Documentation

PDB LS-DYNA

WorldSID 50th – Version 4.0

User's Manual
Manual Release 1.0 for Model v4.0
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1. General information

The development and validation has been performed on different platforms. The following LS-DYNA versions have been used:

LS-DYNA Version	Date	Revision Nr.
971 R6.1.2 MPP	11/05/2013	85139 Product ID 85274

Table 1: LS-DYNA versions

To offer a variety of LS-DYNA versions for the user to run the current WorldSID model, we tested the following releases with the barrier sled tests:

LS-DYNA Version	Date	Revision Nr.	recommended
971 R6.1.2 MPP	11/05/2013	85139 Product ID 85274	yes
971 R7.1 MPP	02/21/2014	87391 Product ID 87391	yes
971 R7.1.2 MPP	01/07/2015	97170 Product ID 97170	yes

Table 2: recommended LS-DYNA versions

With the version 4.0 of the WorldSID 50th model the following keyword files are delivered:

File name	Content
worldSID50_pdb_v4.0_mm_ms_kg.key	Dummy model; the file name might vary depending on the system of units
Psg_v1.3_...	Script to generate pre-simulation input (chapter 3.2).
wsid50_pdb_vx.x_all_units_COMPANY_NAME_DATE1_license_DATE2.asc	License file; the file name might vary depending on the system of units
wsid50_pdb_vx.x_all_units_load_curves_work.key	Work file used for pre-processing instead of license file. The file name might vary depending on the system of units
worldSID50_pdb_v4.0_H-Point_tool.key	H-Point measurement device

Table 3: Delivered Files

The work file wsid50_pdb_vx.x_all_units_load_curves_work.key can be used for pre-processing the dummy.
This work file includes the same input as the encrypted license file. The only difference is the scaling of the load curves in the work file. The load curves are scaled randomly in a wrong range and they are much too soft to be used for a LS_DYNA simulation. But the file can be used to observe the quality and course of the material curves.

A LS-DYNA simulation in use of the work file will give wrong results and is very unstable.

The numbering scheme of the original model is shown in Table 4. On request, we deliver renumbered input decks, according to user specifications.

Component	Min ID	Max ID	Total number
Nodes	10000	233234	221828
Solids	12001	143263	130679
Beams	10000	11561	745
Shells	145001	306609	160008
Discrete elements	10030	10065	26
Accelerometer	1001	1023	22
Set node	1002	1202	16
Set shell	1029	1029	1
Set parts	1001	1501	28
Parts	1	726	682
Materials	1001	1079	78
Sections	1001	1110	109
Hourglass	1001	1010	6
Airbags	1001	1002	2
Joints	1024	1024	1
Joint stiffness	1001	1048	27
Contacts	1001	1024	7
Local coordinate systems	1001	1096	69
Load curves / tables	1001	1138	121
Define SD orientation	1001	1014	14
Time history nodes	10001	10102	22
Time history beam elements	10000	10019	20
Time history discrete elements	10030	10065	26

Table 4: Model numbering scheme

1.1 Keywords used

The following control and database keywords are used:

*CONTROL_ACCURACY	*CONTROL_SHELL
*CONTROL_BULK_VISCOSITY	*CONTROL_SOLUTION
*CONTROL_CONTACT	*CONTROL_TERMINATION
*CONTROL_CPU	*CONTROL_TIMESTEP
*CONTROL_ENERGY	*CONTROL_MPP_DECOMPOSITION
*CONTROL_OUTPUT	_ARRANGE_PARTS

Table 5: Control cards used

The following database cards are defined:

*DATABASE_ABSTAT	*DATABASE_HISTORY_NODE_ID
*DATABASE_BINARY_D3PLOT	*DATABASE_JNTFORC
*DATABASE_BINARY_RUNRSF	*DATABASE_MATSUM
*DATABASE_DEFORC	*DATABASE_NODOUT
*DATABASE_ELOUT	*DATABASE_RBDOUT
*DATABASE_EXTENT_BINARY	*DATABASE_RCFORC
*DATABASE_GLSTAT	*DATABASE_SBTOUT
*DATABASE_HISTORY_BEAM_ID	*DATABASE_SLEOUT

Table 6: Database cards used

The following material models are used:

*MAT_ELASTIC	*MAT_RIGID
*MAT_FU_CHANG_FOAM	*MAT_SIMPLIFIED_RUBBER
*MAT_LINEAR_ELASTIC _DISCRETE_BEAM	*MAT_SIMPLIFIED_RUBBER _WITH_DAMAGE
*MAT_NULL	*MAT_SPRING_ELASTIC
*MAT_PLASTIC_KINEMATIC	*MAT_VISCOELASTIC
*MAT_SHAPE_MEMORY	

Table 7: Material models used

The following other keywords are used:

*CONSTRAINED_JOINT_CYLINDRICAL_ID	*ELEMENT_SEATBELT_ ACCELEROMETER
*CONSTRAINED_JOINT_REVOLUTE_ID	*ELEMENT_SHELL
*CONSTRAINED_JOINT_SPHERICAL_ID	*ELEMENT_SOLID
*CONSTRAINED_JOINT_STIFFNESS_ GENERALIZED	*END
*CONSTRAINED_JOINT_STIFFNESS_ TRANSLATIONAL	*HOURGLASS
*CONSTRAINED_RIGID_BODIES	*INITIAL_FOAM_REFERENCE_

*CONTACT_AUTOMATIC_SINGLE_SURFACE *CONTACT_FORCE_TRANSDUCER_PENALTY *CONTACT_TIED_SHELL_EDGE_TO_ SURFACE_... *DAMPING_PART_STIFFNESS *DEFINE_COORDINATE_NODES *DEFINE_CURVE *DEFINE_SD_ORIENTATION_TITLE *DEFINE_TABLE *ELEMENT_BEAM *ELEMENT_DISCRETE	GEOMETRY *KEYWORD *NODE *PART_... *SECTION_BEAM *SECTION_DISCRETE *SECTION_SHELL *SECTION_SOLID *SET_PART_LIST *SET_SHELL_LIST *TITLE

Table 8: Other keywords used in the model

After the *END keyword the following Primer keywords are defined:

*ASSEMBLY *DUMMY_END *DUMMY_START *H_POINT	*POINT_LOCATION *POSITION *UNITS

Table 9: Primer keywords used

2. Extraction of occupant injury criteria

To extract occupant injury criteria from the model, the following preparations have been made.

2.1 Sign convention in the Model

All relevant coordinate systems are defined according to the SAEJ211 norm. This means that all coordinate axes in the dummy are oriented with respect to an upright standing dummy. Thus the x-axis of the coordinate systems in the upper legs points upwards as shown in Figure 1.

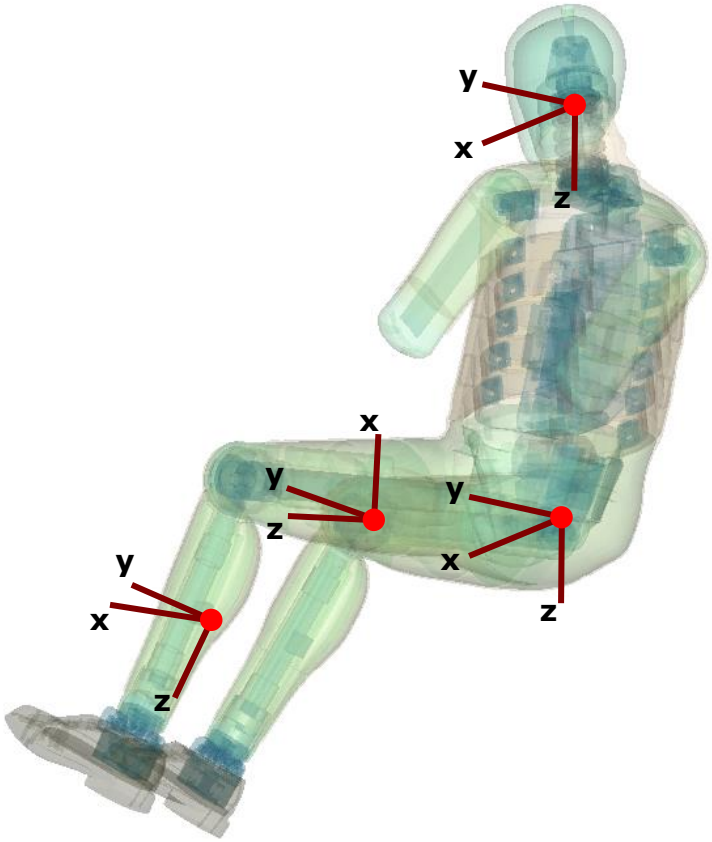


Figure 1: Orientation of the coordinate systems for accelerometers and load cells in the WORLDSID 50th model

Only the coordinate systems for evaluating injury criteria are oriented in this scheme. There are many more coordinate systems in the model which are sometimes oriented arbitrarily because of internal features in the dummy.

2.2 Accelerations

2.2.1 Head acceleration

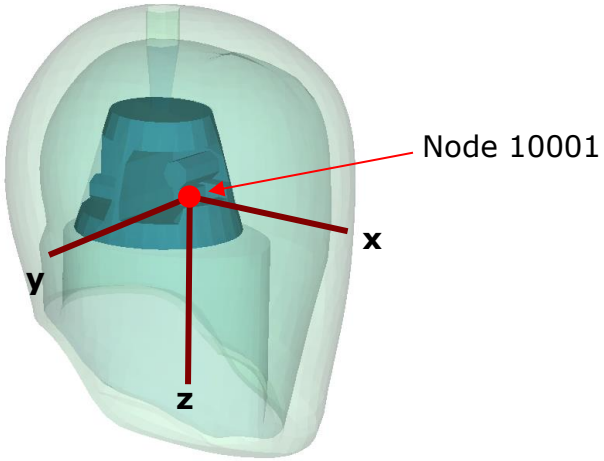


Figure 2: Head accelerometer and local coordinate directions

The marked node is the head accelerometer node. An accelerometer is defined at this node. This prints the results in the NODOUT file in the local coordinate system shown in Figure 2.

