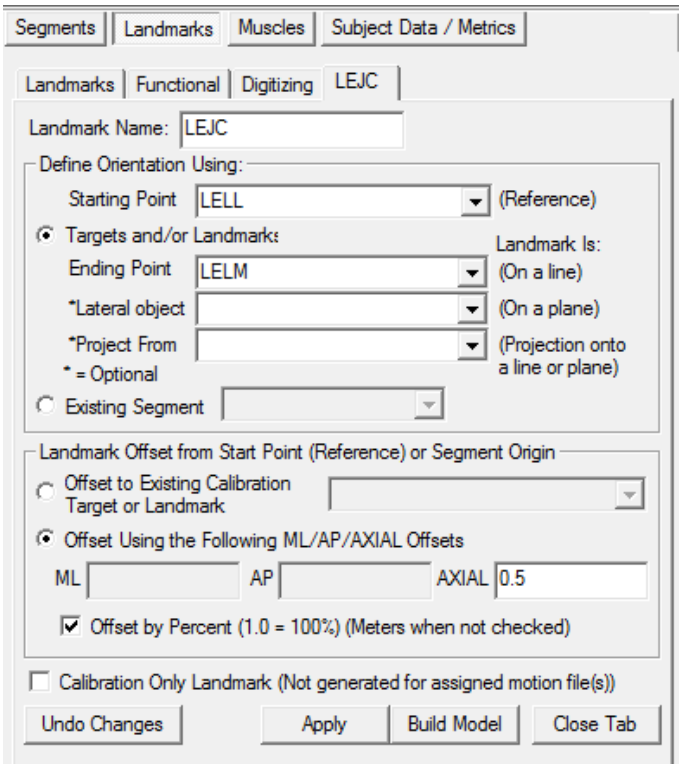
The elbow joint center was defined as the mid-point between the medial and lateral epicondyles during the static trial.

Visual3D Implementation:

Right Elbow Joint Center (REJC)



Left Elbow Joint Center (LEJC)

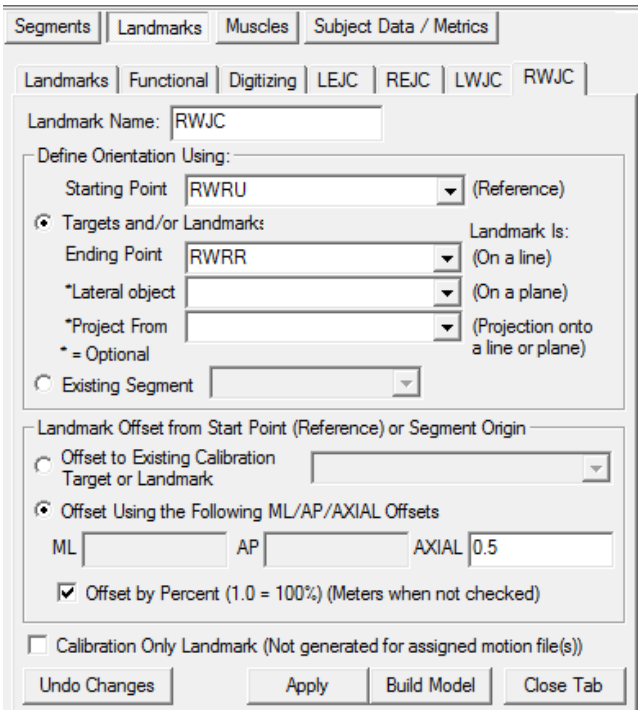


Joint Center: Wrist

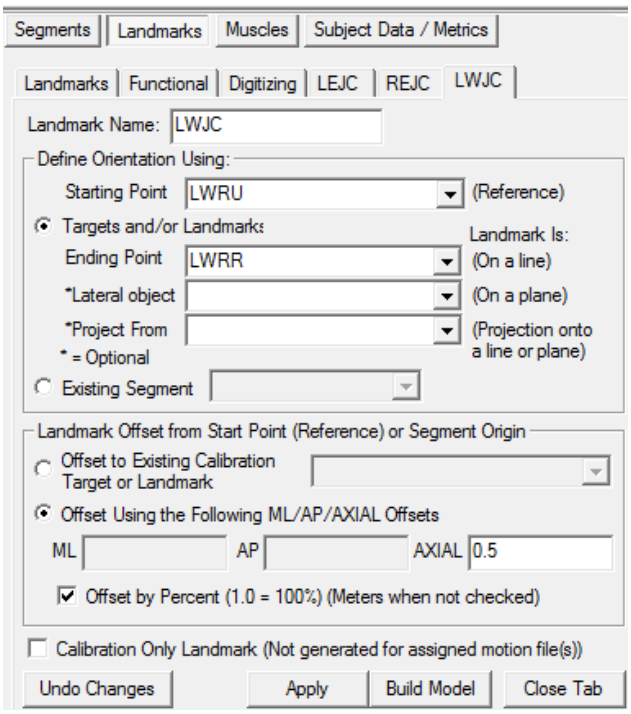
The wrist joint center was the mid-point between the ulnar and radial styloids.

Visual3D Implementation:

Right wrist joint center (RWJC)



Left wrist joint center (LWJC)



Joint Center: Hand (3MC)

The hand joint center was calculated according to Rao et al [3]. First, we define a unit vector from the ulnar styloid (RWRU) to the radial styloid (RWRR).

$$\overrightarrow{J_h} = \frac{\overrightarrow{RWRR} - \overrightarrow{RWRU}}{\overrightarrow{RWRR} - \overrightarrow{RWRU}}$$

i_h is perpendicular to the plane containing RWRU, RWRR, and the fifth metacarpal head (R5MC)

$$\overrightarrow{k_{temp}} = \frac{\overrightarrow{RWRR} - \overrightarrow{R5MC}}{\overrightarrow{RWRR} - \overrightarrow{R5MC}}$$

$$\overrightarrow{i_h} = \overrightarrow{J_h} \times \overrightarrow{k_{temp}}$$

$$\overrightarrow{k_h} = \overrightarrow{i_h} \times \overrightarrow{J_h}$$

Now we define a new plane with the third metacarpal

$$\overrightarrow{k_{temp}} = \frac{\overrightarrow{RWRR} - \overrightarrow{R3MC}}{\overrightarrow{RWRR} - \overrightarrow{R3MC}}$$

$$\overrightarrow{i_{h2}} = \overrightarrow{J_h} \times \overrightarrow{k_{temp}}$$

$$\overrightarrow{k_{h2}} = \overrightarrow{i_{h2}} \times \overrightarrow{J_h}$$

Then we rotate the second plane aobut j_h until it lies in the first plane

$$\theta = \overrightarrow{i_{h2}} \cdot \overrightarrow{J_h}$$

$$R3JC = \begin{bmatrix} \cos(\theta) & 0 & -\sin(\theta) \\ 0 & 1 & 0 \\ \sin(\theta) & 0 & \cos(\theta) \end{bmatrix} \cdot R3MC$$

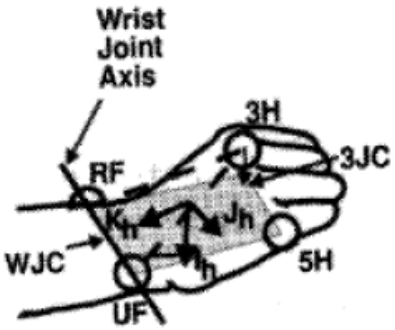
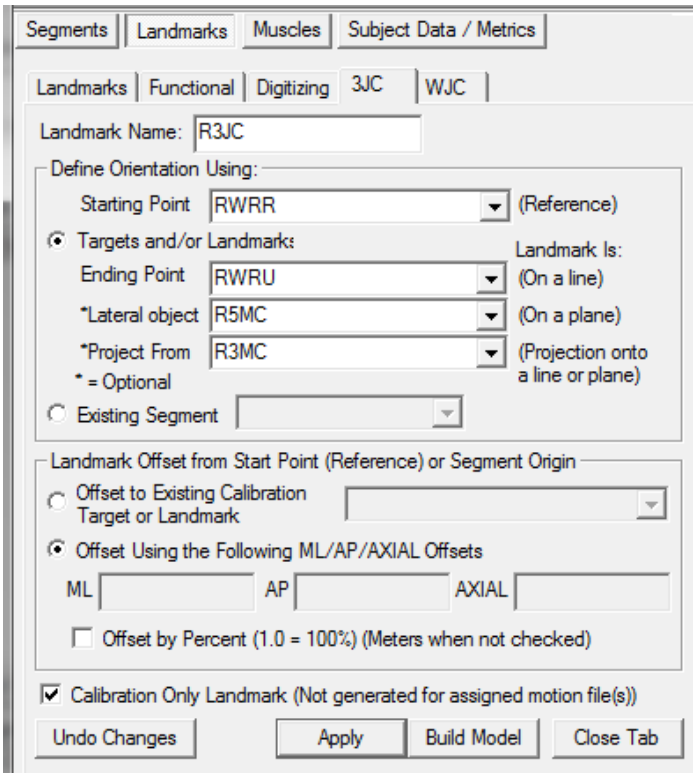


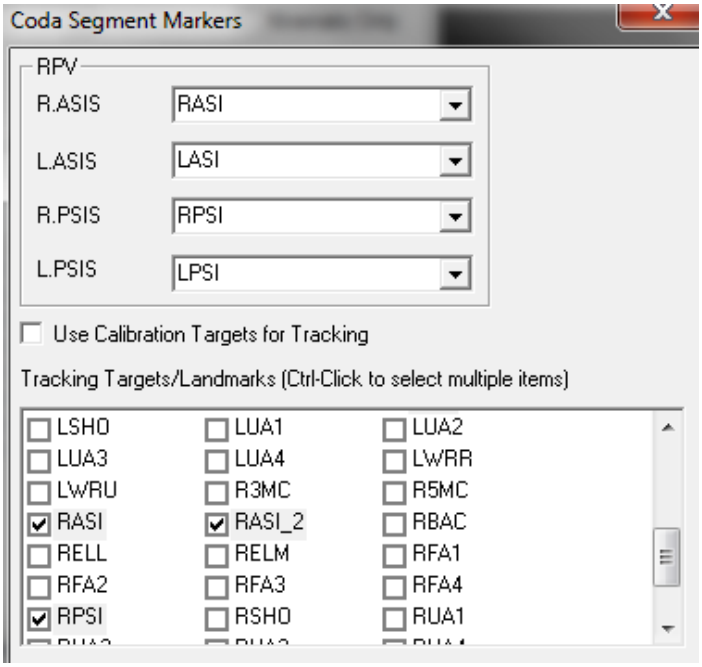
Illustration of the local coordinate system of the hand from Rao {Rao 1996}

Visual3D Implementation



Local Coordinate Systems: Pelvis

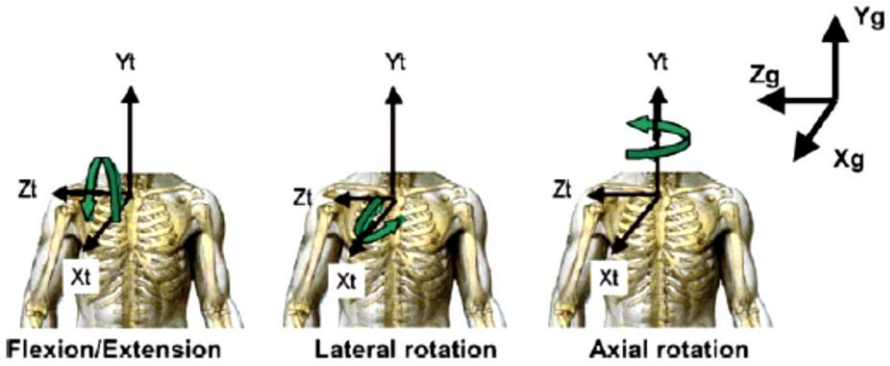
Here we use a standard CODA pelvis with the iliac crest markers (RASI_2, LPSI_2) for additional tracking.



