VICON

Upper Limb Model
Product Guide

This document describes the Upper Limb Model, a BodyBuilder model that uses an extended version of the Plug-in Gait marker set for upper limb modeling. The first part of this document explains how to install, license, and use the Upper Limb Model with Vicon Nexus and Vicon Workstation. The second part provides advanced technical information for users who want to gain a deeper understanding of the scientific basis of the model and its implementation.

Contents

Foundation Notes

This section provides essential product information, which you need to get started using the current release of the Upper Limb Model. It describes the main features and functionality and provides instructions on installing and using the Upper Limb Model.

About the Upper Limb Model

The Upper Limb Model is an extended version of the Conventional Gait Model (Plug-in Gait) written in Vicon BodyLanguage. It defines additional markers for upper limb modeling, which enable a full 3D description of the upper body kinematics to increase the accuracy of motion capture and improve subsequent analysis.

The Upper Limb Model can be included in the processing pipeline of either Vicon Nexus 1.x or Vicon Workstation 5.x. The marker set defined in this is completely compatible with the marker set defined in the Plug-in Gait upper limb model, so you can process, store, and visualize the captured and modeled Upper Limb data in Vicon Nexus or Workstation alongside the Plug-in Gait model. You can also generate reports in Vicon Polygon as you would for any biomechanical model.

Important

This document assumes that you are familiar with standard motion capture and data processing performed in either Vicon Nexus or Vicon Workstation. If you are not, see the documentation supplied with your Vicon software for details on its features and functionality.

Before using the Upper Limb Model, you are advised to read the *Disclaimer* below. For further background information on its implementation in Vicon Nexus and Vicon Workstation, see *Advanced Notes* on page 15. Also see the published papers listed in *References* on page 14, which provide information that is not fully covered in this document, such as the scientific basis for the Upper Limb Model, the interpretation of the results, and the validation of this model.

Disclaimer

The Upper Limb Model described in this document is supplied as an example model only to illustrate the normal operation of BodyLanguage. OMG and Vicon accept no responsibility for its correct operation or the accuracy of its results. Prior to using the model clinically, you are advised to consult the published papers listed in *References* on page 14 and to conduct your own tests. Any clinical decision based on the Upper Limb Model is the sole responsibility of the end user.

Installing the Upper Limb Model

You can install the Upper Limb Model with either Vicon Nexus or Vicon Workstation. You must have already installed the Vicon software on the host PC before installing the Upper Limb Model.

You can obtain the Upper Limb Model from the Life Sciences Downloads page on Vicon Online Support (for details, see *Vicon Online Support* on page 13).

The Upper Limb Model consists of the files listed and described in Table 2-1.

Table 2-1: Upper Limb Model files

Vicon Software	File name	Description
Workstation		
		Marker Set
	Model_UpperLimb.mkr	- Upper Limb
	Model_UpperLimb_PiG.mkr	- Upper Limb including Plug-in Gait
		Model
	Model_UpperLimb.mod	- full Upper Limb
	Model_UpperLimbLeft.mod	- left Upper Limb
	Model_UpperLimbRight.mod	- right Upper Limb
		Model Parameters
	Model_UpperLimb.mp	- full Upper Limb
	Model_UpperLimbLeft.mp	- left Upper Limb
	Model_UpperLimbRight.mp	- right Upper Limb
Nexus		
		Vicon Skeleton Template
	Model_UpperLimb.vst	- full Upper Limb
	Model_UpperLimbLeft.vst	- left Upper Limb
	Model_UpperLimbRight.vst	- right Upper Limb
	Model_UpperLimb_PiG.vst	- full Upper Limb including Plug-in Gait
		Model Parameters
	Model_UpperLimb.mp	- full Upper Limb
	Model_UpperLimbLeft.mp	- left Upper Limb
	Model_UpperLimbRight.mp	- right Upper Limb

To install the Upper Limb Model:

1. In Windows Explorer, navigate to the folder in which you downloaded the self-extracting executable file *Model_UpperLimb_Installer.exe*.

2. Double-click the *Model_UpperLimb_Installer.exe* file.

3. In the **Upper Limb Model** prompt to install the model, click **Yes**.

   The **Upper Limb Model - InstallShield Wizard** starts.