Item	Node-ID	Label	Available components
Head	10001	accelerometer head	local x-,y-,z- acceleration

Table 10: Head accelerometer node

2.2.2 T1, T4 and T12 acceleration

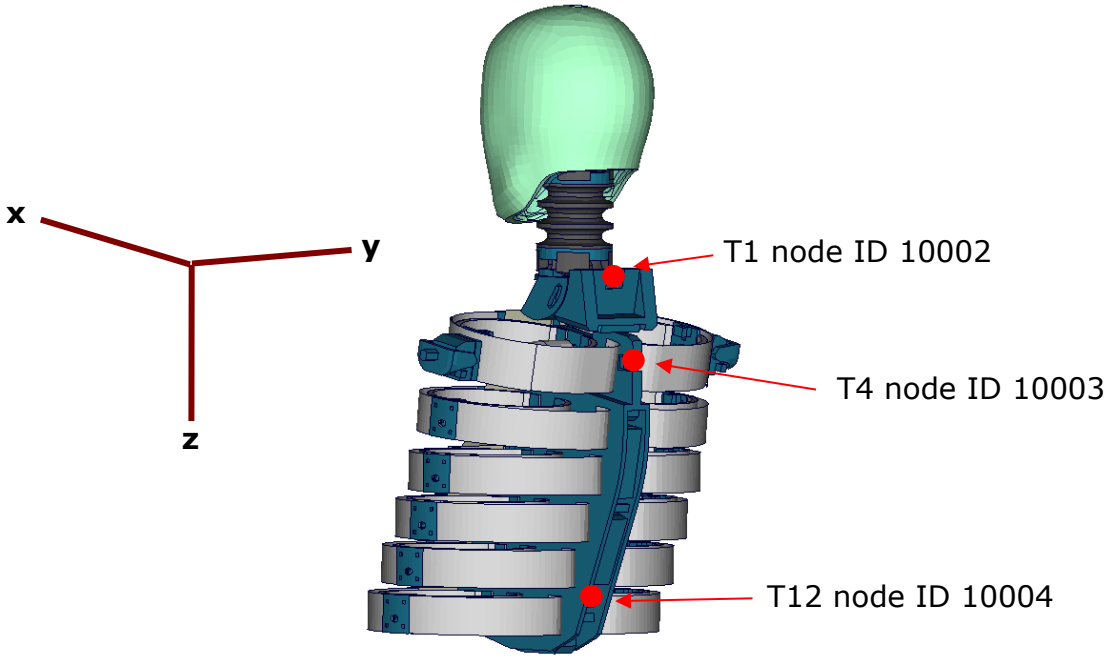


Figure 3: T1, T4 and T12 accelerometer nodes

The Figure 3 depicts the nodes which are used as output nodes in the NODOUT file for T1, T4 and T12 acceleration. For each single node, an accelerometer with the local directions is defined as shown in the Figure.

Item	Node-ID	Label	Available components
T1	10002	accelerometer T1	local x-,y-,z- acceleration
T4	10003	accelerometer T4	local x-,y-,z- acceleration
T12	10004	accelerometer T12	local x-,y-,z- acceleration

Table 11: T1, T4 and T12 accelerometer nodes

2.2.3 Pelvis acceleration

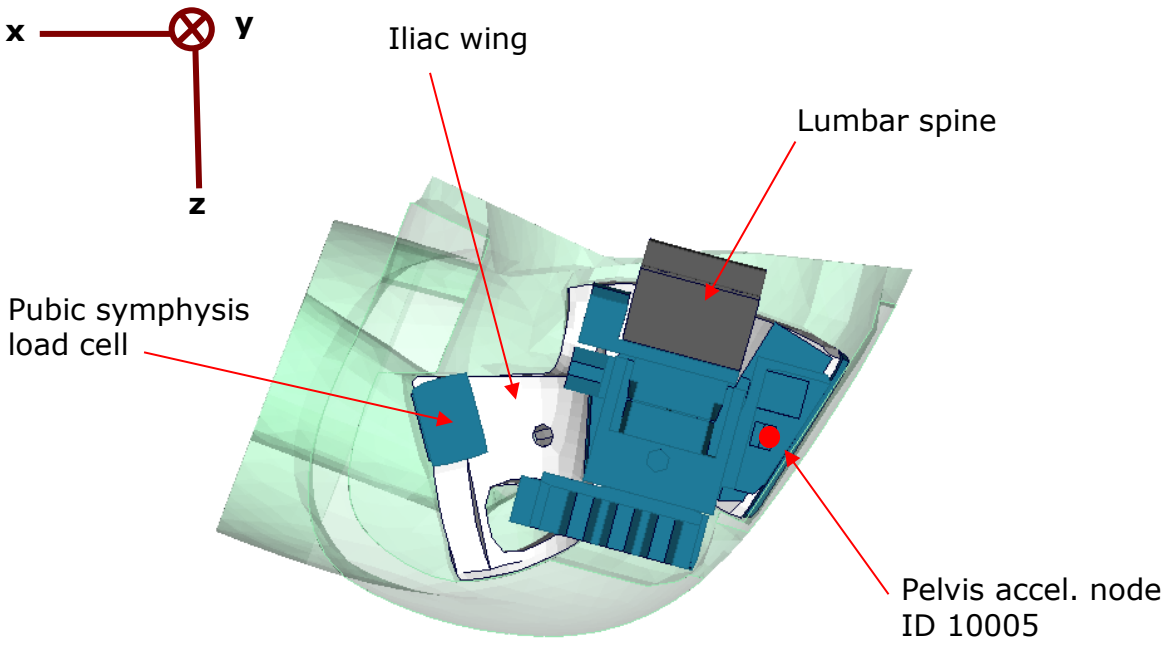


Figure 4: Node to extract pelvis acceleration.

In Figure 4, a plate cut through the pelvis along the z-x-plane is shown. The pelvis accelerometer is located at the back of the sacrum block. The results of the node 10005 are printed in the NODOUT file in the local coordinate system which is shown in Figure 4.

Item	Node-ID	Label	Available components
Pelvis	10005	accelerometer pelvis	local x-,y-,z- acceleration

Table 12: Pelvis accelerometer node

2.2.4 Rib accelerations

The WorldSID 50th model is equipped with twelve rib accelerometers. On each single rib, one accelerometer is mounted on the impact side and one on the opposite side.

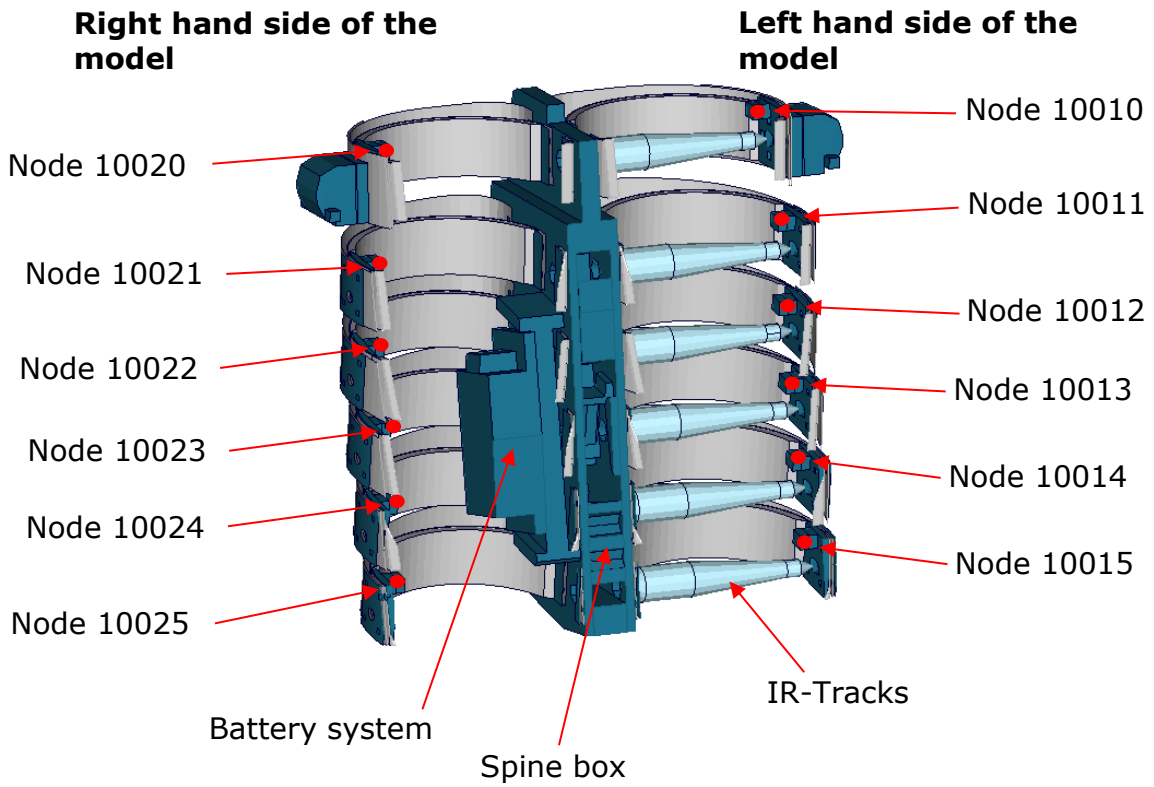


Figure 5: Cut through upper torso and position of rib accelerometer nodes

The nodal results are printed in the NODOUT file in the local coordinate systems of the accelerometers. On the impact side (left hand side for the left handed driver model) the nodes are:

Item	Node-ID	Label	Available components
shoulder rib	10010	accelerometer shoulder rib left	local x-,y-,z- acceleration
1. thorax rib	10011	accelerometer upper thorax rib left	local x-,y-,z- acceleration
2. thorax rib	10012	accelerometer middle thorax rib left	local x-,y-,z- acceleration
3. thorax rib	10013	accelerometer lower thorax rib left	local x-,y-,z- acceleration
1. abdomen rib	10014	accelerometer upper abdomen rib left	local x-,y-,z- acceleration
2. abdomen rib	10015	accelerometer lower abdomen rib left	local x-,y-,z- acceleration

Table 13: Rib accelerometer nodes on the side of impact

On the reverse side of impact (right hand side for the left handed driver model) the accelerometer nodes are:

Item	Node-ID	Label	Available components
shoulder rib	10020	accelerometer shoulder rib right	local x-,y-,z- acceleration
1. thorax rib	10021	accelerometer upper thorax rib right	local x-,y-,z- acceleration
2. thorax rib	10022	accelerometer middle thorax rib right	local x-,y-,z- acceleration
3. thorax rib	10023	accelerometer lower thorax rib right	local x-,y-,z- acceleration
1. abdomen rib	10024	accelerometer upper abdomen rib right	local x-,y-,z- acceleration
2. abdomen rib	10025	accelerometer lower abdomen rib right	local x-,y-,z- acceleration

Table 14: Rib accelerometer nodes on the side of impact

2.3 Load cells

All load cells in the model are defined in the same way. They are modeled using a discrete beam in combination with a local coordinate system. The results of the discrete beam are printed in the ELOUT file with respect to the local coordinate system. The local axes to evaluate the results of the beam are listed in Table 15.