Local Coordinate System: Trunk

ISB Recommendation

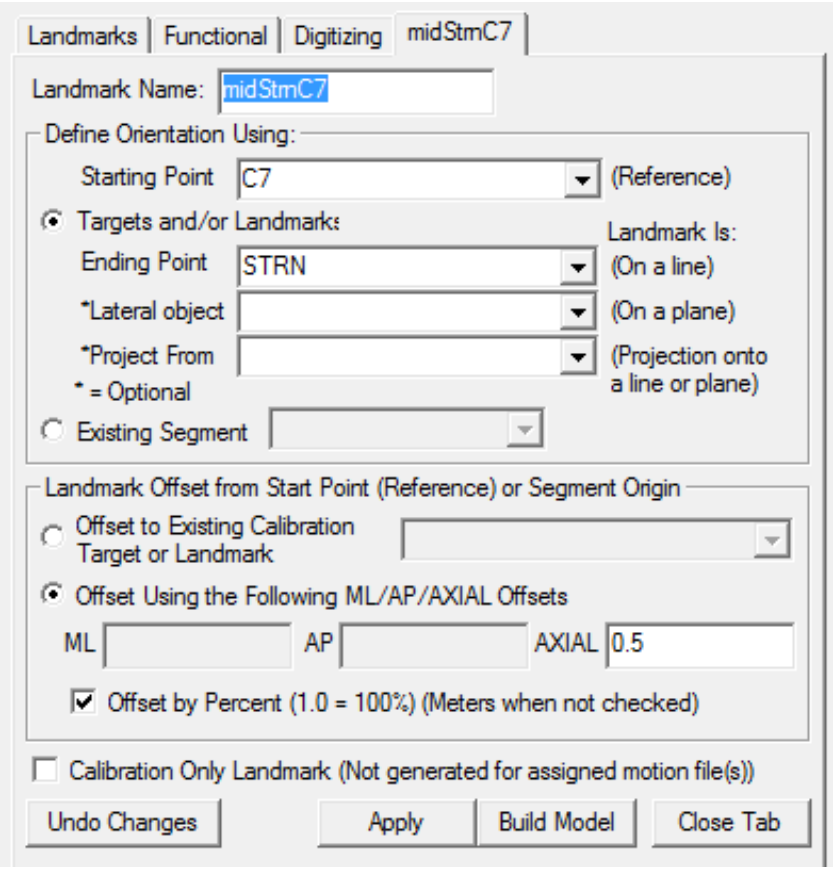
O_t: The origin coincident with the sternum (STRN)
Y_t : The line connecting the midpoint between XIPH and T8 and the midpoint between STRN and C7, pointing upward
Z_t: The line perpendicular to the plane formed by STRN, C7, and the midpoint between XIPH and T8, pointing to the right
X_t: The common line perpendicular to the Z_t and Y_t axis, pointing forward



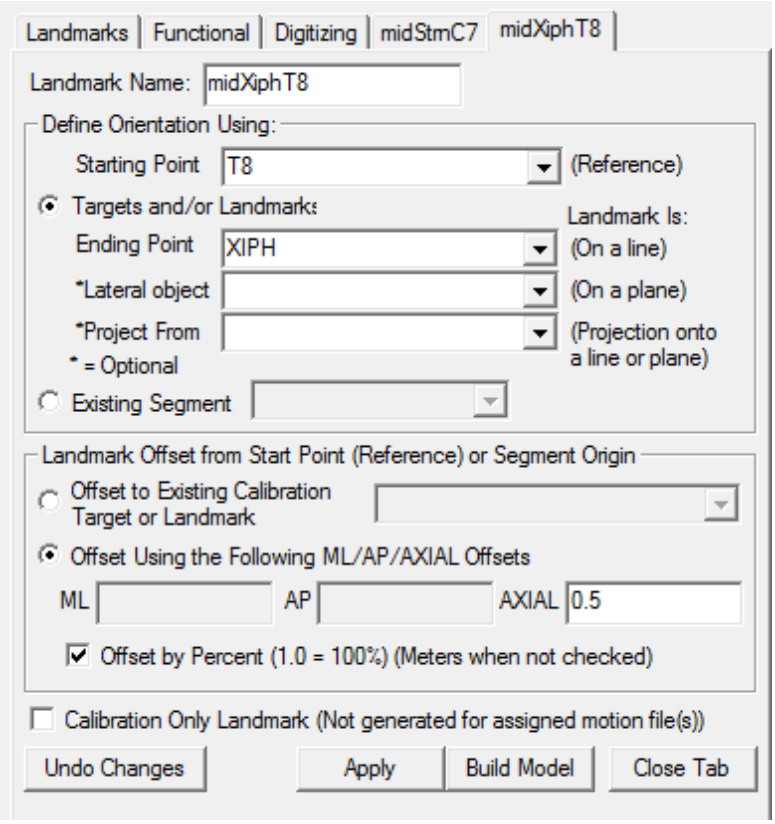
Visual3D Implementation

To define the segmental axes, we first calculate 2 landmarks.

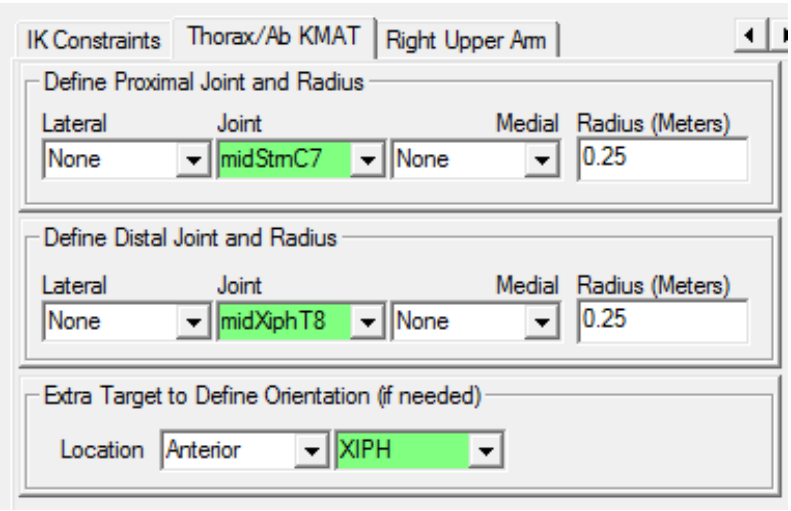
1) midStrnC7: The mid-point between the STRN and C7 markers:



2) midXiphT8: The midpoint between the xiphoid and T8 markers



These landmarks are then used to create the local coordinate system:



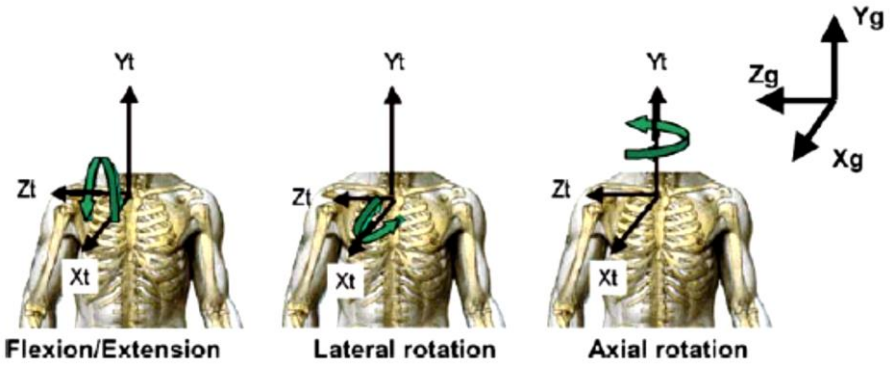
The motion of the local coordinate systems is tracked using the following markers:

1. STRN
2. XIPH
3. C7
4. T8

Local Coordinate System: Right Humerus

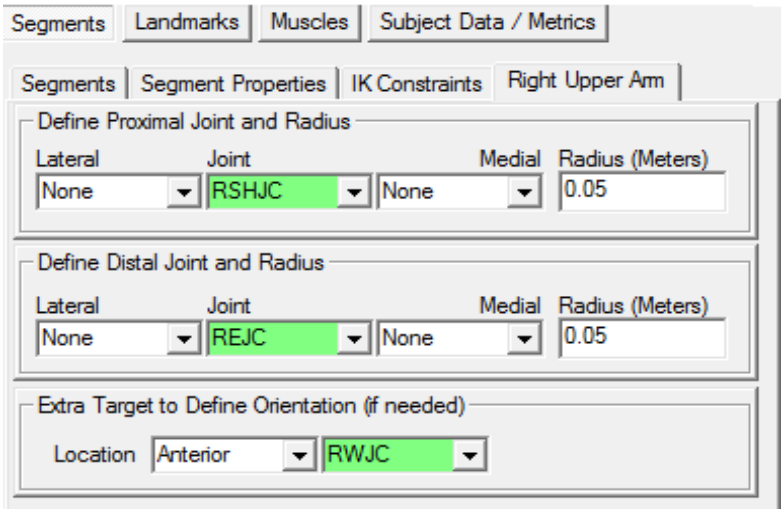
ISB Recommendation

The coordinate system of the humerus was defined using the 2nd option of ISB recommendations
Y_h: The line connecting the shoulder joint center (SHJC) and the elbow joint (EJC) center pointing toward SHJC
Z_h: The common line perpendicular to the plane formed by Y_h and Y_f, pointing to the right.
X_h: The common line perpendicular to the Z_h and Y_h-axis, pointing forward



Visual3D Implementation

The RSHJC, REJC, RWJC landmarks are used to create the local coordinate system:



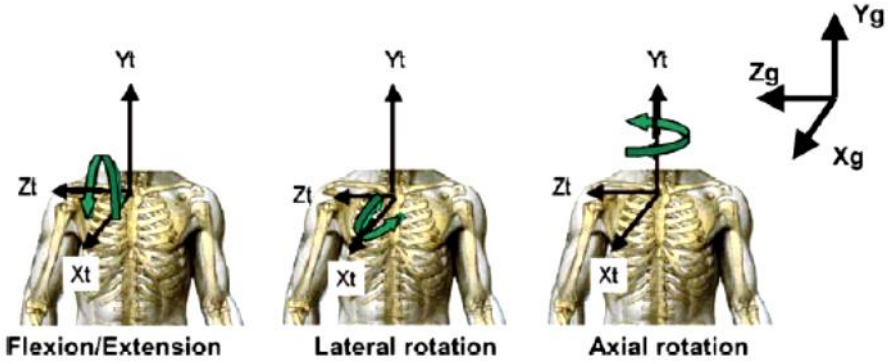
The motion of the local coordinate systems is tracked using the following markers:

1. RUP1
2. RUP2
3. RUP3
4. RUP4

Local Coordinate System: Left Humerus

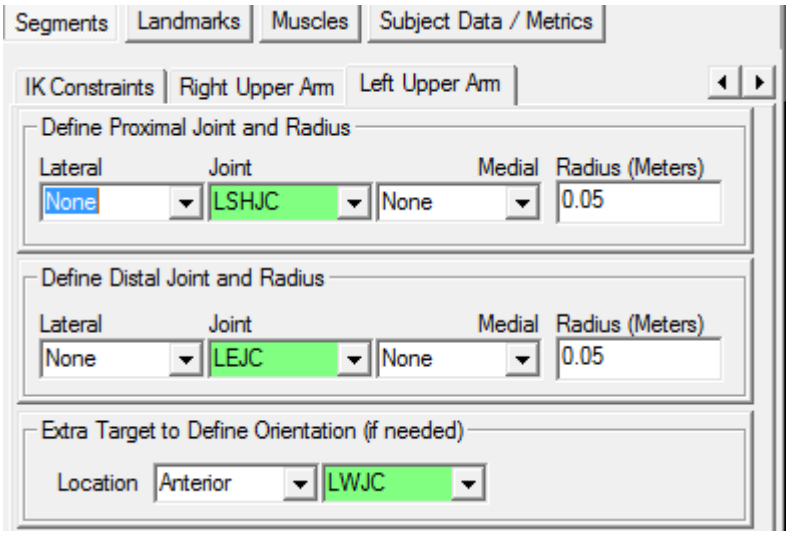
ISB Recommendation

The coordinate system of the humerus was defined using the 2nd option of ISB recommendations
Y_h: The line connecting the shoulder joint center (SHJC) and the elbow joint (EJC) center pointing toward SHJC
Z_h: The common line perpendicular to the plane formed by Y_h and Y_f, pointing to the right.
X_h: The common line perpendicular to the Z_h and Y_h-axis, pointing forward



Visual3D Implementation

The LSHJC, LEJC, LWJC landmarks are used to create the local coordinate system:

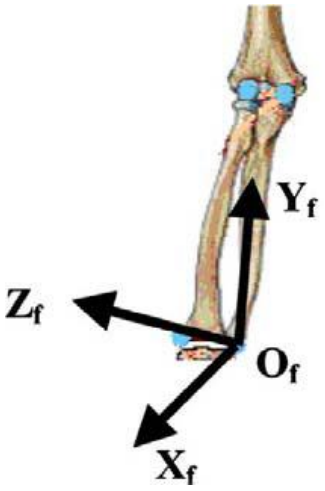


The motion of the local coordinate systems is tracked using the following markers:

1. LUP1
2. LUP2
3. LUP3
4. LUP4

Local Coordinate System: Forearm

ISB Recommendation



O_f: The origin is at the ulnar styloid

Y_f: The line connecting the ulnar styloid to the joint center of the elbow pointing proximally

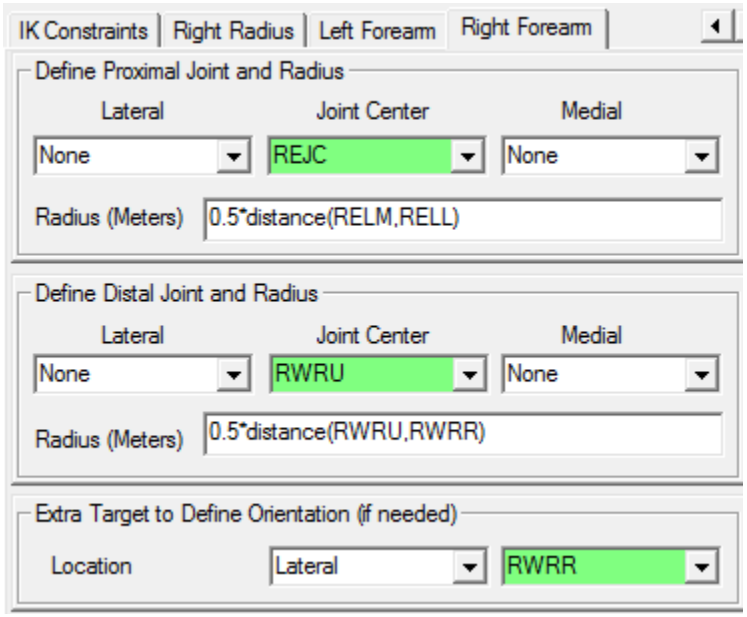
X_f: The line perpendicular to the plane through the ulnar styloid, radial styloid and midpoint between lateral and medial epicondyles, pointing forward

Z_f: The common line perpendicular to the X_f and Y_f axis, pointing to the right

Visual3D Implementation

Right Forearm

The REJC landmark and the two wrist markers (RWRU, RWRR) are used to create the local coordinate system:



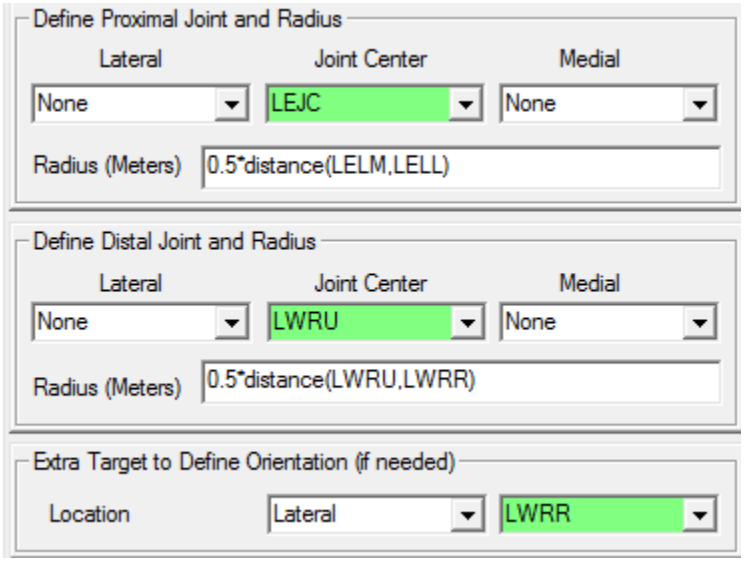
The motion of the local coordinate system is tracked using the following markers:

1. RFR1
2. RFR2
3. RFR3
4. RFR4

Optional

5. RWRR
6. RWRU

Left Forearm



The motion of the local coordinate system is tracked using the following markers:

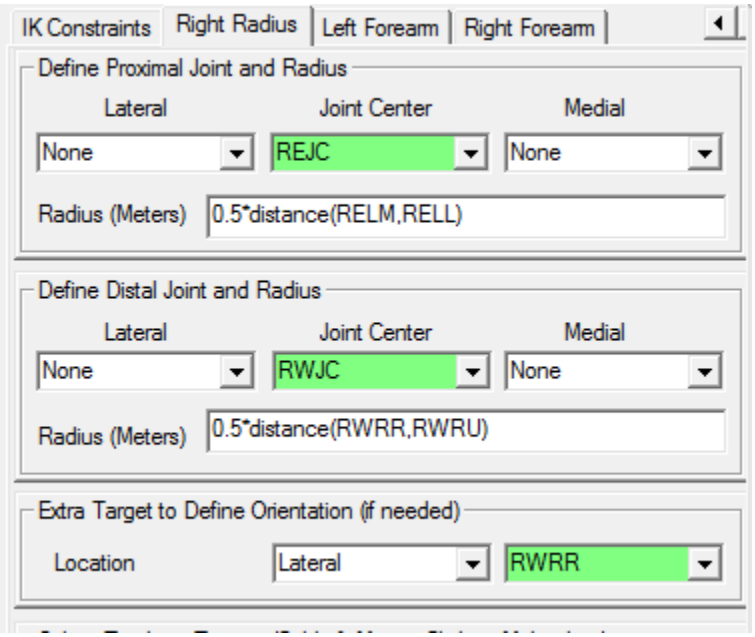
1. LFR1
2. LFR2
3. LFR3
4. LFR4

Optional

5. LWRR
6. LWRU

Local Coordinate System: Radius

The coordinate system of the hand was defined according to ISB recommendations. This segment is equivalent to the forearm, except that the Y-axis runs from the elbow to the wrist joint center, rather than ulnar styloid. This segment is used for determining wrist motion.



Local Coordinate System: Hand

Recommendation

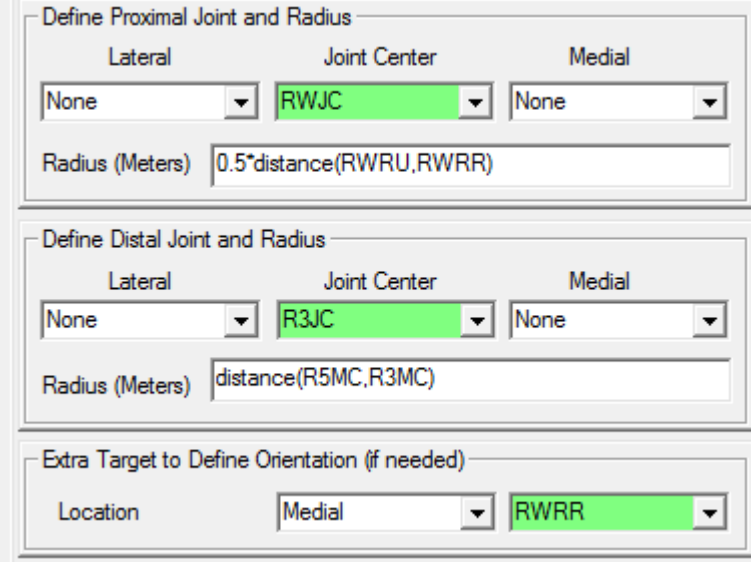
The coordinate system of the hand was defined according to Rao et al. (Rao et al., 1996).

Y_h: The line from the wrist joint center (WJC) to 3JC
X_h: The line perpendicular to the plane formed by Y_h, radial styloid and ulnar styloid
Z_h: The common line perpendicular to the X_h and Y_h axis

Visual3D Implementation

The two wrist markers and the two hand markers are used to create the local coordinate system:

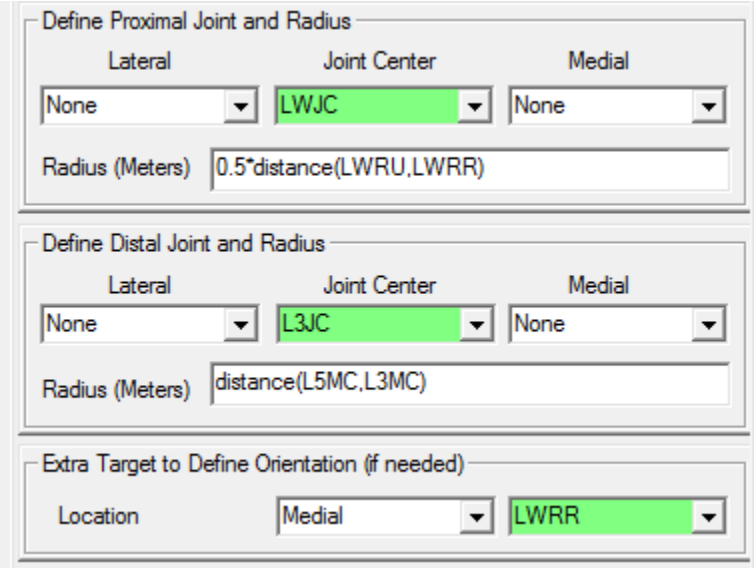
Right Hand:



This segment is tracked using the following markers and landmarks:

1. RWJC
2. R5MC
3. R3MC

Left Hand:



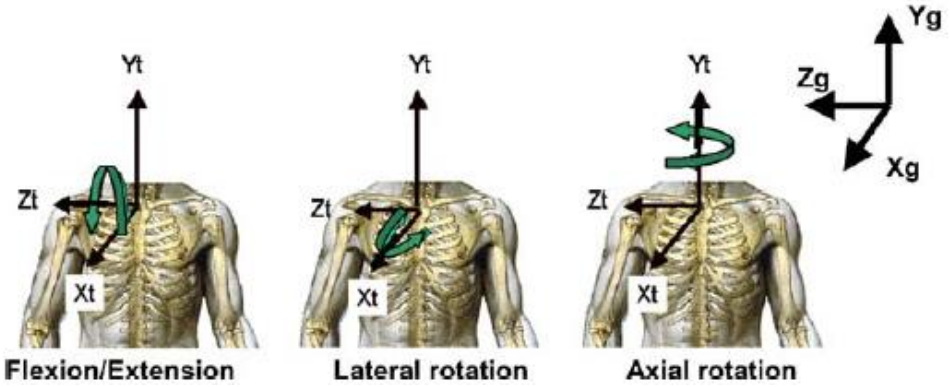
This segment is tracked using the following markers:

1. LWRU
2. LWRR
3. L5MC
4. L3MC

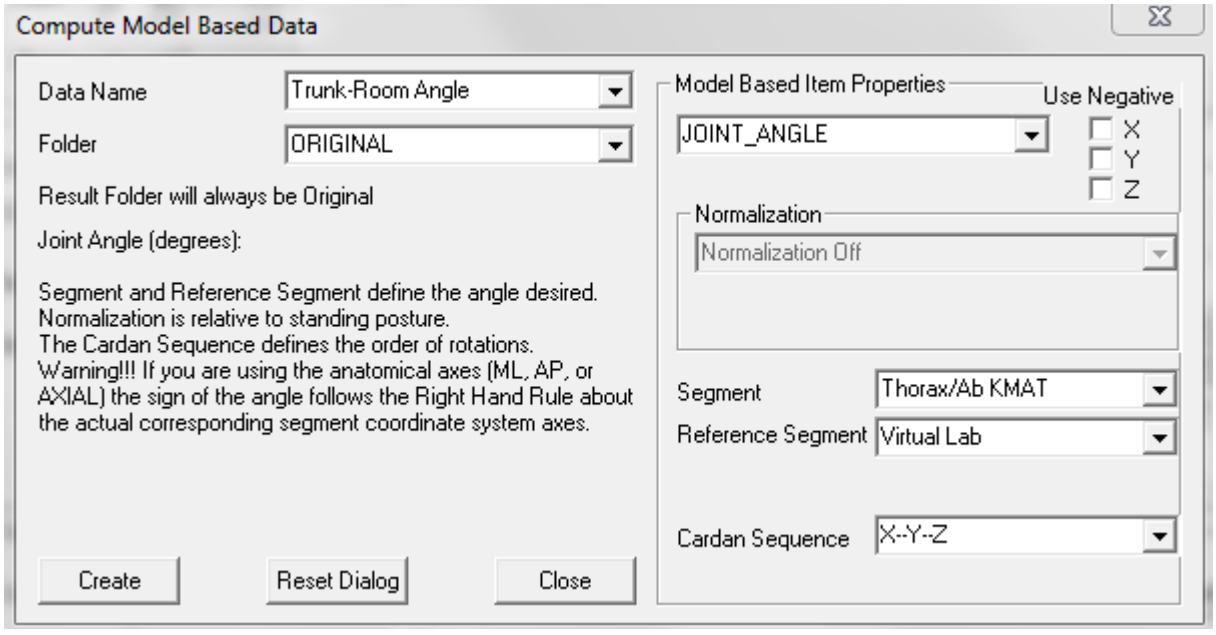
Joint Angles: Trunk Angle (Trunk relative to Global, X-Y-Z)

Motion of the thorax relative to the global coordinate system (X–Y–Z order).

e1: The common axis perpendicular to e1 and e3, i.e., the rotated X_t-axis of the thorax.
Rotation (X-axis): Lateral flexion rotation of the thorax, to the right is positive, to the left is negative.
e2: The axis fixed to the thorax and coincident with the Y_t-axis of the thorax coordinate system.
Rotation (Y-axis): Axial rotation to the left (positive) or to the right (negative).
e3: The axis coincident with the Z_g-axis of the global coordinate system.
Rotation (Z-axis): Flexion (negative) or extension (positive).

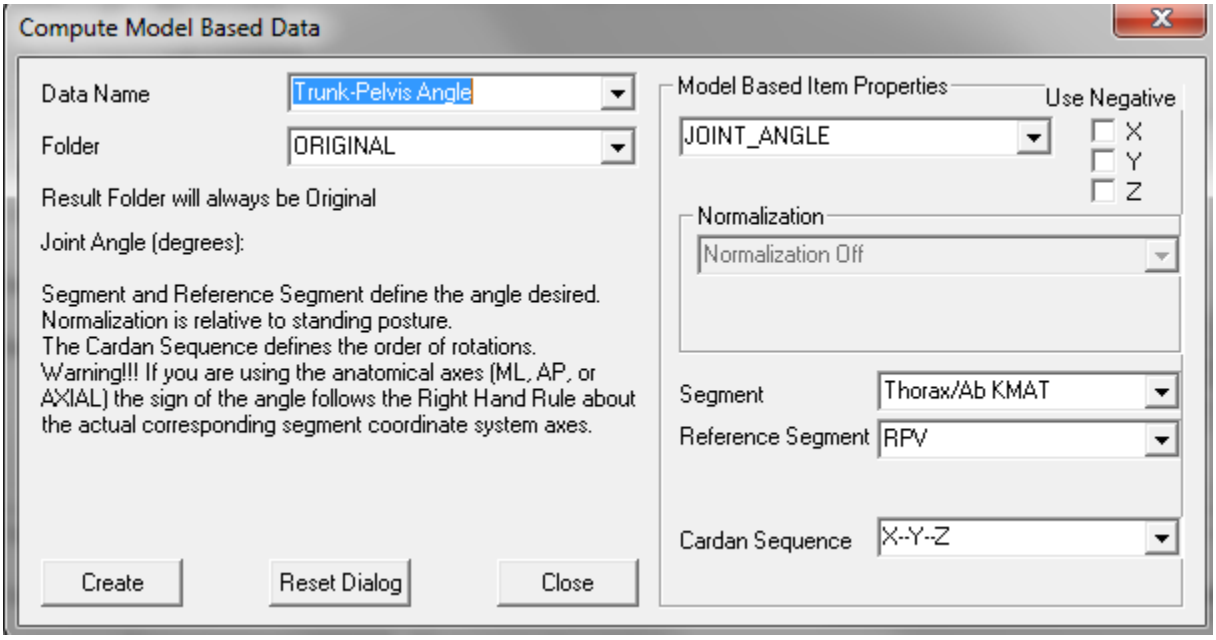


Visual3D Implementation

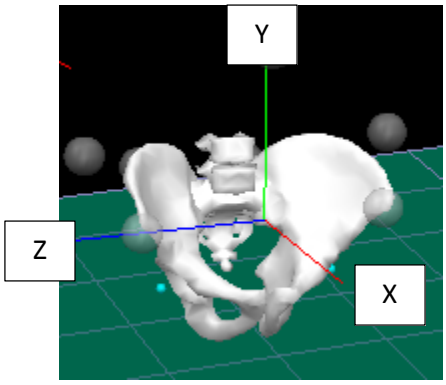


Joint Angles: Trunk-Pelvis Angle (Trunk relative to Pelvis, X-Y-Z)

Motion of the thorax relative to the pelvis coordinate system: ‘lateral flexion (X)’ – ‘axial rotation (Y)’ - ‘flexion/extension (Z)’.