4. Follow the instructions on each wizard page, completing the requested details, and click **Next**.

5. On the **InstallShield Wizard Complete** wizard page, click **Finish**.

   Table 2-2 shows where the installer places the Upper Limb Model files in your Vicon program folder (by default, *C:\Program Files\Vicon*), appropriate for your Vicon software.

Table 2-2: Upper Limb Model file locations

File type	Location	Nexus	Workstation
.mkr	*\Models*		✓
.mod	*\Models\BodyBuilder*	✓	✓
.mp	*\Models\BodyBuilder*	✓	✓
.vst	*\Nexus\ModelTemplates*	✓	

6. After the files are installed, start Vicon Nexus or Vicon Workstation. You can then process files as described in *Processing with the Upper Limb Model*.

Processing with the Upper Limb Model

The Upper Limb Model calculates additional output variables for the additional markers attached to the left and right upper limbs, along with those for the standard Plug-in Gait marker set.

Processing with the Upper Limb Model involves the following stages:

1. *Attaching the Maker Set to the Subject*

2. *Capturing and Processing a Static Trial* on page 9

3. *Capturing and Processing Dynamic Trials* on page 11

The following sections assume that you are familiar with motion capture in Vicon Nexus or Vicon Workstation. You can find more detailed instructions on preparing subjects; capturing and processing trials; and post processing trials in the documentation for your chosen Vicon software.

Attaching the Maker Set to the Subject

The first stage in using the Upper Limb Model is attaching the markers to the subject. This section shows you where on your subject to place the markers corresponding to the labels defined in the Upper Limb Model. It provides front and back views. Some markers are shown in both views to help you better determine their position on your subject. Table 2-3 on page 7 provides detailed descriptions of each marker to help you to accurately position the markers on your subject.

Figure 2-1 illustrates where to attach the markers on the front of the subject. The left markers are not labeled in this figure; they are placed symmetrically to the right markers.
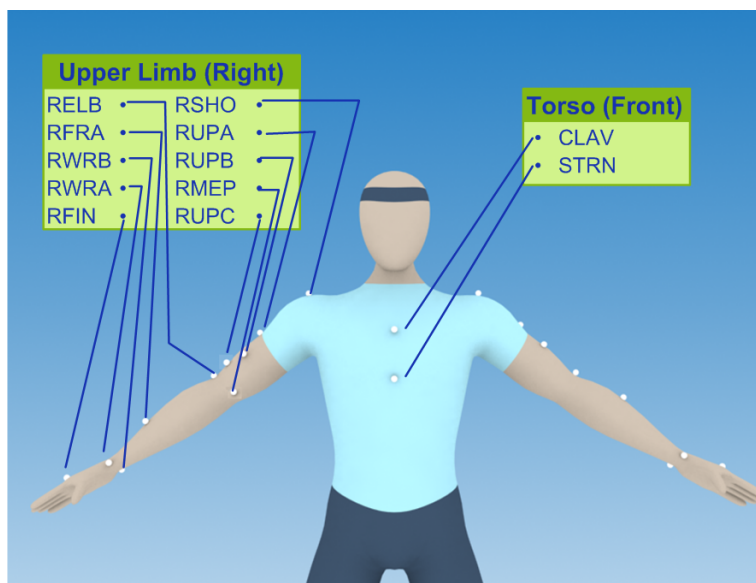

Figure 2-1: Upper Limb Model marker placement—front view

Figure 2-2 illustrates where to attach the markers on the rear of the subject. The right markers are not labeled in this figure; they are placed symmetrically to the left markers.
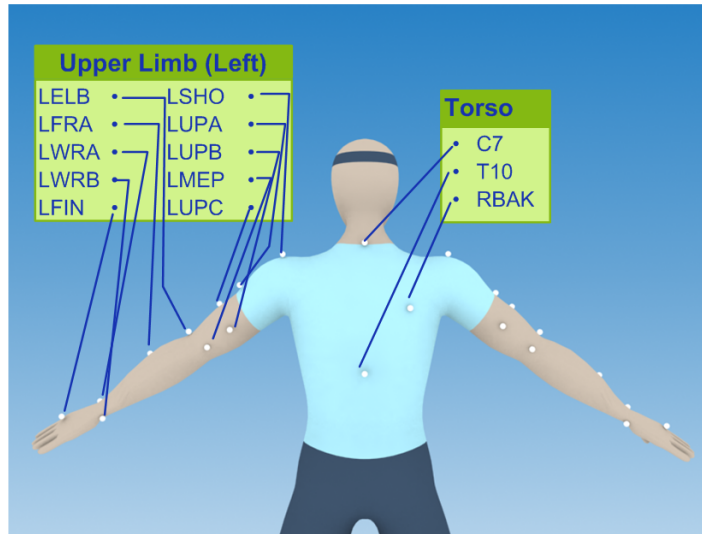
Figure 2-2: Upper Limb Model marker placement—rear view