Item	Component in elout file
local x-force	axial
local y-force	shear-s
local z-force	shear-t
local x-moment	torsion
local y-moment	moment-s
local z-moment	moment-t

Table 15: Components of ELOUT file for evaluating load cell results

2.3.1 Upper and lower neck load cell

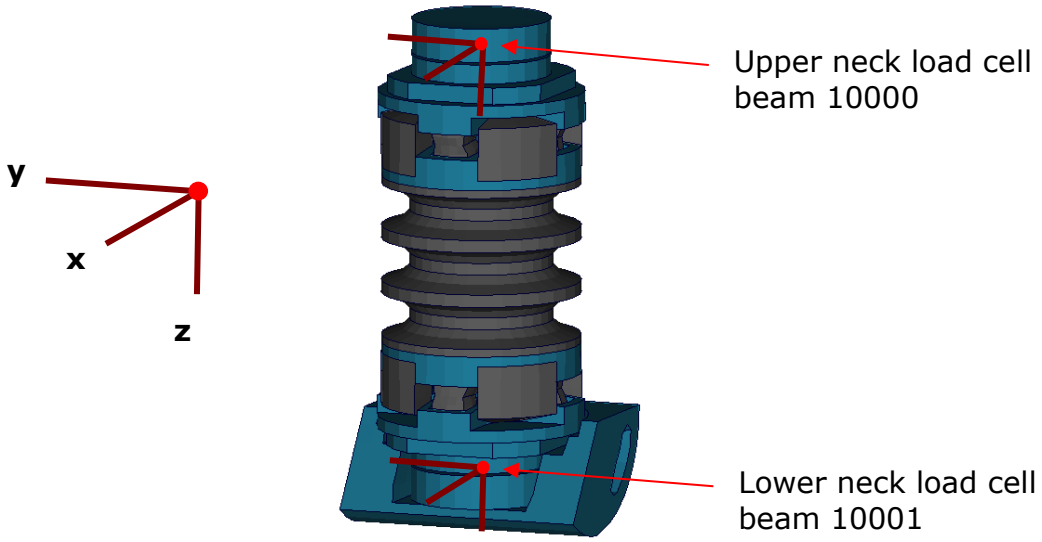


Figure 6: Upper and lower neck load cells

Item	Beam-ID	Label	Channels in physical dummy
Upper neck load cell	10000	upper neck load cell	six-channel load cell
Lower neck load cell	10001	lower neck load cell	six-channel load cell

Table 16: Upper and lower neck load cell beams

The neck load cells are six-channel load cells. This means that the forces and the moments in each direction of axis can be evaluated in the hardware.

2.3.2 Shoulder load cell left and right

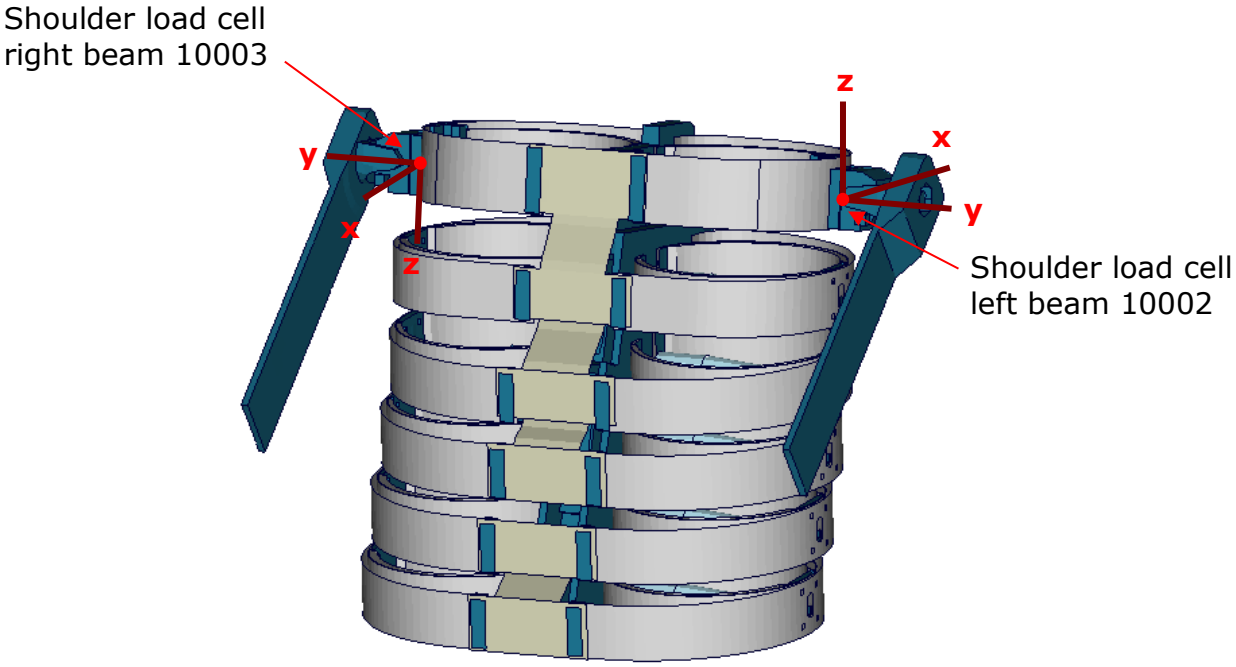


Figure 7: Shoulder load cells, left and right.

Item	Beam-ID	Label	Channels in physical dummy
Left shoulder load cell	10002	shoulder load cell left	three-channel load cell
Right shoulder load cell	10003	shoulder load cell right	three-channel load cell

Table 17: Shoulder load cell beams, left and right hand side

The shoulder load cells are three-channel load cells. This means that the forces in each direction of axis can be evaluated in the hardware.

2.3.3 Lumbar load cell

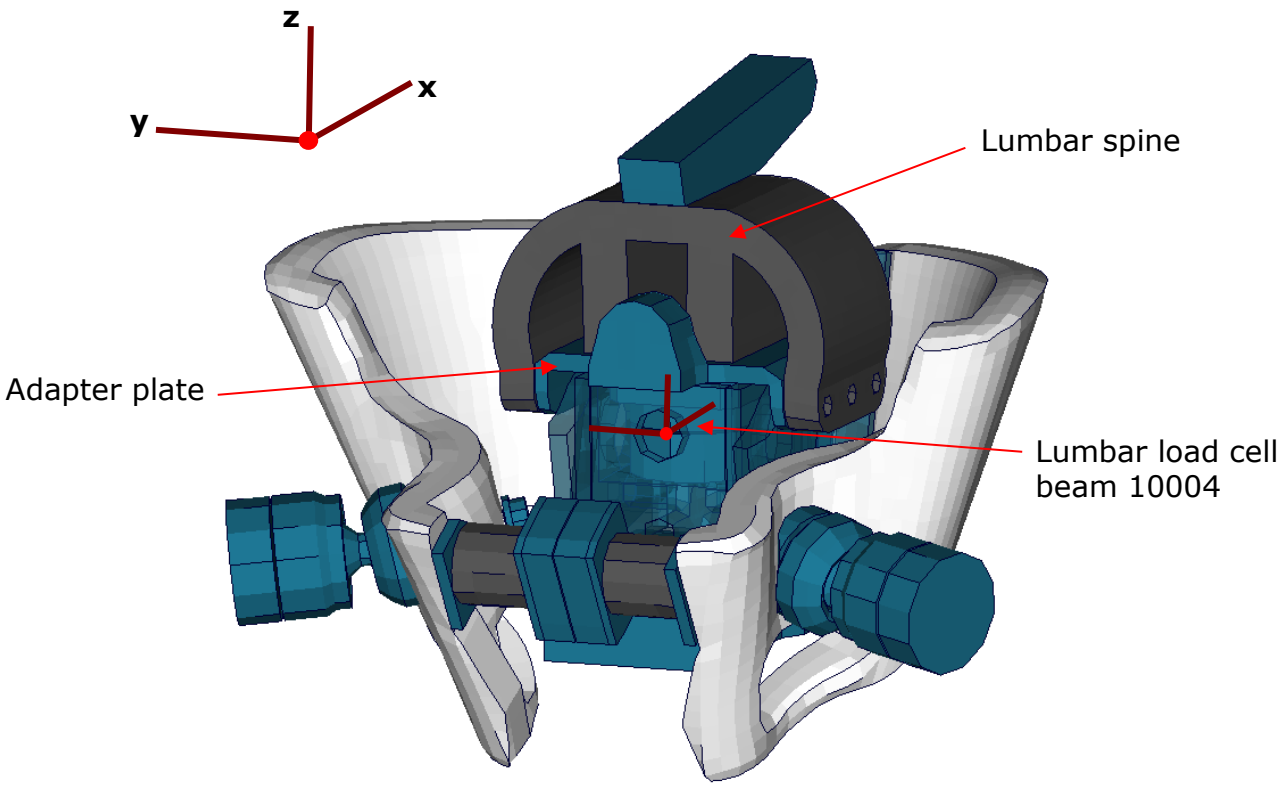


Figure 8: Lumbar load cell in Sacrum block

The lumbar load cell is adapted into the sacrum block. The load cell is connected to the adapter plate and the lumbar spine is connected on this adapter plate.

Item	Beam-ID	Label	Channels in physical dummy
Lumbar load cell	10004	lumbar load cell	six-channel load cell

Table 18: Lumbar load cell beam

The lumbar load cell is a six-channel load cell. This means that the forces and the moments in each direction of axis can be evaluated in the hardware.

2.3.4 Sacro-iliac load cells

The Sacro-iliac load cells are positioned on the left and right hand side of the sacrum block. They are used to measure the forces and moments which come from the pelvis bones into the sacrum block. The load cells are shown in the figure.

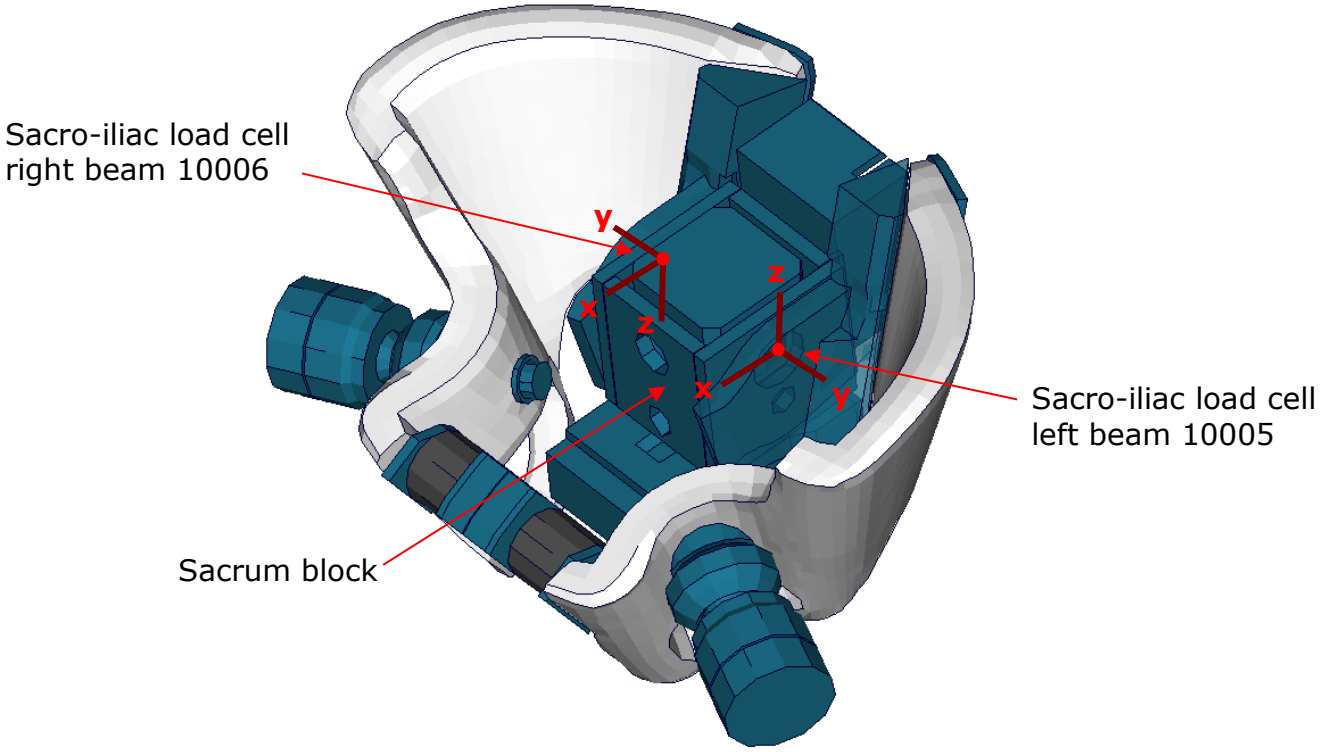


Figure 9: Sacro-iliac load cells, left and right hand side

Item	Beam-ID	Label	Channels in physical dummy
Sacro-iliac load cell left hand side	10005	sacro-iliac load cell left	six-channel load cell
Sacro-iliac load cell right hand side	10006	sacro-iliac load cell right	six-channel load cell

Table 19: Sacro-iliac load cell beams

The sacro-iliac load cells are six-channel load cells. This means that the forces and the moments in each direction of axis can be evaluated in the hardware.