Joint Angles: Pelvic Angle (Pelvis relative to global, Y-X-Z)

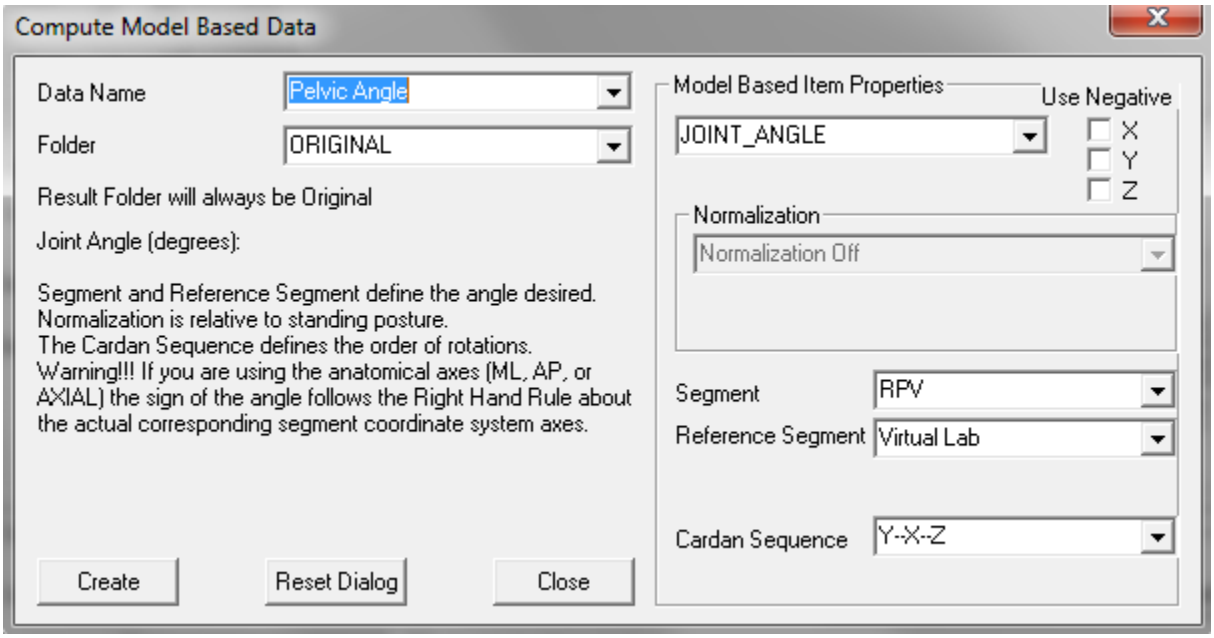


Motion of the pelvis relative to the global coordinate system:

'Pelvic rotation (Y)' – right forward (+) / right back (-)

'Obliquity (X)' – right up (+) / right down (-)

'Pelvic tilt (Z)' – anterior (+) / posterior (-)



Joint Angles: Shoulder Angle (Humerus relative to Trunk, Y'-X-Y'')

ISB Recommendation

e1: The axis fixed to the thorax and coincident with the Y_t-axis of the thorax coordinate system.
Rotation (Y-axis): Plane of elevation, 0° is abduction, 90° is forward flexion.

e2: The axis fixed to the humerus and coincident with the X_h-axis of the humerus coordinate system.
Rotation (X-axis): elevation (negative).

e3: Axial rotation around the Y_h-axis.
Rotation (Y-axis): axial rotation, internal rotation (positive) and external rotation (negative).

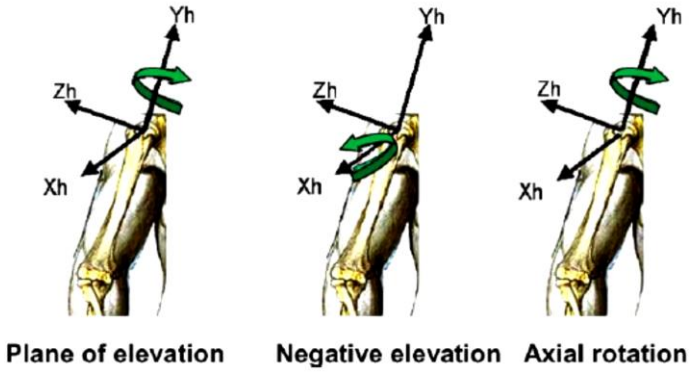
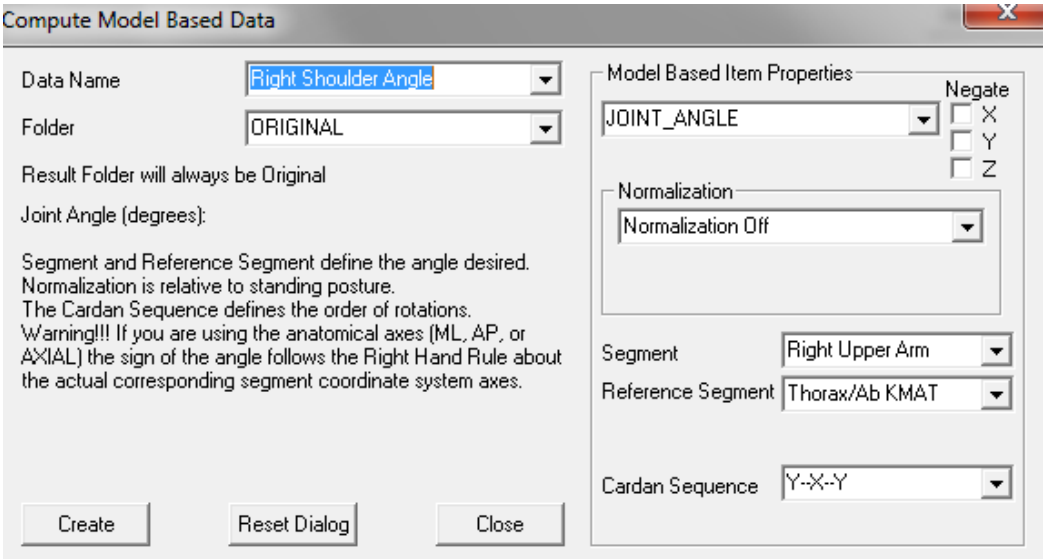


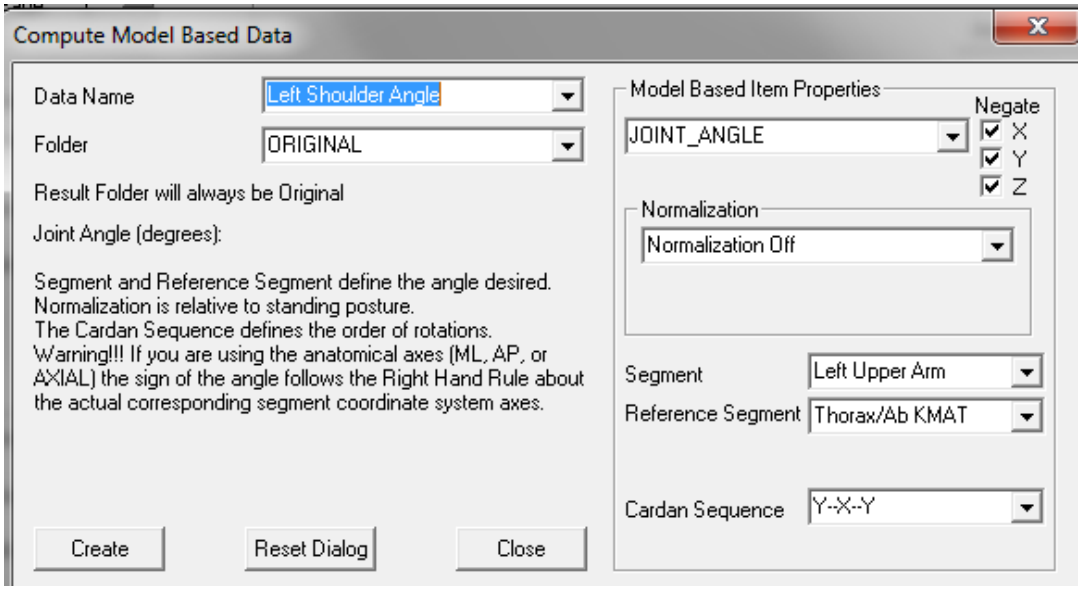
Fig. 7. Definition of thoracohumeral rotations.

Visual3D Implementation

Right Arm



Left Arm


Compute Model Based Data
Data Name
Left Shoulder Angle
Folder
ORIGINAL
Result Folder will always be Original
Joint Angle (degrees):
Segment and Reference Segment define the angle desired.
Normalization is relative to standing posture.
The Cardan Sequence defines the order of rotations.
Warning!!! If you are using the anatomical axes (ML, AP, or AXIAL) the sign of the angle follows the Right Hand Rule about the actual corresponding segment coordinate system axes.
Create
Reset Dialog
Close
Model Based Item Properties
JOINT_ANGLE
Negate
X
Y
Z
Normalization
Normalization Off
Segment
Left Upper Arm
Reference Segment
Thorax/Ab KMAT
Cardan Sequence
Y-X-Y

Joint Angles: Elbow Angle (Forearm relative to Humerus, Z-X-Y)

ISB Recommendation

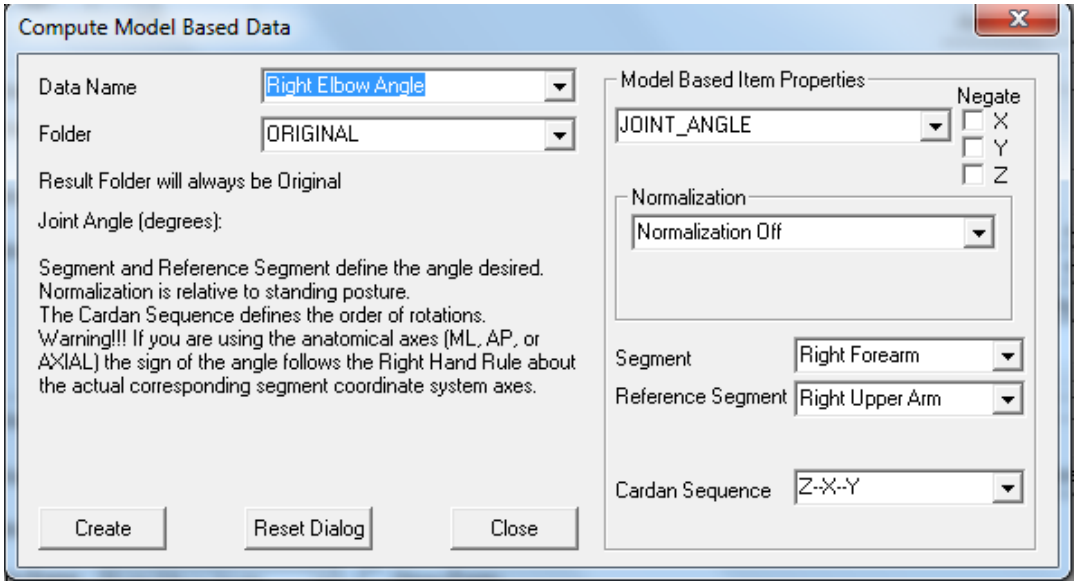
e1: The axis fixed to the proximal segment and coincident with the Zh-axis of the humerus coordinate system (preferably an approximation of the elbow flexion/extension axis).
Rotation (Z-axis): flexion (positive) and hyperextension (negative).

e2: The floating axis, the common axis perpendicular to e1 and e3, the rotated Xf -axis of the forearm coordinate system.
Rotation (Y-axis): carrying angle, the angle between the longitudinal axis of the forearm and the plane perpendicular to the flexion/extension axis.

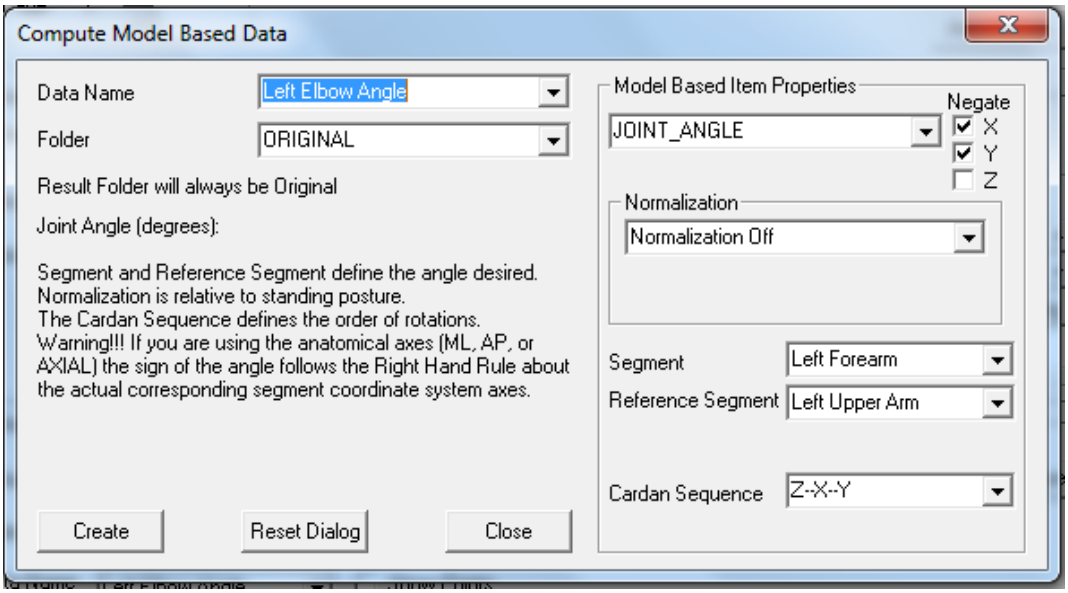
e3: The axis fixed to the distal segment and coincident with the Yf -axis of the forearm coordinate system.
Rotation (X-axis): axial rotation of the forearm. *