Table 2-3 on page 7 lists and defines the markers used in the Upper Limb Model.

Important

The precision of the marker placement is critical for obtaining accurate results. Use the Marker Placement information in the table to locate the most precise point for placing each marker on the subject.

The Notes column in the table identifies markers that are to be attached for a static trial only and those that the Upper Limb Model uses to define a technical reference frame. The remaining markers in the model are used for calibrating the subject during the static trial and for tracking the subject's

movements during dynamic trials. For further details on marker usage, see the *Advanced Notes* on page 15.

Table 2-3: Upper Limb Model Marker Descriptions

Marker Label	Definition	Marker Placement	Notes
Torso Markers			
C7	7th cervical vertebra	On the spinous process of the 7th cervical vertebra	
RBAK	Right back	Over the right scapula	
T10	10th thoracic vertebra	On the spinous process of the 10th thoracic vertebra	
CLAV	Clavicle	On the jugular notch where the clavicles meet the sternum	
STRN	Sternum	On the xiphoid process of the sternum	
Left Upper Limb Markers			
LSHO	Left shoulder	On the acromio-clavicular joint	
LUPA	Left upper arm marker A	On the lateral upper left arm (Place asymmetrically with RUPA)	Technical reference frame
LUPB	Left upper arm marker B	On the lateral upper left arm (Place asymmetrically with RUPB)	Technical reference frame
LUPC	Left upper arm marker C	On the lateral upper left arm (Place asymmetrically with RUPC)	Technical reference frame
LELB	Left elbow	On the lateral epicondyle approximating the elbow joint axis	Technical reference frame
LMEP	Left medial epicondyle	Left humerus medial epicondyle	Static trial only
LFRA	Left forearm	On the lateral left forearm (Place asymmetrically with RFRA)	

Table 2-3: Upper Limb Model Marker Descriptions

Marker Label	Definition	Marker Placement	Notes
LWRA	Left wrist marker A	at the thumb side of left radial styloid attached symmetrically with a wristband on the posterior of the left wrist, as close to the wrist joint center as possible	
LWRB	Left wrist marker B	at the little finger side of left ulnar styloid attached symmetrically with a wristband on the posterior of the left wrist, as close to the wrist joint center as possible	
LFIN	Left finger	Just below the left third metacarpus	
Right Upper Limb Markers			
RSHO	Right shoulder	On the acromio-clavicular joint	
RUPA	Right upper arm marker A	On the lateral upper right arm (Place asymmetrically with LUPA)	Technical reference frame
RUPB	Right upper arm marker B	On the lateral upper right arm (Place asymmetrically with LUPB)	Technical reference frame
RUPC	Right upper arm marker C	On the lateral upper right arm (Place asymmetrically with LUPC)	Technical reference frame
RELB	Right elbow	On the lateral epicondyle approximating the elbow joint axis	Technical reference frame
RMEP	Right medial epicondyle	On the humerus medial epicondyle	Static trial only
RFRA	Right forearm	Right Forearm	

Table 2-3: Upper Limb Model Marker Descriptions

Marker Label	Definition	Marker Placement	Notes
RWRA	Right wrist marker A	At the thumb side of the right radial styloid attached symmetrically with a wristband on the posterior of the right wrist, as close to the wrist joint center as possible	
RWRB	Right wrist marker B	At the little finger side of the right ulnar styloid attached symmetrically with a wristband on the posterior of the right wrist, as close to the wrist joint center as possible	
RFIN	Right finger	Just below the right third metacarpus	

Capturing and Processing a Static Trial

The second stage in using the Upper Limb Model is capturing and processing a static trial. This involves capturing the subject in a stationary position and then labeling the marker images according to the marker file or template file. The static trial enables Vicon software to associate captured markers with known positions or labels. Ensure that you have installed the Upper Limb Model files before capturing a static trial (for details, see *Installing the Upper Limb Model* on page 3).