2.3.5 Pubic symphysis load cell

Item	Beam-ID	Label	Channels in physical dummy
Pubic symphysis load cell	10007	pubic load cell	one-channel load cell

Table 20: Pubic symphysis load cell beam

The pubic load cell is a one-channel load cell. This means that only the force in the local y-direction can be evaluated in the hardware.

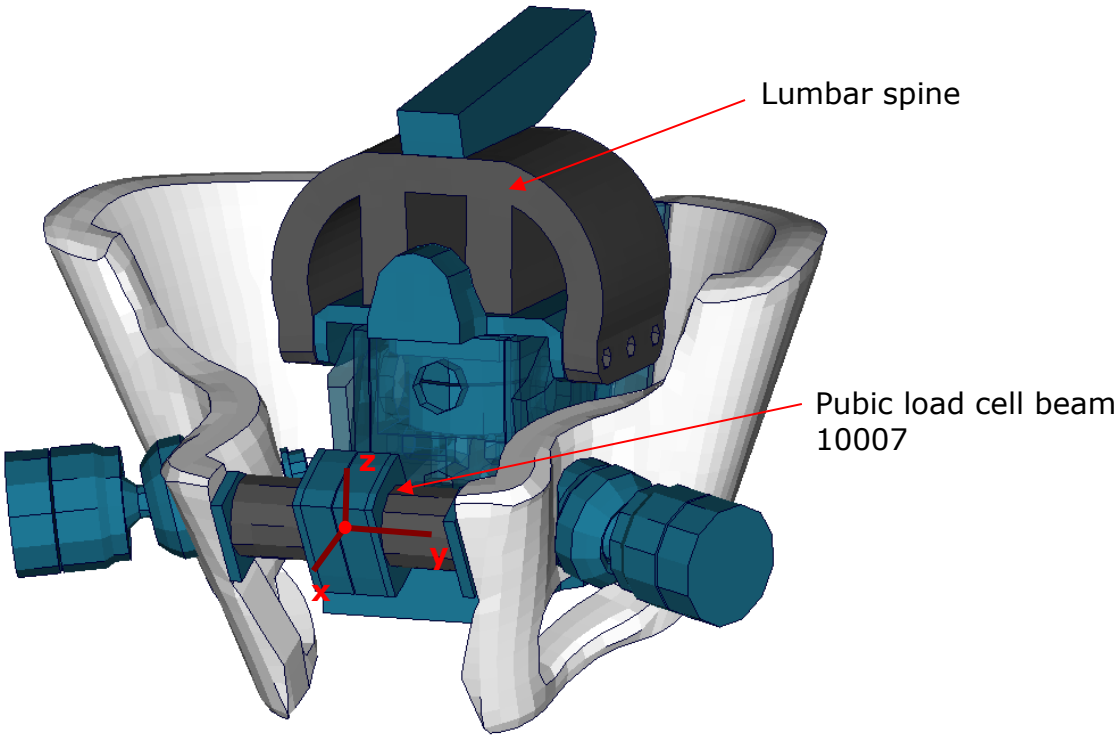


Figure 10: Pubic load cell adapted to pelvis bones

2.3.6 Femoral load cells

The upper legs of the WorldSID are equipped with four load cells: at the femoral neck of the left and right hand side, and in the middle of the left and right hand side femur.

Item	Beam-ID	Label	Channels in physical dummy
Femoral neck load cell left hand side	10008	femoral neck load cell left	three-channel load cell
Femoral neck load cell right hand side	10009	femoral neck load cell right	three-channel load cell
Femur load cell left hand side	10010	femur load cell left	six-channel load cell
Femur load cell right hand side	10011	femur load cell right	six-channel load cell

Table 21: Femoral load cell beams

The results of the load cells can be extracted as described in the following Table. The exact location of the load cells is shown in the figure below:

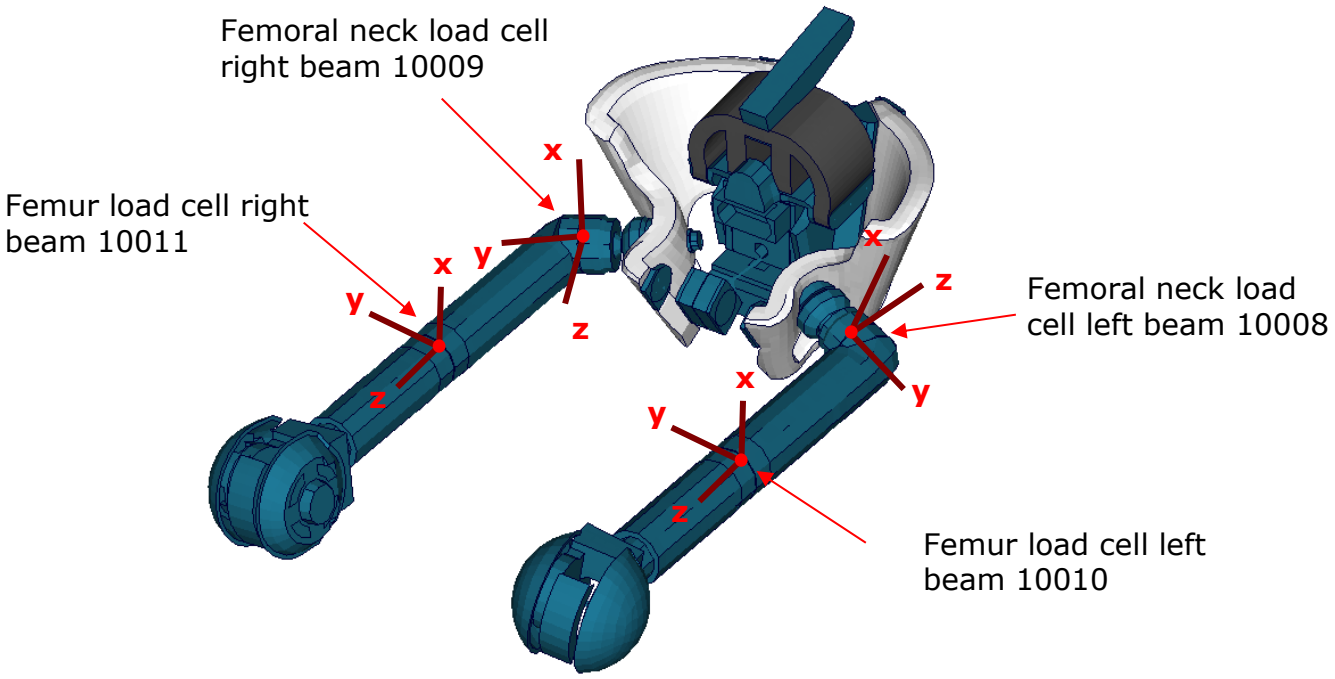


Figure 11: Upper and lower femur load cells

2.3.7 Knee load cells

The knee load cells can be used to determine the contact times. The load cells in the hardware are only one channel load cells.

Item	Beam-ID	Label	Channels in physical dummy
outboard knee load cell left	10012	outer knee contact load cell left	one-channel load cell
outboard knee load cell right	10013	outer knee contact load cell right	one-channel load cell
inboard knee load cell left	10014	inner knee contact load cell left	one-channel load cell
inboard knee load cell right	10015	inner knee contact load cell right	one-channel load cell

Table 22: Knee load cell beams

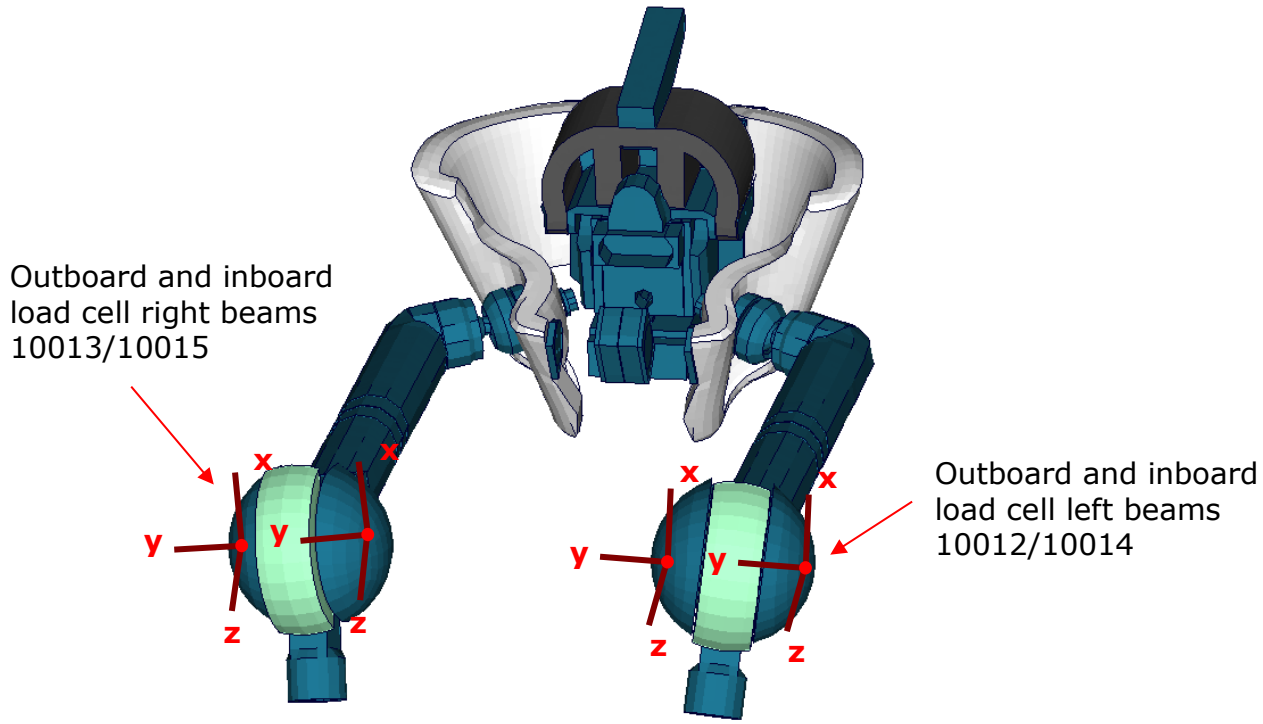


Figure 12: Knee load cell beams

2.3.8 Tibia load cells

The tibias are also equipped with four load cells. Each tibia consists of two load cells, in the upper and the lower tibia. They are listed in the Table 23. The location of the load cells is depicted in the figure below:

Item	Beam-ID	Label	Channels in physical dummy
Upper tibia load cell left	10016	upper tibia load cell left	six-channel load cell
Upper tibia load cell right	10017	upper tibia load cell right	six-channel load cell
Lower tibia load cell left	10018	lower tibia load cell left	six-channel load cell
Lower tibia load cell right	10019	lower tibia load cell right	six-channel load cell

Table 23: Tibia load cell beams, left and right hand side

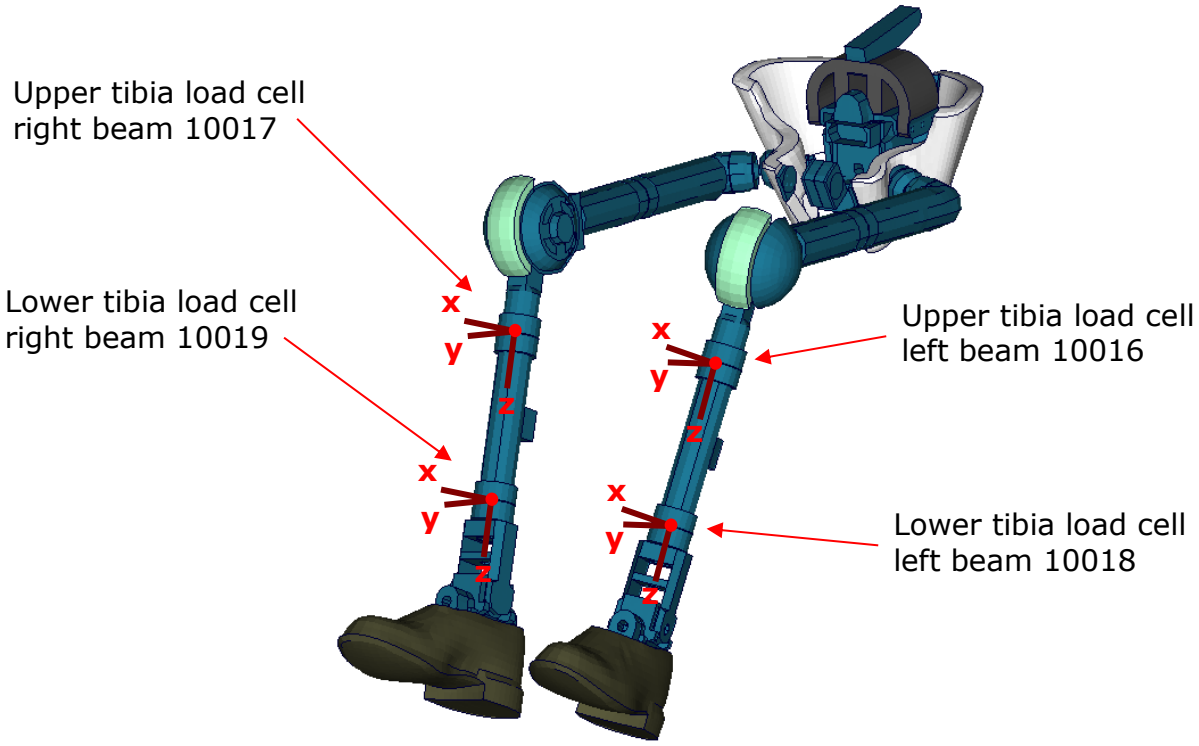


Figure 13: Tibia load cell beams

2.4 Deflections and rotations

In the WorldSID model, it is possible to measure deflections and also rotations of some parts. Therefore discrete elements, which have no stiffness, are used. The elements are only used for the purpose of measurement and do not influence the results of the model. The output of these elements is included in the DEFORC file. From the hardware SBL E1 the WorldSID is equipped with the 2D IR-TRACCs, i.e. the deflection and the rotation of the rib is measured. The LS-DYNA WorldSID model offers the 1D and the 2D IR-TRACC measurement devices.

2.4.1 Rib deflections 1D (up to hardware SBL E)

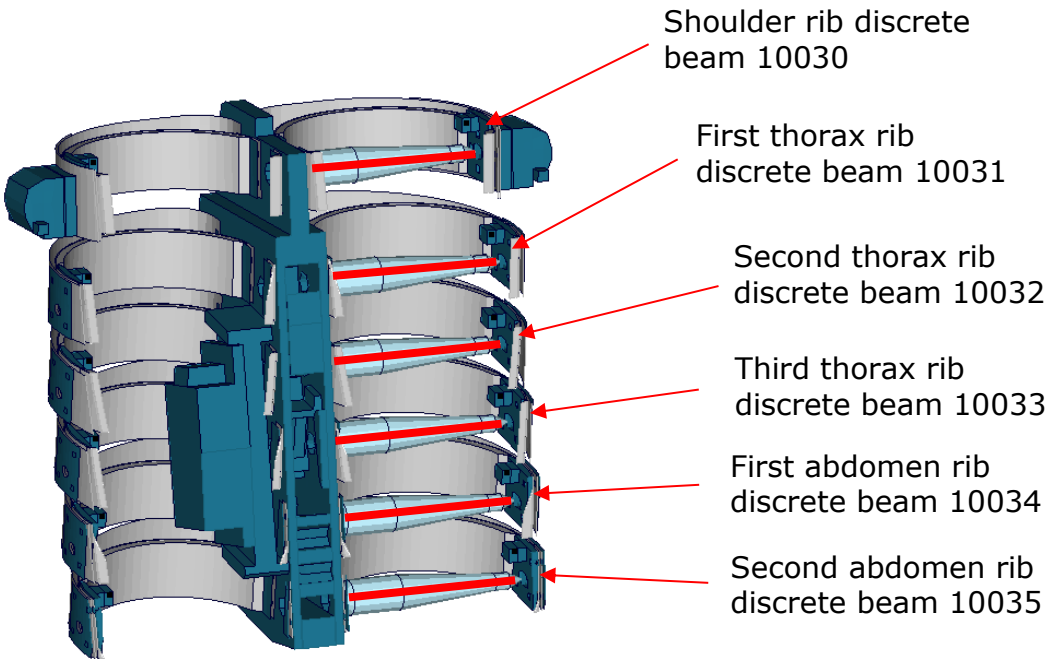


Figure 14: Cut through upper torso and location of rib deflection measurement springs

Item	Discrete beam-ID	Label	Available components
shoulder rib	10030	no label	change in length
1. thorax rib	10031	no label	change in length
2. thorax rib	10032	no label	change in length
3. thorax rib	10033	no label	change in length
1. abdomen rib	10034	no label	change in length
2. abdomen rib	10035	no label	change in length

Table 24: Rib deflection measurement using discrete elements (1D IR-TRACCs)

2.4.1 Rib deflections 2D (from hardware SBL E1)

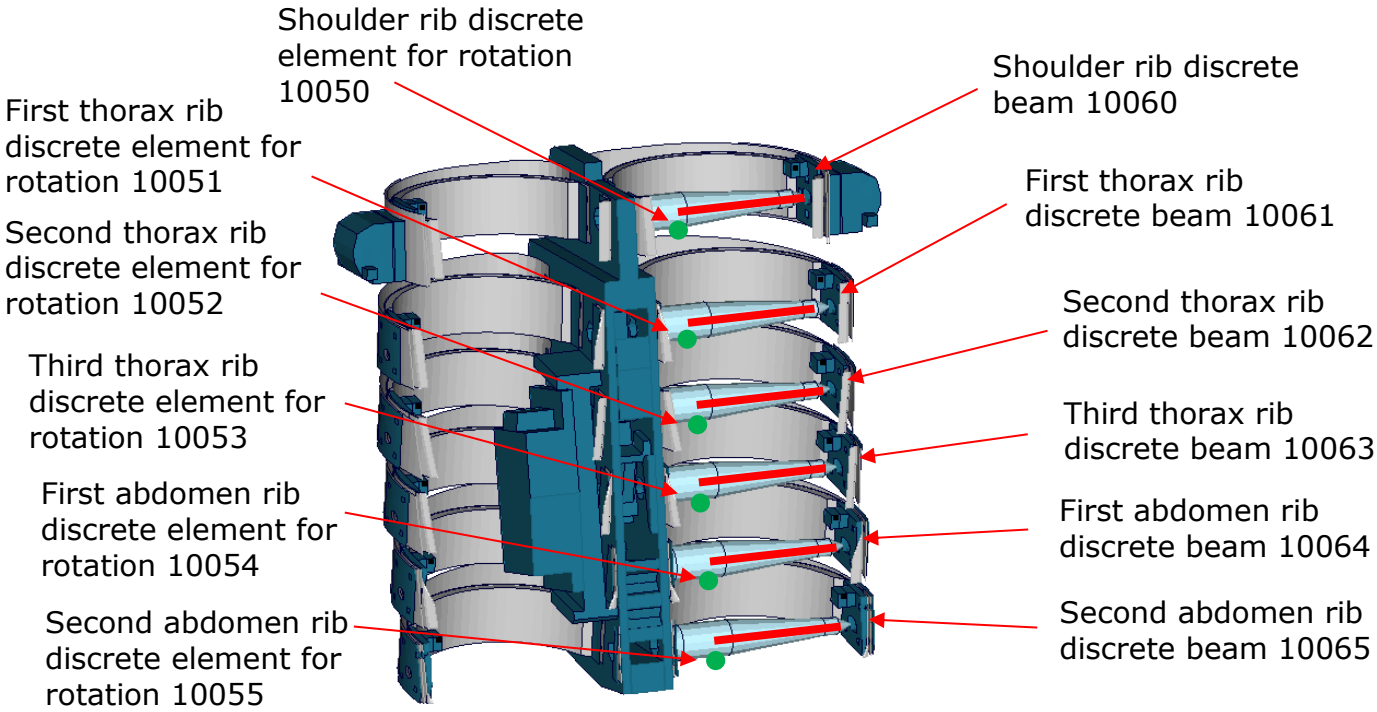


Figure 15: Cut through upper torso and location of rib deflection measurement springs

Item	Discrete beam-ID	Label	Available components
shoulder rib	10060	no label	change in length
1. thorax rib	10061	no label	change in length
2. thorax rib	10062	no label	change in length
3. thorax rib	10063	no label	change in length
1. abdomen rib	10064	no label	change in length
2. abdomen rib	10065	no label	change in length

Table 25: Rib deflection measurement using discrete elements (2D IR-TRACCs)

Item	Discrete beam-ID	Label	Available components
shoulder rib	10050	no label	rotation
1. thorax rib	10051	no label	rotation
2. thorax rib	10052	no label	rotation
3. thorax rib	10053	no label	rotation
1. abdomen rib	10054	no label	rotation
2. abdomen rib	10055	no label	rotation

Table 26: Rib rotation measurement using discrete elements (2D IR-TRACCs)

For EuroNCAP evaluation the local x- and y- deflections in respect to the spine box is calculated by an equation.