Visual3D Implementation

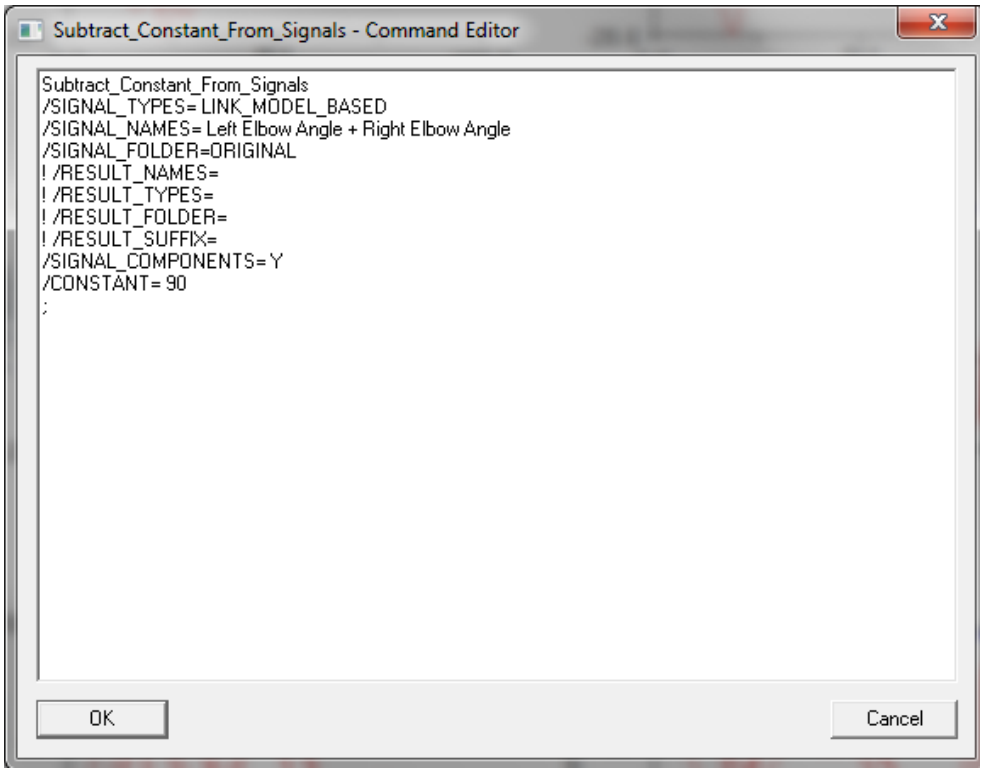
Right Arm



Left Arm



***** Zero degrees of rotation is defined to be at the neutral forearm position. Pronation is a positive rotation while supination is a negative rotation. To translate this, we subtract 90 degrees from the measured elbow angle from the Y-rotation.



Joint Angles: Wrist Angle (Hand relative to Radius, Z-X-Y)

ISB Recommendation (4.4.1. JCS and motion for the interphalangeal, metacarpophalangeal, intercarpal, radiocarpal, and carpometacarpal joints)

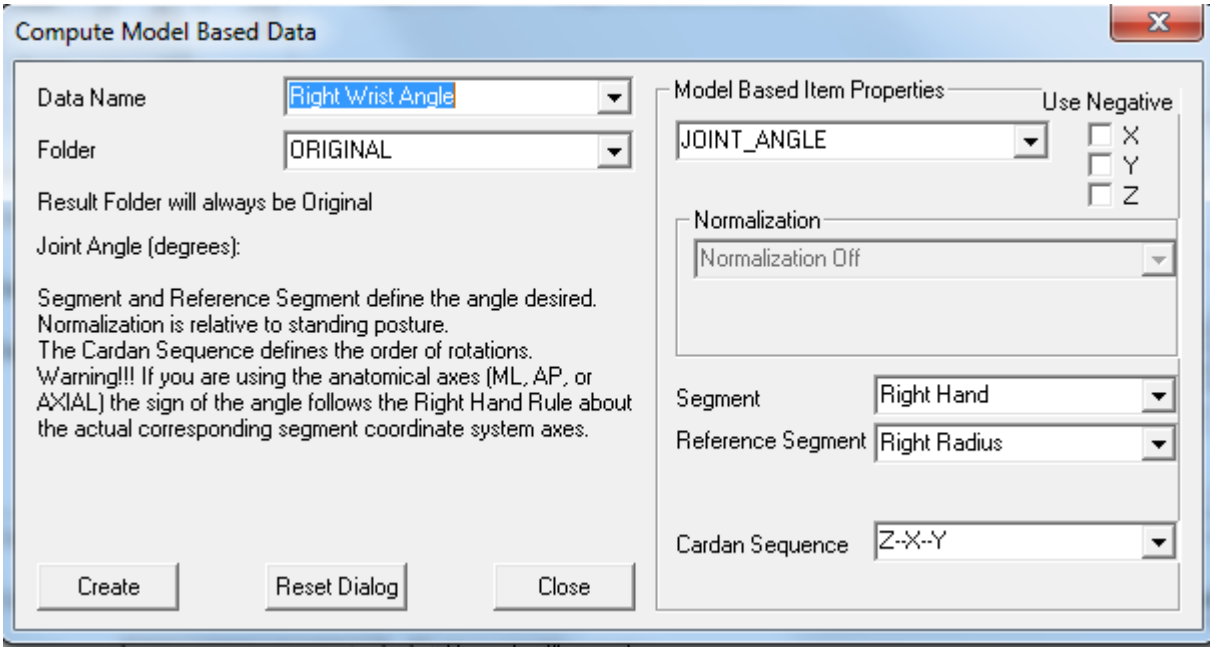
e1: The axis fixed to the proximal segment and coincident with the Z-axis of the proximal segment coordinate system.
Rotation (Z-axis): flexion (positive) or extension (negative)

e2: The common axis perpendicular to e1 and e3.
Rotation (X-axis): adduction or abduction, or radial or ulnar deviation (ulnar deviation is positive).

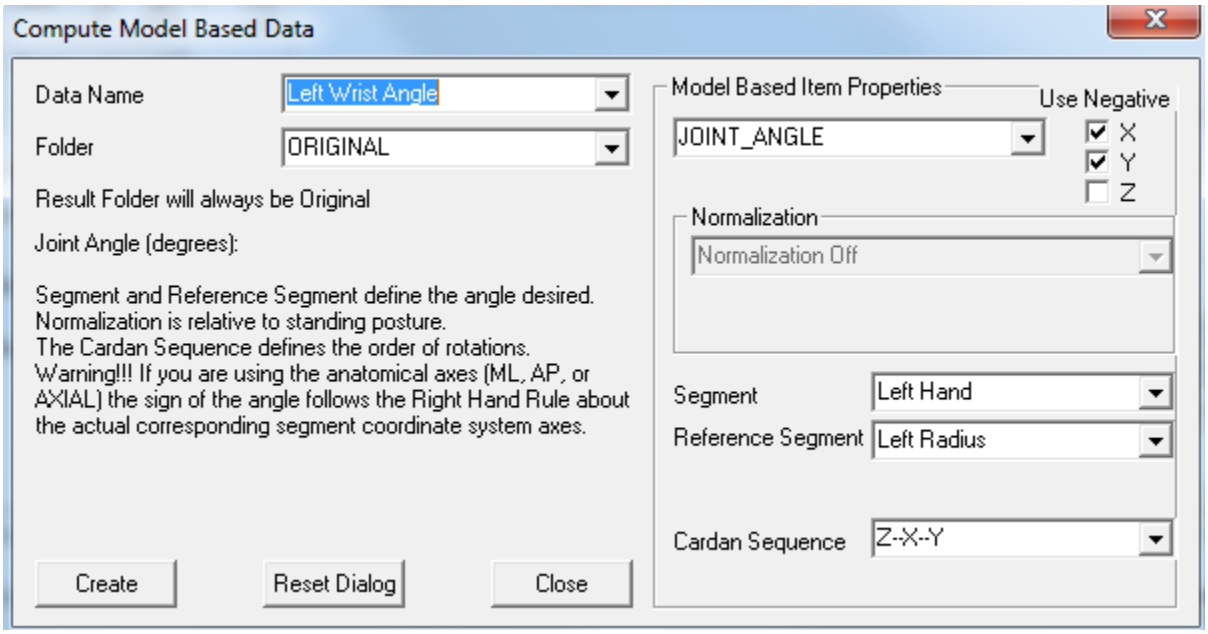
e3: The axis fixed to the distal segment and coincident with the Y-axis of the distal segment coordinate system.
Rotation (Y-axis): rotation (pronation–supination).

Visual3D Implementation

Right Arm



Left Arm


Compute Model Based Data
Data Name
Left Wrist Angle
Folder
ORIGINAL
Result Folder will always be Original
Joint Angle (degrees):
Segment and Reference Segment define the angle desired.
Normalization is relative to standing posture.
The Cardan Sequence defines the order of rotations.
Warning!!! If you are using the anatomical axes (ML, AP, or AXIAL) the sign of the angle follows the Right Hand Rule about the actual corresponding segment coordinate system axes.
Create
Reset Dialog
Close
Model Based Item Properties
JOINT_ANGLE
Use Negative
X
Y
Z
Normalization
Normalization Off
Segment
Left Hand
Reference Segment
Left Radius
Cardan Sequence
Z-X-Y

References

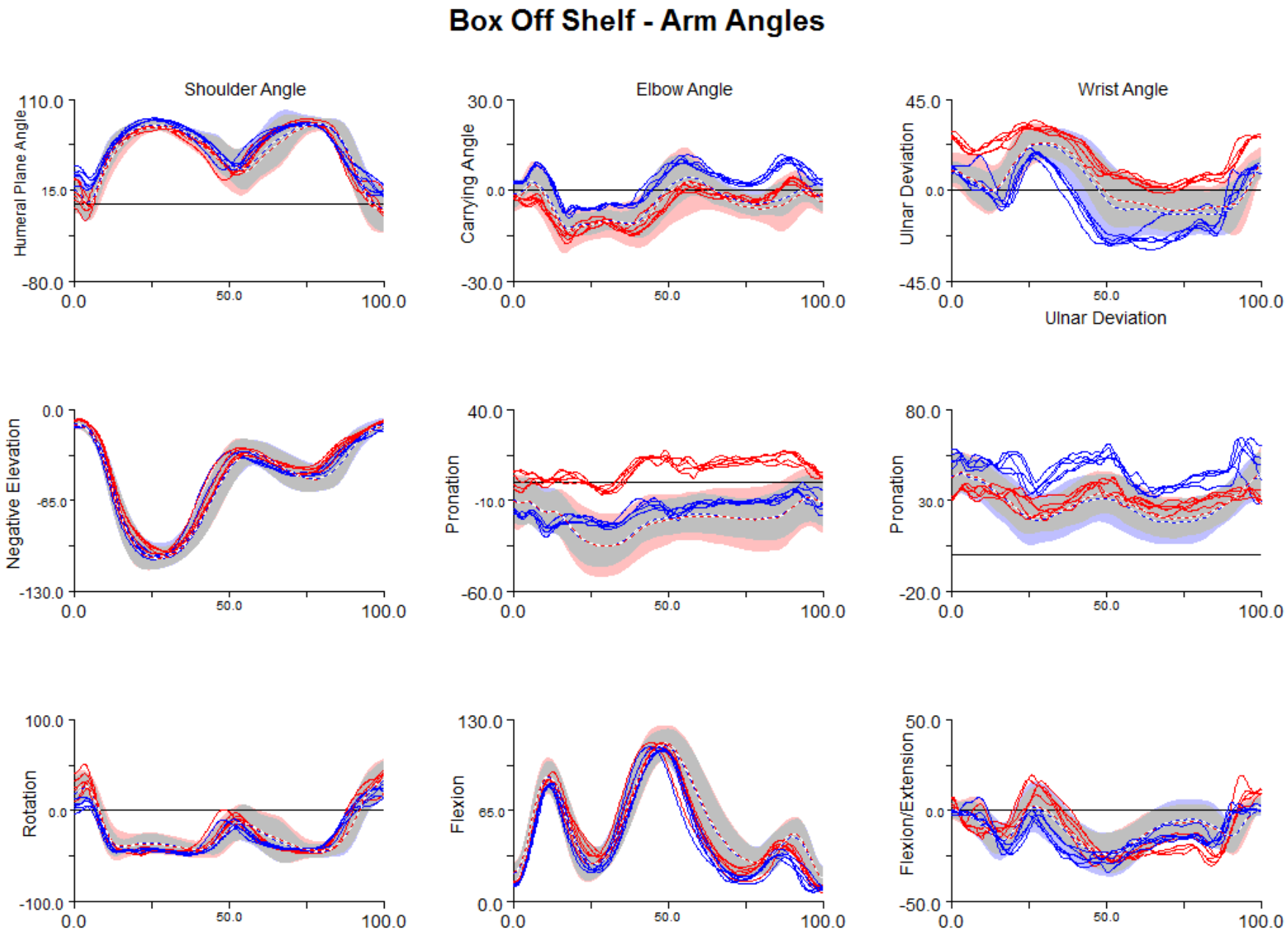
[1] Wu G, van der Helm FC, Veeger HE, Makhsous M, Van Roy P, Anglin C, Nagels J, Karduna AR, McQuade K, Wang X, Werner FW, Buchholz B, ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion--Part II: shoulder, elbow, wrist and hand. J Biomech, 2005; 38: 981-992.