This section outlines how to capture and process a static trial using the Upper Limb Model. For specific steps for doing this with your chosen Vicon software, see the *Workstation Realtime Engine System Options* book (Workstation) or the *Vicon Nexus Information System* (Nexus).

To capture and process an Upper Limb Model static trial:

1. Create or open a session in the database in which you want to store the trial data, and ensure that it is the active session by double-clicking on the session name in the **Data Management** window (Nexus) or the Eclipse data directory browser (Workstation).

2. Create a new subject, associate it with the appropriate file containing the Upper Limb Model marker set (*.vst* for Nexus, *.mkr* for Workstation), and ensure this is the only subject enabled for capture (for details on these files, see *Installing the Upper Limb Model* on page 3).

3. Ensure that the Vicon markers are attached to the subject in accordance with the marker set defined in the Upper Limb Model (for details, see *Attaching the Maker Set to the Subject* on page 5).

4. In the capture volume, have the subject stand in the anatomical position, with hands by the side and palms forward as shown in Figure 2-1 on page 5, ensuring that all the markers on the subject are visible to the cameras for at least one frame.

5. Capture a static trial and reconstruct markers for the subject in the capture volume.

6. Manually label the reconstructed markers according to Table 2-3 on page 7.

> **Caution**
> Ensure that you use a frame in which all of the markers are visible and that you label them correctly. If markers are missing or incorrectly labeled, the static trial processing will either fail or produce erroneous results.

7. Select the **Calibrate Labeling Model** pipeline and run the **Processing Static Subject Calibration (Static Subject Calibration)** operation to produce a Vicon Skeleton (*.vsk* file) scaled to the subject.

8. Create and run a pipeline containing the **Perform static BodyLanguage modeling** operation configured to use the Upper Limb Model *.mod* and *.mp* files (for details on these files, see *Installing the Upper Limb Model* on page 3).

   The Upper Limb Model writes the local coordinates of the points it calibrates to the *subject.mp* file within the active session folder.

Capturing and Processing Dynamic Trials

The third stage in using the Upper Limb Model is capturing and processing one or more dynamic trials on which your clinical analysis will be based. You must first have successfully processed the static trial as described in *Capturing and Processing a Static Trial* on page 9.

This section outlines how to capture and process a dynamic trial using the Upper Limb Model. For specific steps for doing this with your chosen Vicon software, see the *Workstation Realtime Engine System Option* book (Workstation) or the *Vicon Nexus Information System* (Nexus).

To capture and process an Upper Limb Model dynamic trial:

1. Remove from the subject the LMEP and RMEP markers that were required for the static trial only (for details, see Table 2-3 on page 7).

2. Ensure that the subject you created containing the Upper Limb Model marker set (*.vst* for Nexus, *.mkr* for Workstation) in the static trial is the only subject enabled for capture.

3. Ensure that the Vicon markers are attached to the subject in accordance with the marker set defined in the Upper Limb Model (for details, see *Attaching the Maker Set to the Subject* on page 5).

4. In the capture volume, have the subject perform the required movements.

   Important

   Ensure that the markers are attached in the same position on the upper limbs as they were during the static trial. Vicon Nexus and Workstation use the Upper Limb Model marker positions calibrated during the static trial to accurately locate the position of the medial epicondyles and the glenohumeral joint centers during dynamic trials. If the marker positions have changed, any further data processing is impossible.

5. Capture a dynamic trial and reconstruct and automatically label the markers.

6. Create and run a pipeline containing the **Perform dynamic BodyLanguage modeling** operation configured to use the Upper Limb Model *.mod* and *.mp* files (for details on these files, see *Installing the Upper Limb Model* on page 3).

   The Upper Limb Model calculates the kinematic data described in *Interpreting the Data* on page 12. The reconstructed and labeled markers corresponding to the joint centers and segment orientations calculated by the model are displayed in a **3D Perspective** view pane.

7. Save the trial data to a *.c3d* file in the active session folder.

8. If you want to process or analyze the trial data further in a software application other than Vicon Polygon, export the trial data to ASCII using the appropriate pipeline operation.