In simulation model we also added possibility to evaluate the local x- and y-deflections directly form the nodout file. Therefor the following Nodes are defined:

Item	Node-ID	Label	Available components
shoulder rib	10751	shoulder rib deformation Local X/Y/Z	x-, y-, z-displacement
1. thorax rib	10752	1 thorax rib deformation Local X/Y/Z	x-, y-, z-displacement
2. thorax rib	10753	2 thorax rib deformation Local X/Y/Z	x-, y-, z-displacement
3. thorax rib	10754	3 thorax rib deformation Local X/Y/Z	x-, y-, z-displacement
1. abdomen rib	10755	1 abdomen rib deformation Local X/Y/Z	x-, y-, z-displacement
2. abdomen rib	10756	2 abdomen rib deformation Local X/Y/Z	x-, y-, z-displacement

Table 27: Rib local measurements in respect to Torso using nodout (2D IR-TRACCs)

The results of these nodes should give the same output than calculation the local deflections from resultant deflection and rotation of 2D IR-TRACCs.

2.4.2 Knee and ankle rotation

The WorldSID also offers the possibility to measure the relative rotations between the upper legs and the lower legs and also between the lower legs and the feet. Therefore discrete elements are additionally used to measure these rotations. The location of the elements in the model is depicted in the following figure.

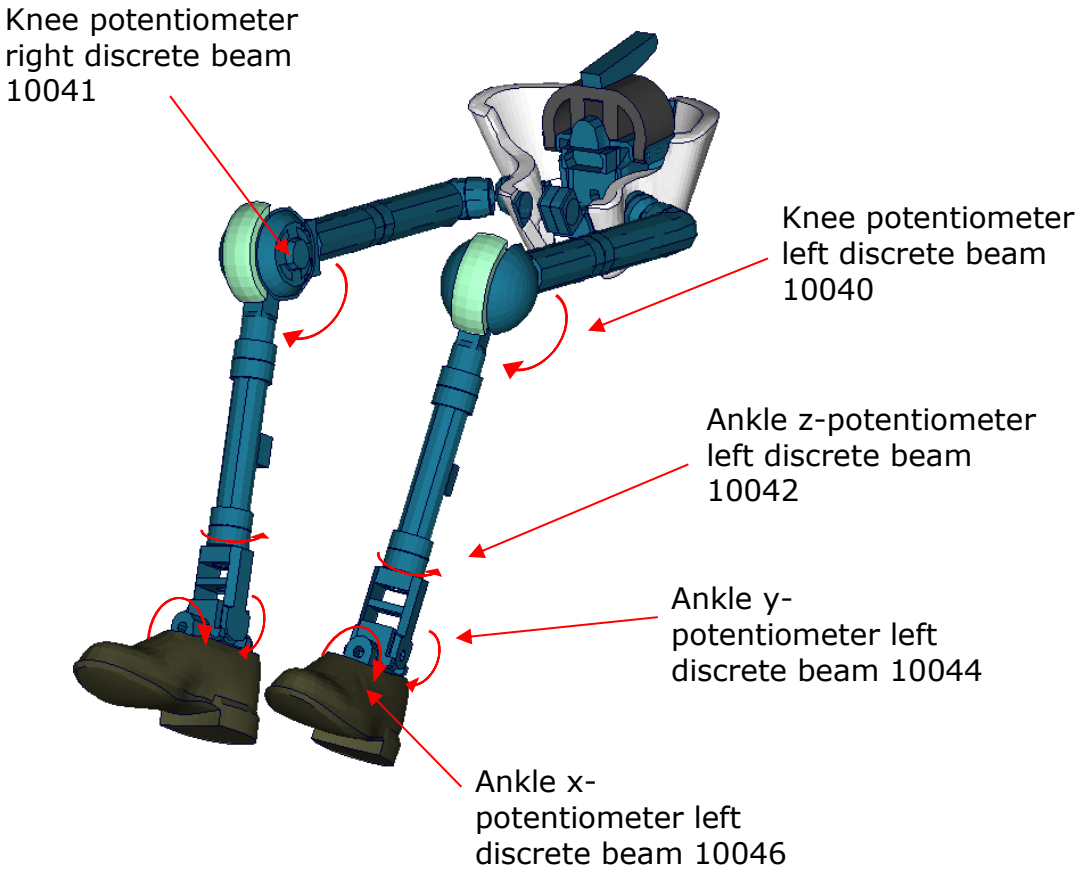


Figure 16: Location of rotation measurement springs in the WorldSID model

Item	Discrete beam-ID	Label	Available components
knee potentiometer y-rotation left	10040	no label	change in length
knee potentiometer y-rotation right	10041	no label	change in length
ankle potentiometer z-rotation left	10042	no label	change in length
ankle potentiometer z-rotation right	10043	no label	change in length
ankle potentiometer y-rotation left	10044	no label	change in length
ankle potentiometer y-rotation right	10045	no label	change in length
ankle potentiometer x-rotation left	10046	no label	change in length
ankle potentiometer x-rotation right	10047	no label	change in length

3. Incorporating the dummy into vehicle models

3.1 Positioning by preprocessor

The WorldSID model is delivered with a tree file for the Primer pre-processor (may also work for ALTAIR Hypermesh, BETA CAE-Systems ANSA and LS-PrePost, not verified by DYNAmore). This allows the user to position the dummy and adjust the parts according to their degrees of freedom. The Figure below shows the connections of movable parts via tree file. All revolute joints are visualized by beams.

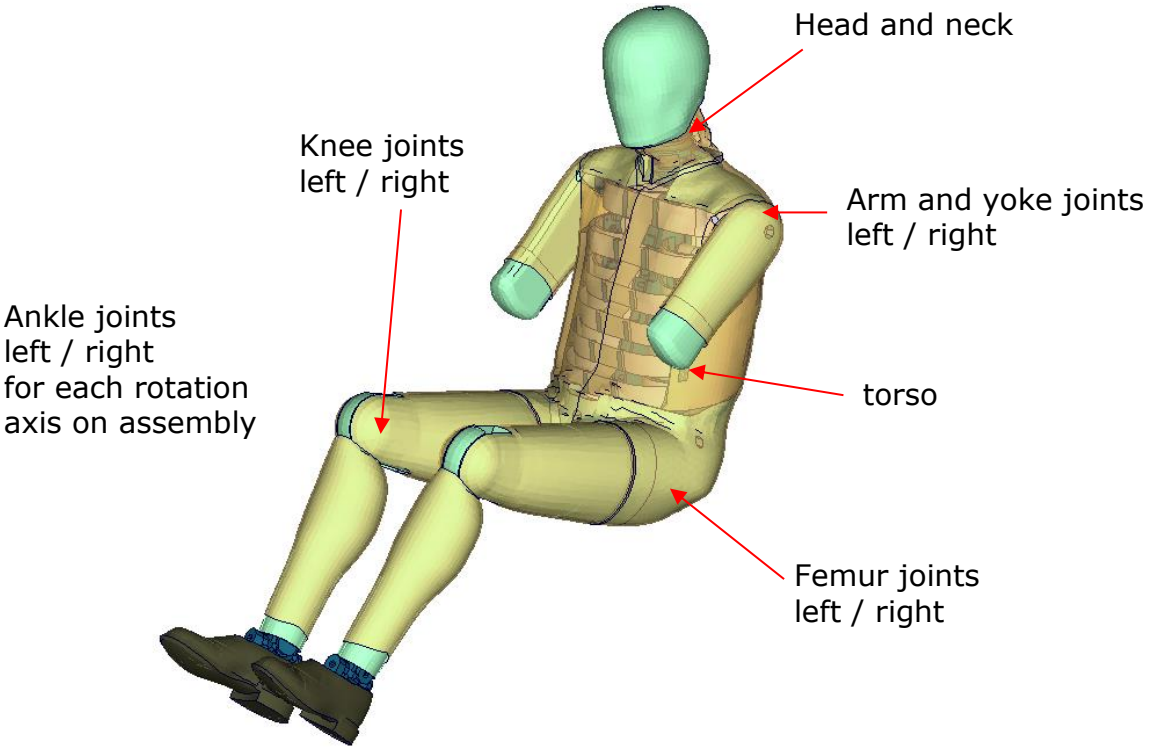


Figure 17: Tree-file assemblies of the WorldSID model.

Two coordinate systems are modelled at the H-Point of the dummy model. These coordinate systems are connected to each other by a spherical joint. One coordinate system is constrained to global directions, which means only translations are possible, rotations are disabled. The other one is connected to the dummy, thus making it possible to measure the pelvis angle of the WorldSID during the positioning simulation quickly and easily. These coordinate systems are also used to determine the initial pelvis angle with Primer.

Movable parts and revolute joints are:

assembly	stop angles
Foot, left and right about their ankle joints	
local z-axis	stop angle: -29.0 and 29.0 degrees
Lower leg, left and right about their knee joints:	
local y-axis	stop angle: -0.1 and 145.0 degrees
Upper leg bone, left and right about hip joint:	
local x-axis	no stop angle
local y-axis	no stop angle
local z-axis	no stop angle
Torso	no stop angle

Head and neck	no stop angle
Upper arm	no stop angle
Yoke	no stop angle

Table 28: Movable parts of WorldSID by a pre-processor

The stop angles of the feet and the knees are adjusted to the physical range of motion of the individual components.

However it might be possible that some pre-processors do not support the stop function of this tree-file structure. In this case, initial penetrations can occur if the upper legs are rotated at the hip joints beyond the values given in Table 28. This reaction is based on the hardware. In the hardware, the geometry is deformed if the position of the upper leg is changed with respect to the pelvis.

The arms cannot be rotated in a pre-processor, because the jacket has to be deformed when the arms rotate. Here we recommend a pre-simulation to rotate the arm in the desired position.

3.2 Positioning by pre-simulation

For the WorldSID v4.0 DYNAmore developed a new positioning pre-simulation procedure. The basic idea for this was to improve and simplify the usability of the dummy model. There are only a few steps necessary to achieve a correct positioned and ready-to-run WorldSID dummy model.
The first step is to adapt the posture of the dummy to your desired position in your car by using the preprocessor of your choice. You should not take care of penetrating parts and highly distorted elements. Save this dummy model to a separate file.