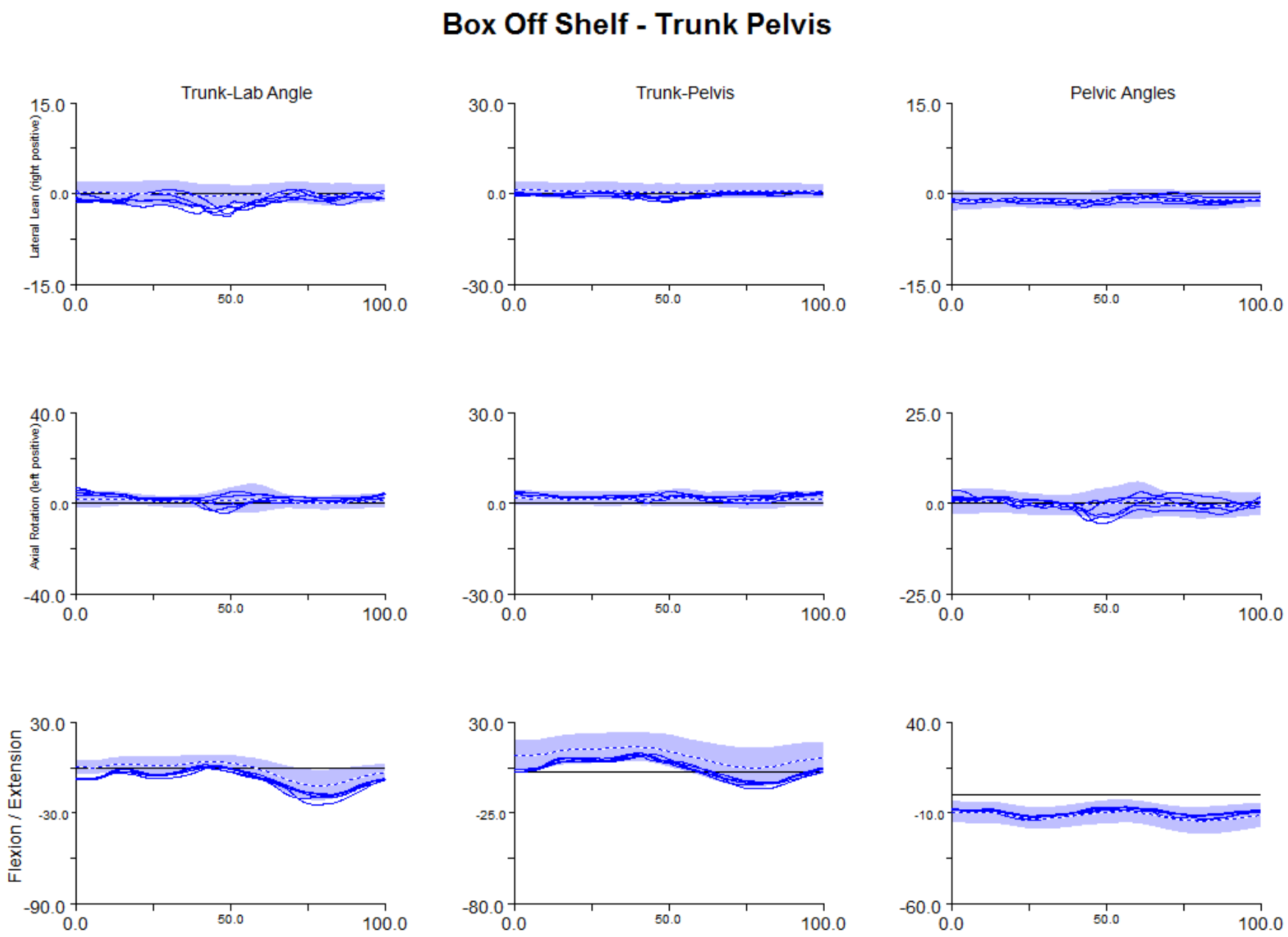
[2] Hingtgen B, McGuire JR, Wang M, Harris GF, An upper extremity kinematic model for evaluation of hemiparetic stroke. J Biomech, 2006; 39: 681-8.

[3] Rao SS, Bontrager EL, Gronley JK, Newsam CJ, Perry J, Three-dimensional kinematics of wheelchair propulsion. IEEE Trans Rehabil Eng, 1996; 4: 152-60.

Example Joint Angles: Box off shelf task

Right arm is shown in red, while the left arm is shown in blue. Data are shown as a percent of the total movement time.

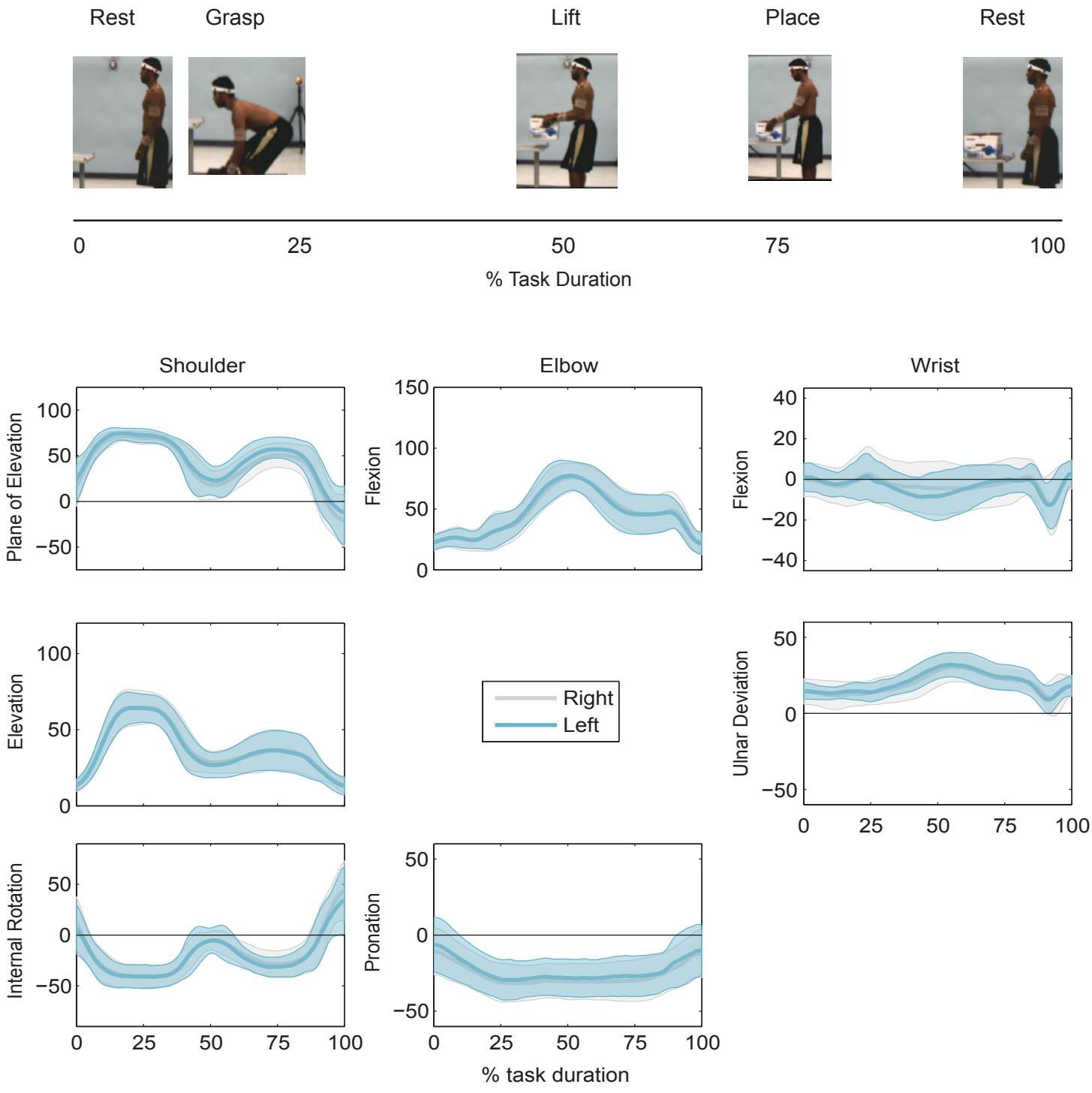




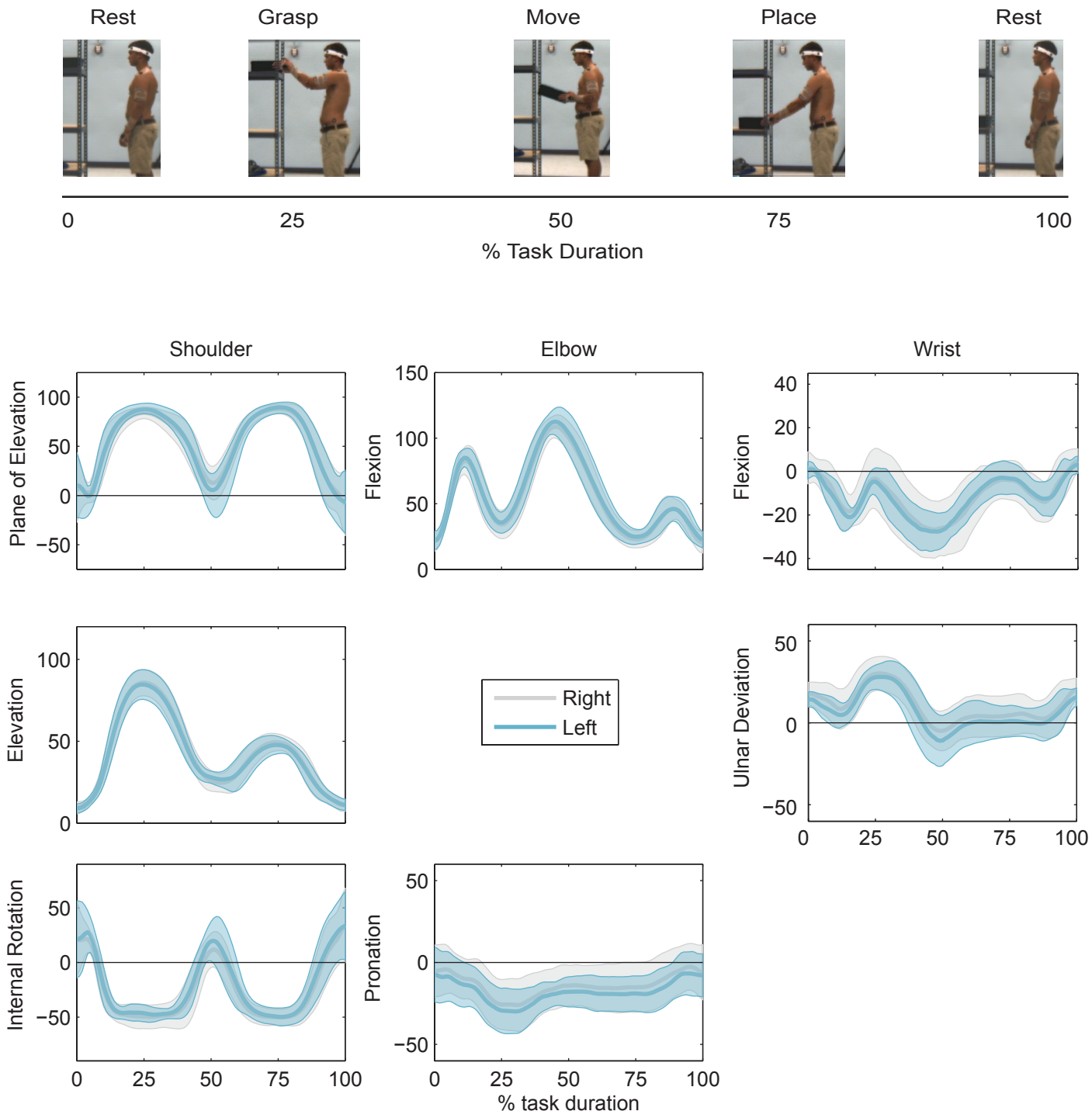
Suggested citation: Gates, D. H., Smurr Walters. L., Cowley, J., Wilken, J. M., & Resnik, L. (2016). Brief Report—Range of motion requirements for upper-limb activities of daily living (Suppl. Appendix 1). *American Journal of Occupational Therapy, 70,* 7001350010. http://dx.doi.org/10.5014.ajot.2016.015487

Supplemental Appendix 2. Figures for All Tasks

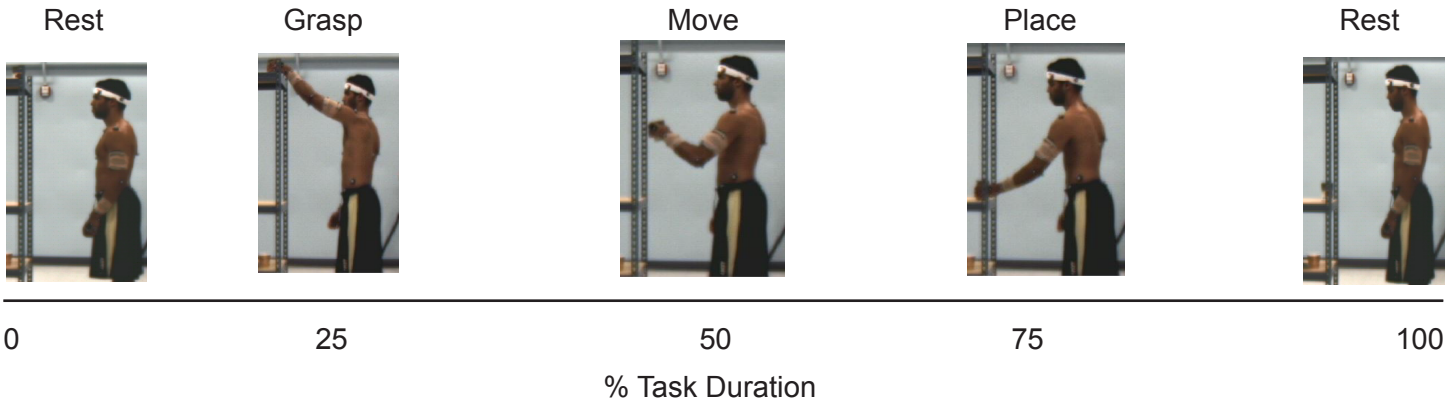
Box off ground task.