Interpreting the Data

After you have processed dynamic trials, the Upper Limb Model adds additional variables to the **Angles** section in the *.c3d* file. Table 2-4 describes these additional output angles.

Table 2-4: Additional Output Angles

Output Angle	Description
ShoulderAnglesYZY	right/left shoulder angles calculated using the YZ'Y'' Euler angles sequence
ShoulderAnglesXZY	right/left shoulder angles calculated using the XZ'Y'' Euler angles sequence
ElbowAnglesXZY	right/left elbow angles calculated using the XZ'Y'' Euler angles sequence
WristAnglesXZY	right/left wrist angles calculated using the XZ'Y'' Euler angles sequence

You can use the Upper Limb Model (full, left, or right) on its own to obtain just these output angles. If you want to view these along with the standard Plug-in Gait output angles, use the appropriate Upper Limb Model file containing the Upper Limb Model and Plug-in Gait marker set (*Model_UpperLimb_PiG.vst* for Nexus, *.Model_UpperLimb_PiG.mkr*) for Workstation). For a full list of available Upper Limb Model files, see Table 2-1 on page 3.

User Assistance Materials

Vicon provide user assistance materials to support your use of our products:

• *Product Documentation* on page 13

• *Training Video* on page 13

• *Vicon Online Support* on page 13

Published research papers provide related information you may find useful:

• *References* on page 14

Product Documentation

The following product documentation is available to familiarize you with the features and functionality in Upper Limb Model Version 1.0:

- **Product Guide**

  This document provides the information you need to know about the current release of the Upper Limb Model. It contains the following key sections:

  - **Foundation Notes**

    Essential product information: describes the current release, provides prerequisites, installation, licensing, startup, and basic usage instructions; details new features; and identifies any known issues.

  - **Advanced Notes**

    Advanced technical information: provides more detailed background on the scientific basis for the Upper Limb Model and its implementation in Vicon Nexus and Vicon Workstation. This additional information is intended for users who want to gain a deeper understanding of product.

  This document is installed in PDF format (requires Adobe Acrobat version 5.0 or later). To access it, from the Windows **Start** menu, point to **All Programs**, then **Vicon**, then **Documentation**, then **Release Documents**, and select *Model_UpperLimb_ProductGuide.pdf*.

Training Video

An audiovisual tutorial that shows—rather than just tells—you how to use the key features and functionality in Upper Limb Model.

The training video is installed in AVI format (requires AVI compatible media player and an audio codec, such as DivX). To access it, from the Windows **Start** menu, point to **All Programs**, then **Vicon**, then **Training Videos**, and then click **Upper Limb Model Training Video.**

Vicon Online Support

If you are a licensed Vicon user and have a valid Vicon System Maintenance Agreement, you can access the Vicon Online Support knowledge base at www.vicon.com/support.

Vicon Online Support provides the following online support resources:

- **Downloads**

  Obtain latest firmware and other software patches, models and scripts, and product documentation.

- **FAQs**

  Locate topics providing answers to frequently asked questions about Vicon hardware, software, plug-ins, and licensing as well as third-party software.

- **Cases**

  Submit your own question or report a problem if you cannot locate the information you need in the FAQs, then track responses to your questions and updates to your problems.

References

These research publications provide supporting information on the scientific basis and validation of this Upper Limb Model:

- CUTTI ET AL. *Soft tissue artefact assessment in humeral axial rotation.* Gait & Posture 21, 2005, 341 - 349.

- MURRAY, I. A. *Determining upper limb kinematics and dynamics during everyday tasks*. Ph.D. Thesis. University of Newcastle upon Tyne, 1999.

- STAGNI R., FANTOZZI S., CAPPELLO A., USSIA L., LEARDINI A. *Propagation of skin motion artefacts to knee joint kinematics. Gait and Posture* 16 (sup1) , 2002, 211 - 212.

Advanced Notes

This section provides background information on the development of the Upper Limb Model and its implementation in Vicon Nexus and Vicon Workstation. It is provided as an additional resource for users who want to gain a deeper understanding of the scientific basis of the model; it is not essential to using the Upper Limb Model.

