

## Vicon Upper Limb Model

### Marker Placement

- Thorax: IJ, PX, C7, T8
- Acromion marker cluster: 4 markers, placed so that the longer leg faces posteriorly (AClong), remaining markers numbered clockwise: AC2, AC3, AC4
- Humerus: 4 markers, first marker placed at a superior and posterior location on the humerus (HUMSupPost), remaining markers numbered clockwise: HUM2, HUM3, HUM4
- Forearm: EL, EM, RS, US

### Static Trials

First static trial: the subject is placed in the "motorcycle position". (This trial is optional: you can use one of the other static trials instead. The motorcycle position simply makes it easy to identify all upper limb markers.)

Remaining static trials require use of a calibrating probe. This is a stick with two markers along its length (PROX and DISL), with the point of the stick a known distance from the proximal marker (PROX). In the current Bodybuilder script, this distance is assumed to be 15 cm (based on the calibrating probe used in ORLAU).

In each of these trials, the point of the stick is placed on the location of one of the bony landmarks (see table below). The location of this bony landmark with respect to a particular segment will be saved during post-processing, so it is important that the segments listed in the table are clearly visible.

The first trial, besides recording the location of SC with respect to the thorax, is also used to save the location of EL and EM with respect to the humerus, so the humerus also needs to be visible.

Trial order	Bony landmark	Segment
1	SC	Thorax, Humerus
2	AC	Acromion
3	PC	Acromion
4	TS	Acromion
5	AI	Acromion
6	AA	Acromion

## Post-processing

There are three labeling skeleton templates that can be used with the upper limb model:

- UpperLimb.vst: only the 16 markers placed on the subject
  - UpperLimbCalib.vst: the 16 markers placed on the subject + the calibrating probe (2 extra markers - PROX and DISL). This is only used for the static trials.
  - UpperLimbForcePole.vst: the 16 markers placed on the subject + a pole with a force sensor (3 extra markers - MarkerT, MarkerB and MarkerS). This is only used for the trials where external forces are measured
1. In the Data Management window (bottom of Nexus window), go to the directory that contains the data files.
  2. In the Subjects panel (left), if you haven't already created your subject, click on "Create a new subject from a Labeling Skeleton", select the template "UpperLimb" and name your subject. Your subject will appear as <Subject Name>(UpperLimb).
  3. If you have MVC trials for EMG that do not contain kinematic data, export to C3D for further processing:
    - Select the MVC trials in the Data Management window, right click and select "Mark Trials"
    - If not already shown, click the "Show File Transfer/Batch Processing Interface (top right of the Data Management window). You will see the marked trials listed there.
    - Go to the Pipeline tool (top right of Nexus window) and create a new pipeline that contains the operation "Export C3D" (found under "File Export"). Save it as "Export MVC".
    - Select "Export MVC" from the menu in the bottom of the Batch Processing Interface, and click "Start Processing".
    - When finished, clear the trials from the Batch Processing Interface.
  4. Choose the static trial at the "motorcycle position" and run the "Reconstruct and Label" pipeline. Manually label any unlabeled markers, and run the "Scale Subject VSK" and "Static Skeleton Calibration" operations. Save your subject.
  5. To increase the covariances in the vsk file, which allows more relative movement between markers, you can also run "Functional Skeleton Calibration" using a dynamic trial, after you have labelled all the markers (but not filled in any gaps). Make sure you save your subject.
  6. For every dynamic trial (that does not involve the pole with the force sensor), run "Reconstruct and Label" (manually label any unlabeled markers), and save the trial. You can batch-process your trials (see step 3 above), but it is safer to check each one and make sure no markers are mislabeled. (Pay particular attention to US and RS.)

7. For the dynamic trials that involve the pole with the force sensor, right click on the subject name, select "Attach Labeling Skeleton Template..." and then "UpperLimbForcePole.vst". Reconstruct and label as in step 6. Always make sure that the pole markers are identified correctly (i.e. depending on how the pole is held, MarkerT and MarkerB might be misidentified).
8. Right click on the subject name, select "Attach Labeling Skeleton Template..." and then "UpperLimbCalib.vst". In the "Properties" window, click on "Add Parameter..." and add a parameter named MarkerFlag with value 1. Save the subject.
9. Move the operation "Run Static BodyLanguage Model" into the Current Pipeline and set the model file to Model\_ShoulderUL.mod.
10. For each of the six calibration trials:
  - Reconstruct and label as in step 6. Make sure the two markers on the calibrating probe are correctly identified (PROX is closer to point on the bony landmark).
  - Set MarkerFlag to the correct value. This is the same as "Trial order" in the table above. For example, when you are processing the trial for AI, set MarkerFlag to 5.
  - Run the Static BodyLanguage model. The position of the bony landmark in the local segment will appear under Properties of the subject and will also be written in the subject .mp file.
  - Note: If a marker is not visible at all for the duration of the trial, the Bodybuilder model will fail, even if that marker is not needed (e.g. if the trial is for a scapula marker and PX is not visible, the model will fail even though PX is not on the acromion marker cluster). In that case, open Model\_ShoulderUL.mod in a text editor, go to line 287, and add the marker that is missing to the list of optional points. Save the .mod file and run the operation again. Remember to remove the marker from the list of optional markers afterwards.
11. After you have added the location of all six bony landmarks, choose a trial where the acromion cluster is visible (e.g. the trial used for AA) and run the Static BodyLanguage Model again setting MarkerFlag to 7. This will calculate the location of GH using the regression equation of Meskers et al. (1998) and add it to the .mp file. The bony landmarks will also appear in the 3D Perspective window so you can check their location graphically.
12. Create a new pipeline that contains one of the "Filter Trajectories" operations, and the operation "Run Dynamic BodyLanguage Model" with the model file set to Model\_ShoulderUL.mod. Save it as "Calculate Upper Limb Angles". Select all dynamic trials that do not involve the pole with the force sensor and add them to the Batch Processing Interface (see step 3). Run "Calculate Upper Limb Angles". If you look under "Model Outputs" in the subjects panel, you should have Angles (ACAnglesYZX, ACthorAnglesYZX, ELAnglesXZY, GHAnglesYZY, GHthorAnglesYZY, SCAnglesYZX and THAnglesXYZ) and Modeled Markers (the

bony landmarks and virtual markers defining the segment coordinate frames). These will be exported to the C3D files.

13. Set the template to "UpperLimbForcePole.vst", the MarkerFlag to 8 and run the same pipeline on the trials that involve the pole with the force sensor. In the Model Outputs you will also get Forces: ForceAG.

### Troubleshooting

- During batch processing, if the progress box for any of the trials is red instead of green, check whether any markers were not visible for the entire duration of the trial, and assuming there were at least 3 other markers visible on each segment, set the missing markers to be optional in the BodyBuilder model (see note under step 10).
- If the Bodybuilder script is not calculating all the angles, check that the markers required to build each coordinate frame are visible. For example, "UPTECH", the humerus coordinate frame, requires HUMSupPost, HUM2 and HUM4. In theory, if HUM3 was visible instead of HUM4, the script should still work, but it doesn't seem to. In that case, replace HUM4 with HUM3 in the script and re-run both the static calibration trial (for the humerus this is trial 1) and the dynamic trials.
- If, when switching from one template to another (e.g. between steps 12 and 13) all the parameters disappear from the Properties window, navigate out of the data directory and in again... this appears to re-load the .mp file with all the parameters.