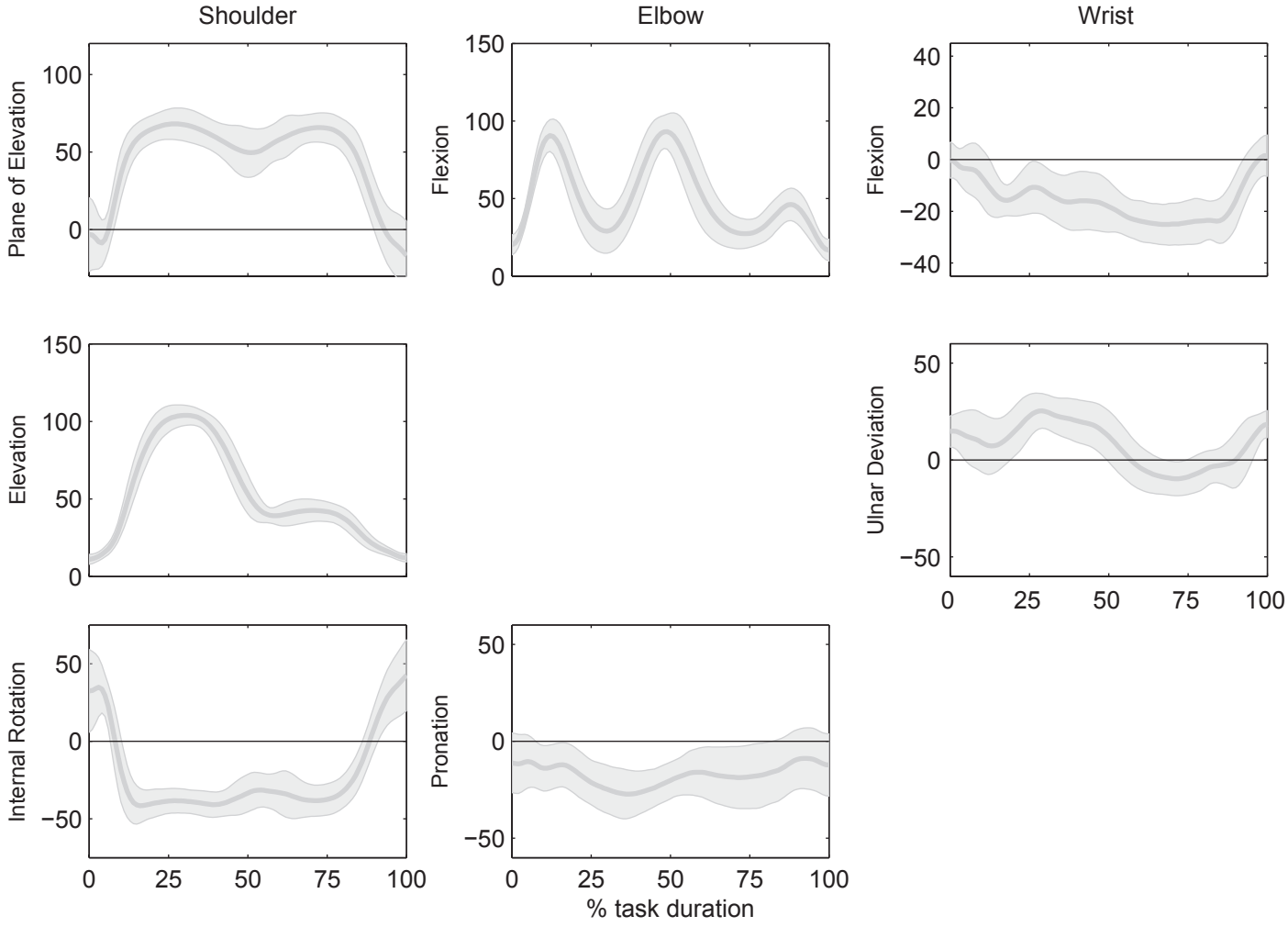


Box off (low) shelf task.

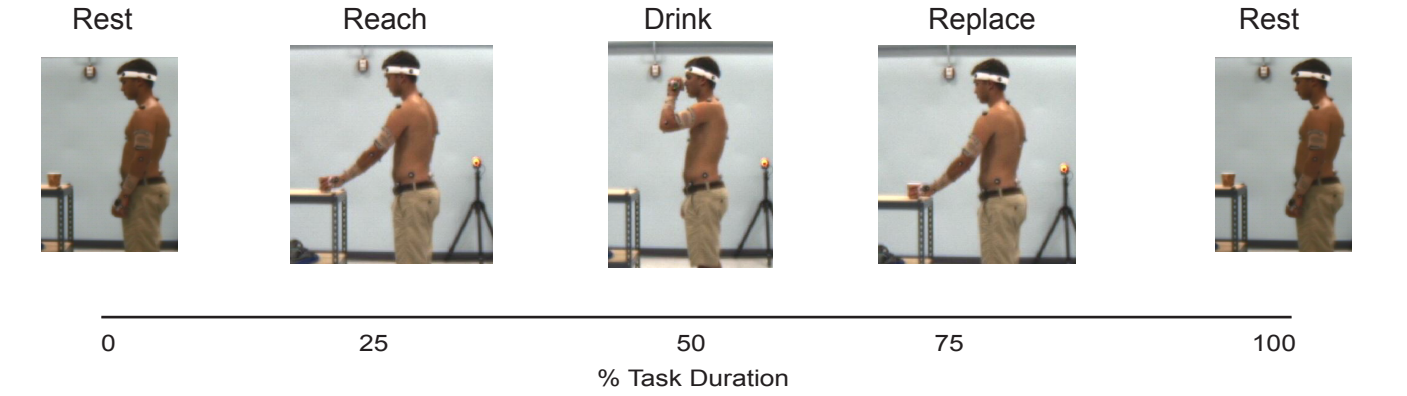


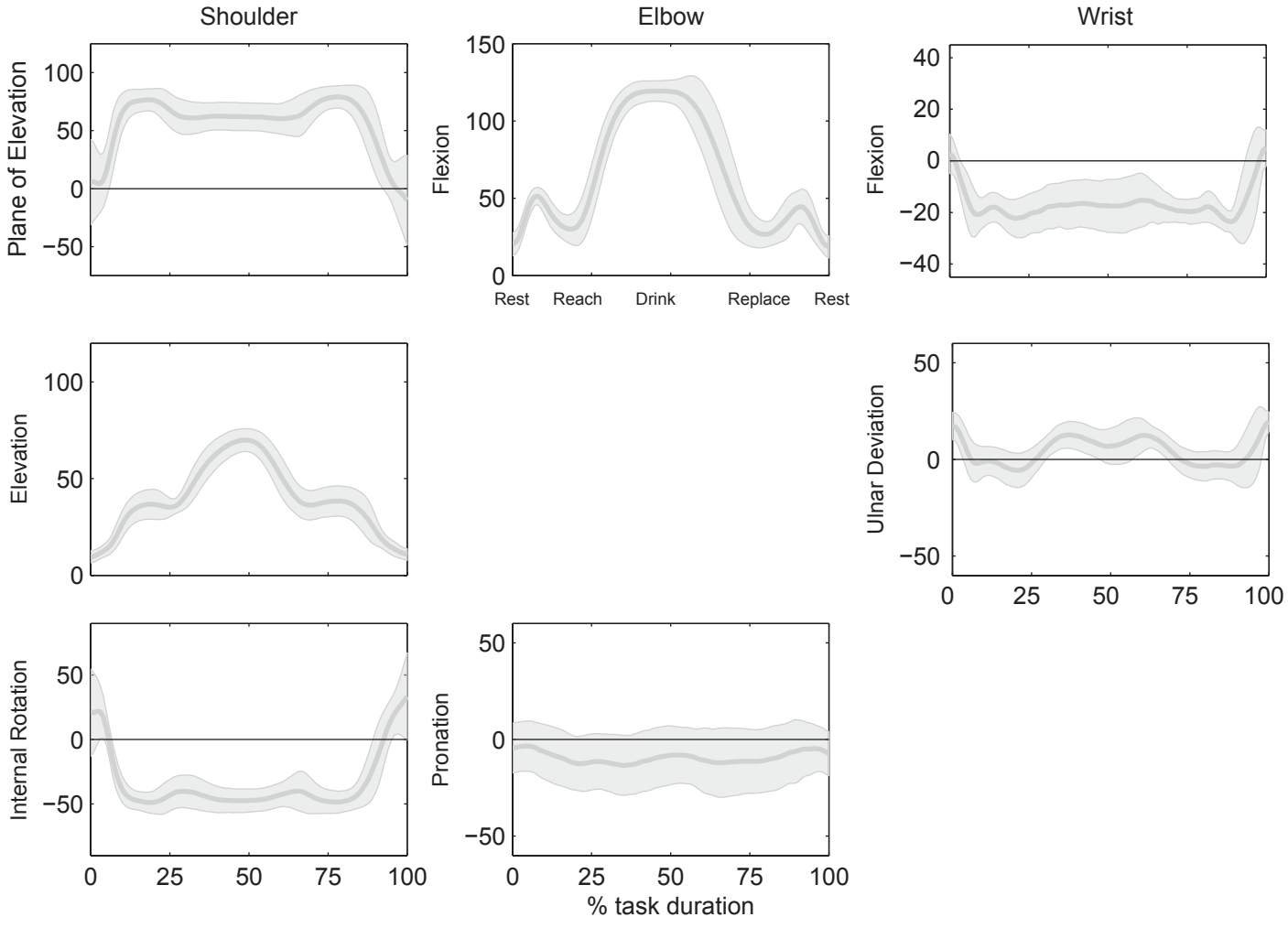
Can off shelf task.



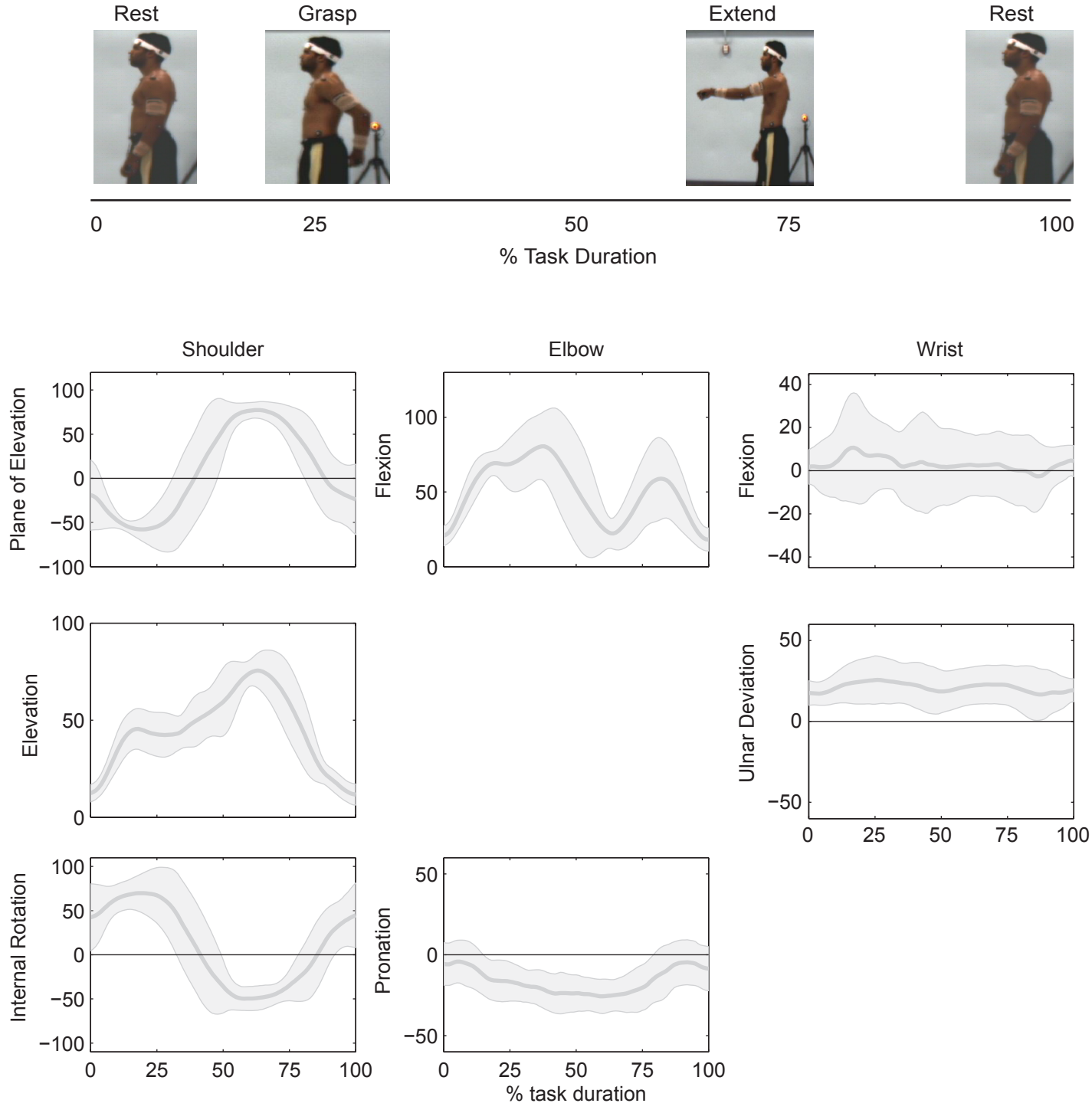


Drinking from a cup.