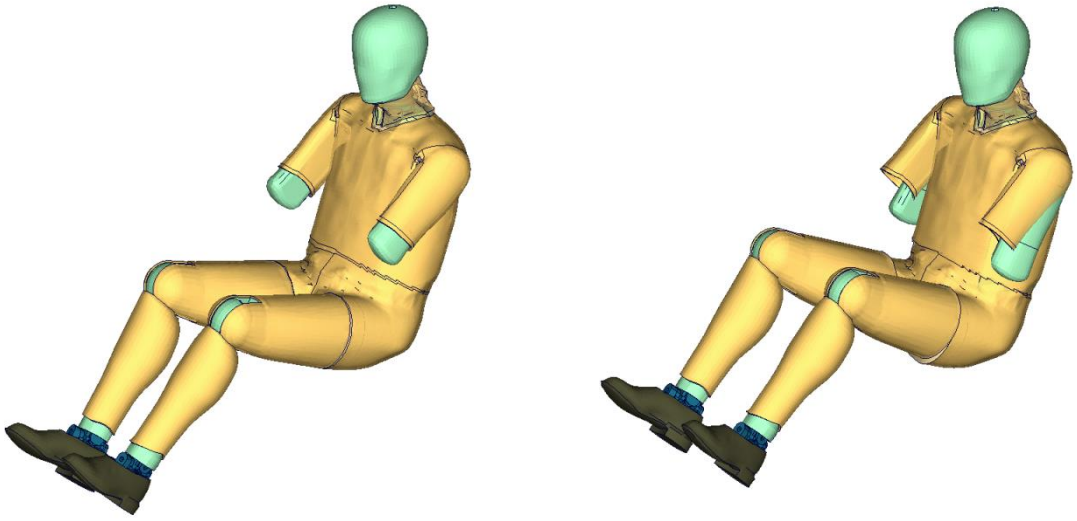


Figure 18: WorldSID origin position (left) and target position (right)

Second step is to run the enclosed positioning script which is enclosed to the delivery package. The script needs the dummy model inputs of the origin and the target position. Run

```
psg_vX.X_... -d dummyinput_origin.key -t target_pos_dummy.key
```

The script generates a pre-simulation input for LS-DYNA. This one refers to the origin dummy model input (and also the license file) as a include file.
The script is generating a BOUNDARY_PRESCRIBED_FINAL_GEOMETRY Card for the positions of Pelvis, Torso, Head/Neck and upper legs. For all other libs, there are generated spring and damper elements which pull the limbs in position.

The third step is to run the generated input in LS-DYNA and use the results for your actual car model as the initial geometry.

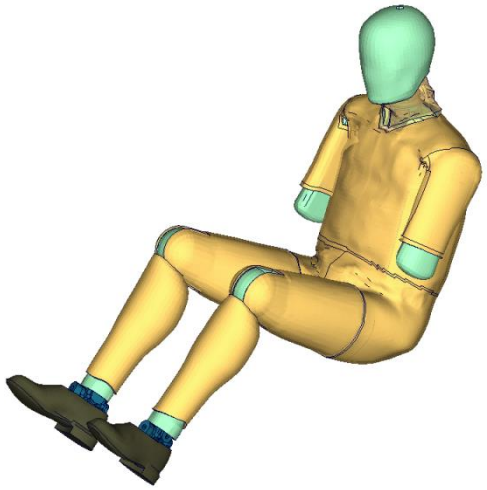


Figure 19: WorldSID position after pre-simulation

The Results can be extracted bye using any post processors. Only the new nodal coordinates are needed for the new position.

A very helpful tool to replace the nodal coordinates in the original Input is plot2coor from the DYNAmore LS-DYNA Tools. This Tool can be requested on our Webpage here:

http://www.dynamore.de/en/products/tools

Pretentions are automatically applied by reference geometry so you do not have to take care about this.

3.3 Measurement of pelvis and torso angle

The pelvis, torso and head angles are measured in the physical WorldSID by three tilt sensors. These three sensors are also included in the model. They can be used to measure the pelvis and torso angle as shown in the following figure.

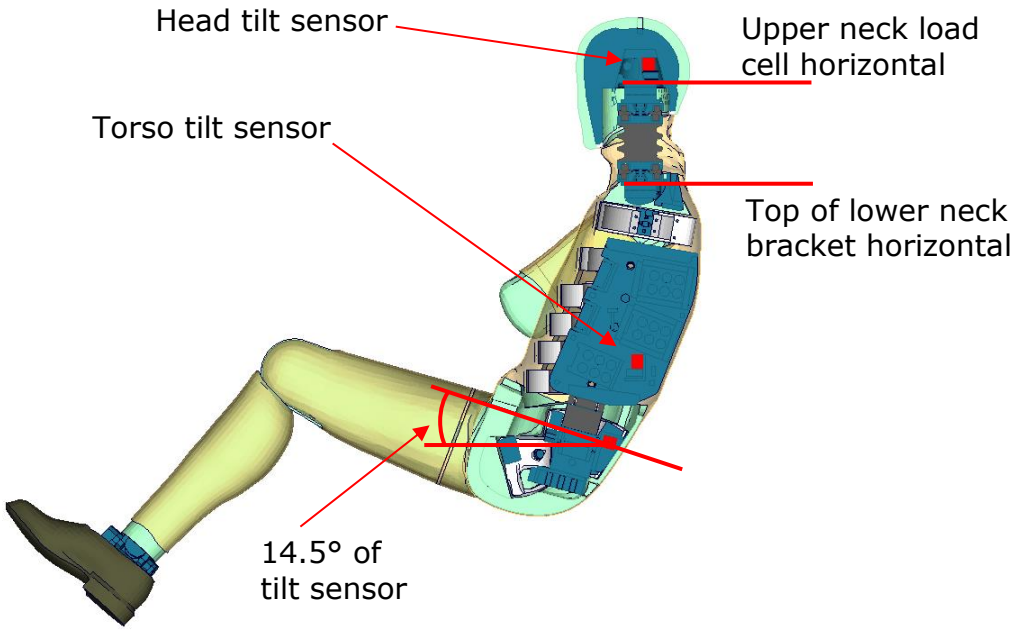


Figure 20: Cut through WorldSID model with positions of tilt sensors

The initial position of the WorldSID model uses a pelvis angle of 14.5 degrees. For this position the H-Point tool, which is used to measure the pelvis angle without tilt sensor, has an angle of 45 degrees below the horizontal. For this pelvis angle, the torso (top of the lower neck bracket is horizontal) and head (upper neck load cell is horizontal) angle is zero degrees.

3.4 Numbering

- Nodes in the range of 10.000 to 11.000 are used for joints, accelerometers, ... definitions.
- Nodes with node IDs above 11.000 are used only in *NODE and *ELEMENT cards.
- Elements in the range of 10.000 to 11.000 are used for history, discrete elements, ... definitions.
- Elements with IDs above 11.000 are used only in *ELEMENT cards.

The numbering of the material tables and load curves is defined by parameters. The default range is given in Table 4: Model numbering scheme Table 4. If the model should be renumbered all tables and load curves must be renumbered by using the parameter **lcoff**. This parameter gives a numbering offset on all table IDs and load curve IDs.

3.5 Contact Definition

Please define a *CONTACT_AUTOMATIC_SURFACE_TO_SURFACE for the contact between dummy and seat (environment). We recommend the use of the SOFT 1 option of LS-DYNA, because this option shows a high robustness for contact between very stiff and very soft components. The WorldSID properties for this contact are defined in the part set 1500.

The second part set defined in the model (Part Set ID 1501) includes all parts of the model in it. This set can be used to exclude the model out of contacts, which are defined by the use of exclude part sets.

3.6 Additional Remarks

- The modification of the *CONTROL cards of the dummy file may have an influence on the performance and robustness of the model. Therefore the *CONTROL cards of the dummy models are proposed for integrated simulations as well.

  Important flags on LS-DYNA control cards:

  - CONTROL ACCURACY flag INN=2
  - CONTROL BULK VISCOSITY flag TYPE=-1
  - CONTROL SHELL flag ESORT=1
  - CONTROL SOLID flag ESORT=1
  - CONTROL_MPP_DECOMPOSITION_ARRANGE_PARTS

- If the CONTROL_MPP_DECOMPOSITION_ARRANGE_PARTS is erased from the model the simulation time in large models can be two or three times longer. It is strongly recommended to use this control card in MPP simulations.

- The model should be used with a time step size of 0.9 microseconds or less!

- If a model for right side impact is needed, please contact DYNAmore. RHD models in both systems of units are available.

- All nodes are connected to an element, except the third beam nodes of the beam elements.

- No mass less nodes are present in the input file of the dummy except the third beam nodes of the beam elements.

- The model is free of initial penetrations.

- The Version 4.0 and higher of the WorldSID provides parameters to scale the friction of the joint off all limbs. As default a 1 g adjustment of the joints is included. The user is now able to increase ore decrease the friction values of the joints. The scale factors are used for the left and right

hand side assemblies. So it is not possible to scale left and right assembly different.

Parameter name	Joint
Sfarmx	Scale factor arms local x-rotation
sfarmy	Scale factor arms local y-rotation
sffemr	Scale factor upper legs all directions
sfknee	Scale factor knees
sfankl	Scale factor ankle joins all directions

Table 29: Parameters to scale joint friction

4. License file and usage

The WorldSID is distributed with a license file which uses an expiry date. The license file is sent to the user with the whole dummy package. It is a PGP encrypted part of the dummy model input and includes all load curves referenced in the WorldSID model. For the WorldSID there is a general license file for any unit system provided.
There are parameters defined which can be used to offset the numbering of the load curves. The load curves can be scaled by using parameters provided in the main WorldSID input. The names of the parameters refer to the table or load curve ID of each material. So if the values of the table ID 1002 are to be scaled then the parameter s1002 should be used.

The principle structure is as follows:

Input data in the WorldSID license file:

```
*PARAMETER
$ Load Curve offset
I lcoff           0

$ Load Curve scale values
R sTABID         1.0
```

Input of the license file:

```
*PARAMETER_EXPRESSION
I lcTABID    TABID + &lcoff
R eTABID     1.0 * &sTABID


*DEFINE_CURVE
&lcTABID           0       1.0&eTABID            0.0         0.0
          <Values_x>          <Values_y>
              .
              .
              .
```

The license file must be included like a normal include file. But it is necessary that the license file is included **IN** the WorldSID model main file **AFTER** the *PARMETER block. If you get error messages like “missing parameter” you should check if the license file is included at the correct position in the file.

The expiry date and the owner of the license are printed out in the message file of LS-DYNA. The name of the license file also includes the company name and the expiry date of the dummy.

We recommend storing the license file of dummy models in a central place as read only. Furthermore the name of the license include should be simple like for instance

wsid_v4.0_license.asc.

With a symbolic link from the current license to this name it is possible to keep older input decks running without updating the input data of them.

For the work in a pre-processor, an additional file is delivered:

wsid50_pdb_v4.0_all_units_load_curves_work.key

This work file includes the same input as the encrypted license file. The only difference is the scaling of the load curves in the work file. The load curves are scaled randomly in a wrong range and they are much too soft to be used for a LS_DYNA simulation. But the file can be used to observe the quality and course of the material curves.

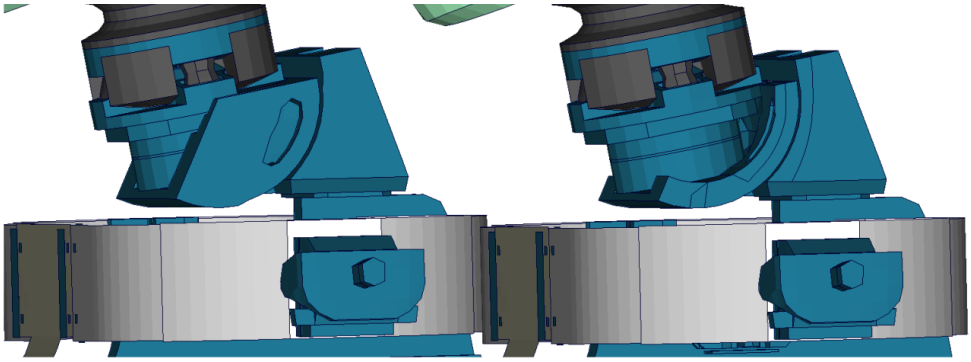
A LS-DYNA simulation in use of the work file will give wrong results and is very unstable. So if you observe dummy model crashes without appreciable load you should check if you included the load-curves-work file instead of the license file.