Model Background

The Plug-in Gait model provided a qualitative representation of the kinematics and kinetics of the upper limbs that was not appropriate for use in scientific research. Users involved in scientific research had to create their own model, which could be a time consuming and complicated process. The Upper Limb Model provides Vicon system users with a model can be included in the processing pipeline of either Vicon Nexus 1.x or Vicon Workstation 5.x. and provide modeling that could possibly be used in research.

Important

Before using the Upper Limb Model, you are advised to read the *Disclaimer* on page 2 and the *References* on page 14.

Model Description

The Upper Limb Model defines the following seven rigid segments and fourteen Degrees of Freedom (DoF)—seven for each side:

- **Segments**
    - Thorax
    - Right upper arm
    - Right forearm
    - Right hand
    - Left upper arm
    - Left forearm
    - Left hand

- **Degrees of Freedom**
    - **Shoulder:** Ball and socket joint with three DoF (two calculations available):

• Plane of elevation	• Flexion–extension
• Elevation	• Ab-adduction
• Internal–external rotation	• Internal-external rotation

- **Elbow:** Universal joint with two DoF:
  - Flexion–extension
  - Pronation–supination

- **Wrist:** Universal joint with two DoF:
  - Flexion–extension
  - Radial–ulnar deviation

For a full details on the kinematic structure of the model, see *References* on page 14.

Marker Set Definition

The Upper Limb Model marker set is based on the upper limb markers used by the Plug-in Gait model with additional markers on the upper arm.

Markers are defined in the *.vst* (Nexus) or *.mkr* (Workstation) file, which defines the generic relationship between physical markers attached to a subject and the underlying skeletal structure to which the markers are attached for a certain type of subject. During a static trial, the marker information in the generic *.vst* file is calibrated to create a kinematic model scaled to a specific subject. For full details on the marker set used to define the model, see *Attaching the Maker Set to the Subject* on page 5.

The calibrated subject is then processed by a static BodyLanguage modeling pipeline operation, which calculates a technical reference frame describing the fixed relationship between the LUPA/RUPA, LUPB/RUPB, LUPC/RUPC, and LELB/RELB markers in the Upper Limb Model.

This scaled marker and modeling information is stored in a *.vsk* file. which is subsequently used to track and analyze the subject's movements during dynamic trials.

Method Description

The MEP marker is placed on the humerus medial epicondyle for each upper arm and the UPB and UPC markers are placed on each lateral upper arm. The addition of these markers to describe upper arm motion improves the accuracy of calibrating the joints associated with the humerus as well as the quality of tracking the subject's movement.

The ELB, WRA, and WRB markers must still be placed directly on the anatomical points of interest. While placing a marker on a bony prominence leads to greater inaccuracies due to skin movement, this positioning results in greater ease of use and reduces subject preparation time.

During the static trial, Nexus or Workstation calibrates the medial epicondyles and the glenohumeral joint center with respect to the upper arm. The LMEP/RMEP markers are calibrated with respect to the technical reference frame based on the LUPA/RUPA, LUPB/RUPB, LUPC/RUPC, and LELB/RELB markers. The local coordinates of those points with respect to the upper arm technical reference frame are written to the model parameters (*.mp*) file for the subject within the active session folder. This resolves the problems caused by low visibility of medial markers and allows for increased freedom of movement during dynamic trials.

The LWRA/RWRA and LWRB/RWRB wrist joint center markers are used to define the upper arm anatomical reference frame. This eliminates the previous problem of very high inaccuracies when measuring the internal-external rotation at the upper arm as described in Cutti et al (2005). For details, see *References* on page 14.

Joint Kinematics

Joint kinematics are calculated for the Upper Limb Model using the Euler angles technique:

- **Shoulder:**
    - YZ'Y'' (plane of elevation, elevation, internal-external rotation) This Euler angle may require more complex clinical interpretation, but reduces the effect of the gimbal lock problem.
    - XZ'Y'' (flexion - extension, Ab - adduction, internal - external rotation).

    You can choose which of these two calculated Euler angle sequences to analyze for the shoulder depending on the motor task carried out by the subject.

- **Elbow**

    X'ZY'' (flexion-extension, internal-external rotation)

- **Wrist**

    X'ZY'' (flexion-extension, Ab-adduction)

For details on the Upper Limb Model variables that are output by a dynamic trial using the Upper Limb Model, see *Interpreting the Data* on page 12.