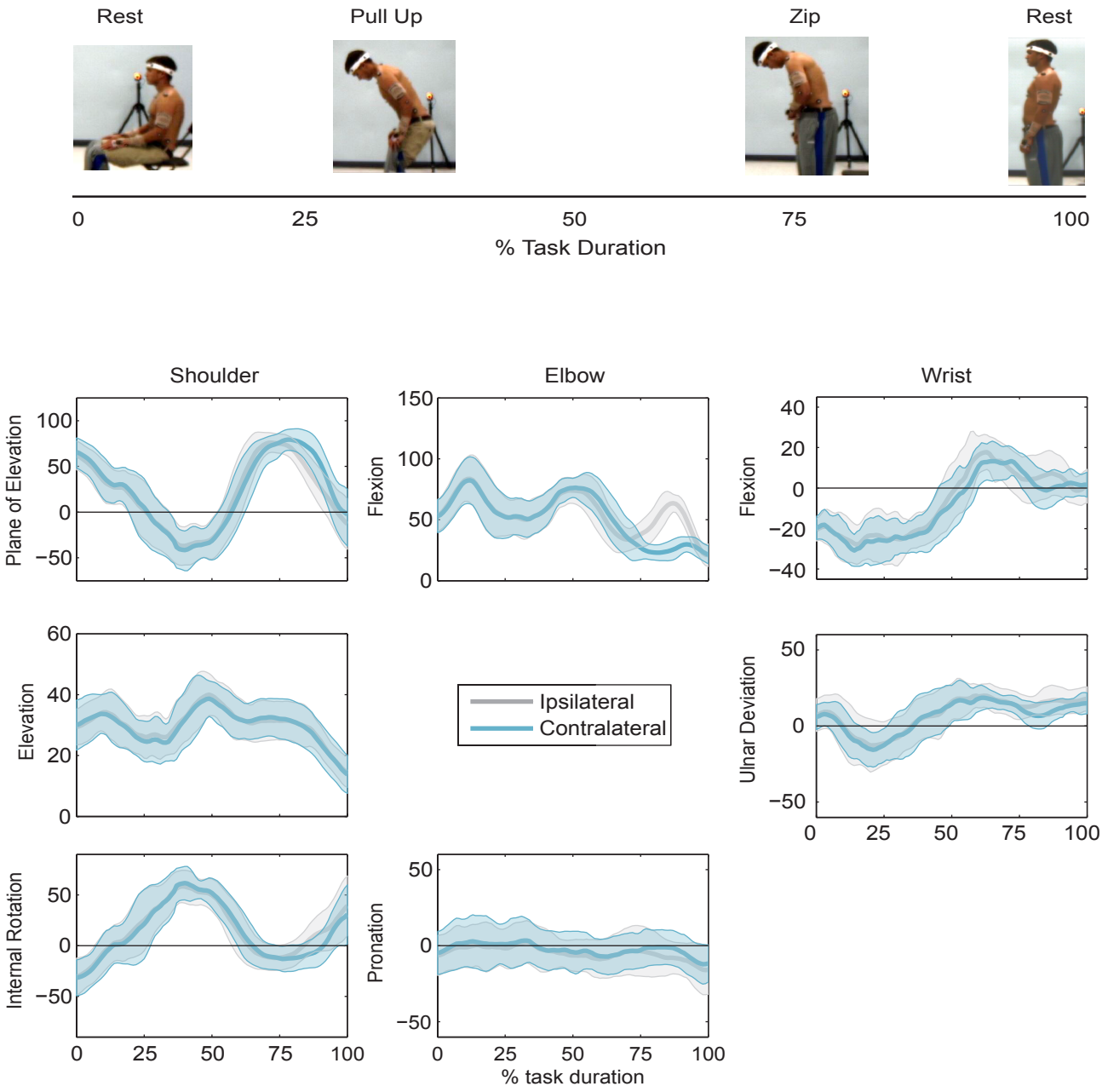




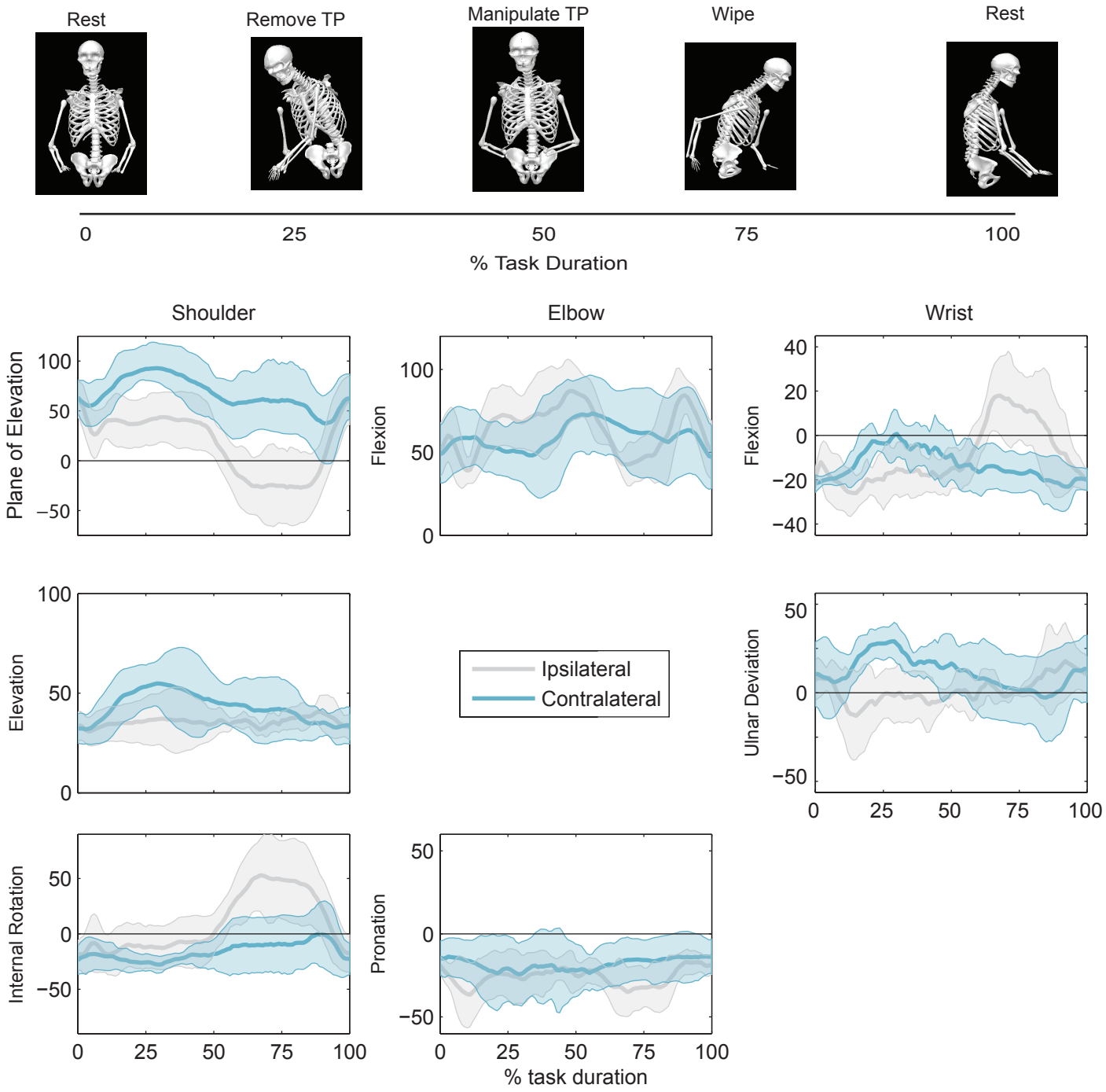
Hand to back pocket.



Donning Pants Task.



Perineal Care Task.



Suggested citation: Gates, D. H., Smurr Walters. L., Cowley, J., Wilken, J. M., & Resnik, L. (2016). Brief Report—Range of motion requirements for upper-limb activities of daily living (Suppl. Appendix 2). *American Journal of Occupational Therapy, 70,* 7001350010. http://dx.doi.org/10.5014.ajot.2016.015487

Supplemental Appendix 3

Table A1. Range of Motion for the Trunk and Pelvis.

		Segmental Trunk Angle											
		Lateral Lean				Axial Rotation				Flexion / Extension			
Task Name	N	Mean	Median	5th	95th	Mean	Median	5th	95th	Mean	Median	5th	95th
Box off ground	15	6	5	5	7	11	11	9	12	59	59	51	67
Donning and zippering pants	15	10	10	9	12	10	11	8	11	50	52	44	55
Perineal care	5	23	19	13	32	32	32	25	39	42	35	11	74
Box off shelf - Head height	15	3	3	2	4	7	6	4	10	18	16	13	23
Box off shelf - Fixed height	9	3	2	1	4	5	4	3	7	12	12	9	15
Deodorant	14	7	5	3	11	18	17	13	22	12	7	5	18
Can off shelf - Head height	15	9	9	8	11	22	20	18	27	11	10	9	13
Can off shelf - Fixed height	9	7	6	4	9	19	17	14	25	8	7	6	9
Drinking from a cup	9	5	4	3	6	14	14	11	17	6	5	4	8
Hand to back pocket	9	4	3	2	5	15	13	9	21	5	5	4	6
		Trunk-Pelvis Angle											
		Lateral Lean				Axial Rotation				Flexion / Extension			
		Mean	Median	5th	95th	Mean	Median	5th	95th	Mean	Median	5th	95th
Donning and zippering pants	15	9	8	8	10	7	8	6	8	38	36	34	43
Box off ground	15	6	6	5	7	6	6	5	7	36	32	29	42
Perineal care	5	27	29	16	39	21	19	18	24	29	37	13	46
Box off shelf - Head height	15	3	3	2	4	4	3	3	5	14	10	10	18
Box off shelf - Fixed height	9	2	2	1	4	3	3	2	4	10	9	8	12
Can off shelf - Head height	15	8	7	7	9	9	9	7	11	8	7	7	10
Deodorant	14	5	5	4	7	7	7	6	8	7	6	4	10
Can off shelf - Fixed height	9	6	5	4	8	9	8	6	11	6	6	5	7
Drinking from a cup	9	3	4	3	4	6	7	4	7	5	5	4	6
Hand to back pocket	9	4	4	2	6	9	9	7	11	5	4	4	6
		Segmental Pelvic Angle											
		Obliquity				Rotation				A-P Tilt			
		Mean	Median	5th	95th	Mean	Median	5th	95th	Mean	Median	5th	95th
Donning and zippering pants	15	5	5	4	6	9	9	7	11	43	41	38	48
Box off ground	15	6	6	5	6	13	14	11	15	32	32	28	36
Perineal care	5	17	18	9	25	18	20	10	25	31	28	8	53
Box off shelf - Head height	15	2	2	1	2	6	5	4	8	7	8	6	9
Box off shelf - Fixed height	9	1	1	1	2	4	4	3	6	4	5	3	6
Deodorant	14	2	2	1	4	13	11	8	18	4	4	3	6
Can off shelf - Head height	15	2	2	1	2	15	13	11	19	4	3	3	5
Drinking from a cup	9	1	2	1	2	9	9	7	12	3	2	2	3
Can off shelf - Fixed height	9	2	1	1	2	12	10	7	17	3	2	2	3
Hand to back pocket	9	1	1	1	2	9	6	4	13	2	2	2	3

Note. Trunk angles are calculated as segmental angles (trunk motion with respect to the global coordinate system) and relative trunk-pelvis angles (trunk motion with respect to the pelvis).

Suggested citation: Gates, D. H., Smurr Walters, L., Cowley, J., Wilken, J. M., & Resnik, L. (2016). Brief Report—Range of motion requirements for upper-limb activities of daily living (Suppl. Appendix 3). *American Journal of Occupational Therapy, 70,* 7001350010. http://dx.doi.org/10.5014.ajot.2016.015487

Supplemental Appendix 4

Table A2. Comparison With Previous Studies

			Shoulder			Elbow		Wrist	
Task Category	**Task description**	**Study**	**Plane of Elevation**	**Elevation**	**Rotation**	**Flexion**	**Supination (-) / Pronation (+)**	**Extension (-) / Flexion (+)**	**Radial(-) / Ulnar (+) deviation**
Perineal care	Perineal care	Magermans, 2005*	-67.2 (24.3)	35.0 (10.3)	105.4 (25.2)	61.0 (20.1)	-4.4 (36.1)		
	Touch perineum	Aizawa, 2010	-86 (18)	41 (8)	135 (17)	56 (22)	-78 (12)	-1 (17)	-5 (8)
	Hand to back pocket	van Andel 2008 +	-63	48	101.7	85.6	36.2	-5.4 / 8.5	-1 / 15.5
	Perineal care	Current Study	-46	55	65	107	-20	-38 / 34	-28 / 38
	Hand to back pocket	Current Study	-65	80^	79	101^	-28	-15 / 28	7 / 35
Deodorant Application	Wash contralateral axilla	Magermans, 2005*	99.6 (8.9)	53.0 (10.8)	-15.2 (6.8)	117.5(8.9)			
	Touch contralateral axilla	Aizawa, 2010	109 (12)	42 (13)	-11 (24)	100 (10)	-12.7 (23.0)	32 (19)	18 (9)
	Deodorant application	Current Study	100	55	-39	104	-63 (25)	11 / -27	-12 / 23
Feeding Tasks	Eating with spoon	Magermans, 2005*	60.0 (14.4)	63.6 (22.8)	-49.3 (14)	131.5 (7.5)	-53		
	Drinking from glass	Aizawa, 2010	80 (14)	87 (12)	-62 (17)	115 (5)		-15 (13)	-3 (12)
	Drinking from cup	Current Study	81	71	-53	121	-18.1 (31.4)	-33 / 8	-11 / 23
Lifting tasks	Lift 4 kg bag from ground	Magermans, 2005*	79.2 (18.8)	63.6 (22.8)	-47.7 (25.3)	93.4 (23.9)	20 (20)		
	Lift 20-lb box from ground	Current Study	75	69	-45	81	6		
Reaching	Reach above shoulder level	Magermans 2005	72.6 (11.7)	121.4 (6.5)	-60.6 (36.4)	39.3(18.2)	30.8 (17.4)		
	Reach to can - head height	Current Study	72	105	-46	105	-29		
	Reach to box - head height	Current Study	86	108	-48	120	-32		

Note. Data in parentheses represent standard deviations if provided.
* Shoulder angles were measured as motion of the humerus relative to scapula, rather than humerus relative to thorax.
+ Values from supplemental material.
^ Occurs as the hand the wallet to the investigator (not done in other studies).

Suggested citation: Gates, D. H., Smurr Walters, L., Cowley, J., Wilken, J. M., & Resnik, L. (2016). Brief Report—Range of motion requirements for upper-limb activities of daily living (Suppl. Appendix 4). *American Journal of Occupational Therapy, 70*, 7001350010. http://dx.doi.org/10.5014.ajot.2016.015487