5. Release Notes

5.1 Release notes of WorldSID v4.0

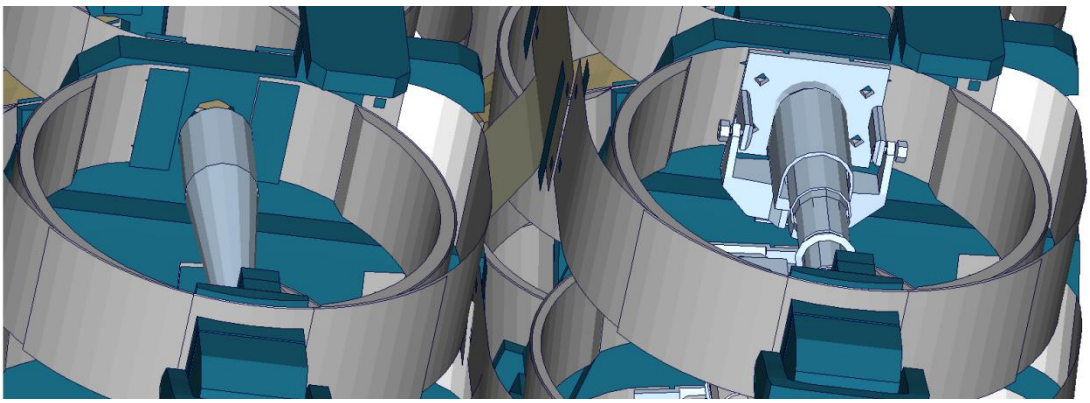
- Geometric modifications to the latest ISO hardware state (SBL-E):
    - Geometric update of neck bracket and can be adjusted also in positioning simulation.

WSID v3.5 v4.0



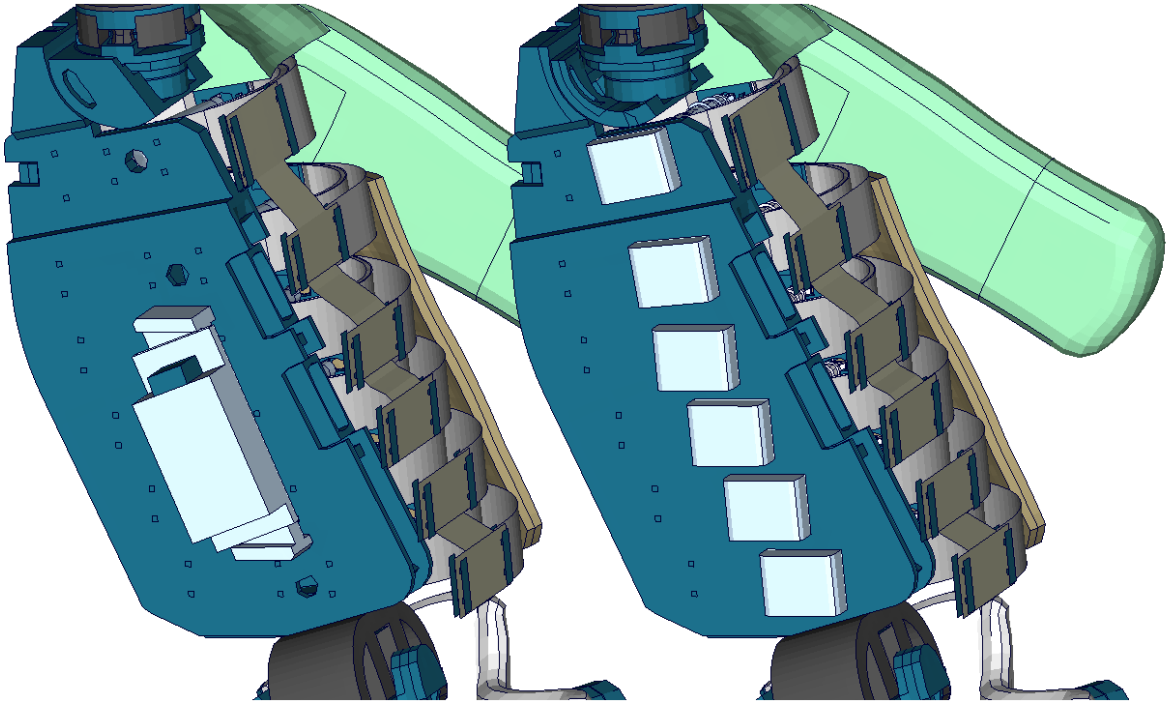
    - Update of 2D IR-TRACC geometry. Due to this the physical stop angles are captured much more accurate.

WSID v3.5 v4.0



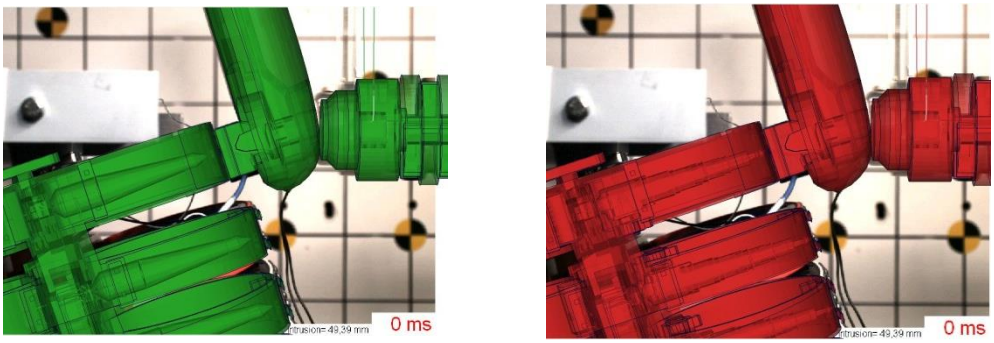
- Battery in thorax has been changed to some smaller mass replacements

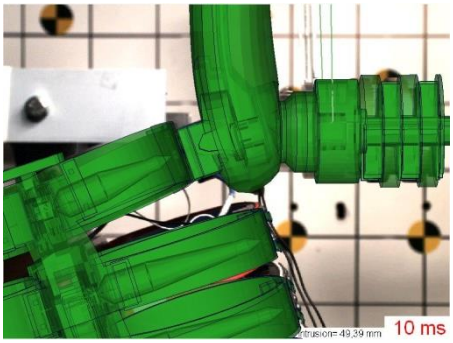
WSID v3.5 v4.0

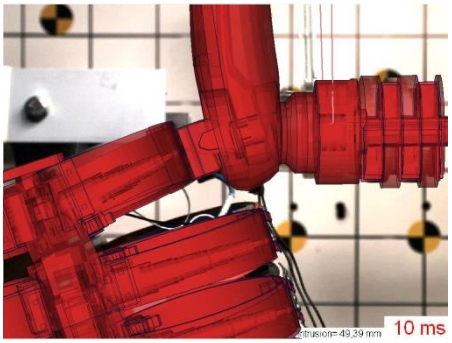


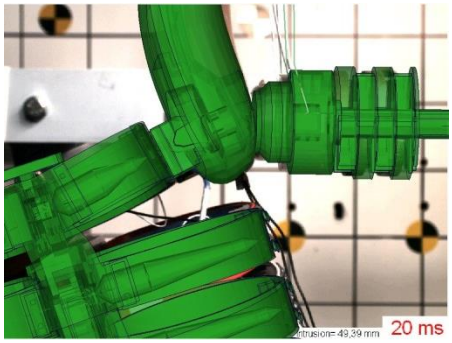
- Other modifications:
  - Arm validation is improved. In some Rib component test it is observer that WSID v3.5 seams to have a very soft arm behavior in bending. Due to this the behavior of the arm is compared to video evaluations and improved. In the following a rib component test with arm is shown for both versions of WorldSID:

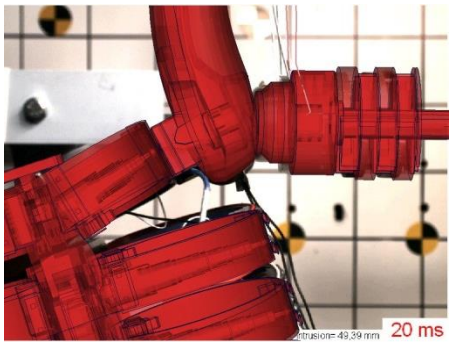
WSID v3.5 v4.0

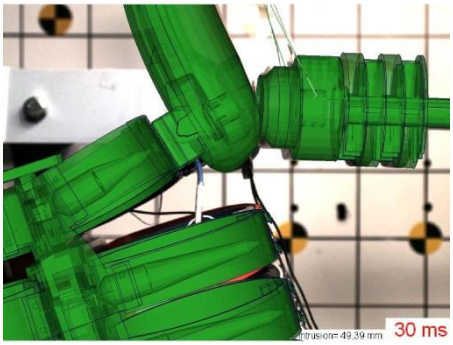


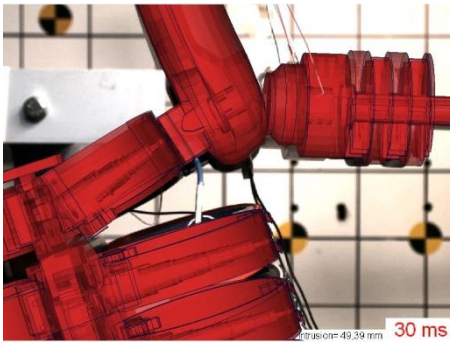

10 ms

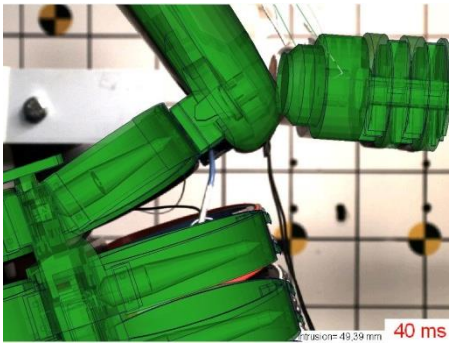

10 ms

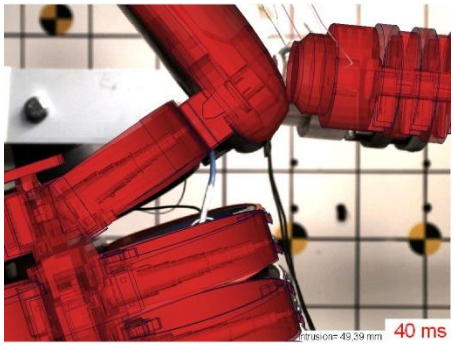

20 ms

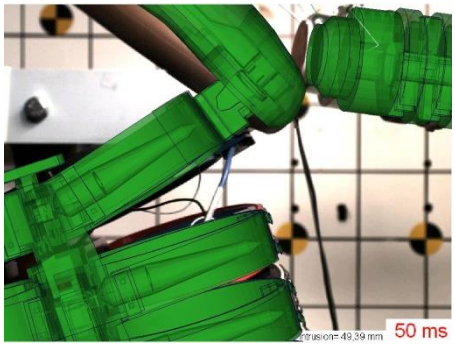

20 ms

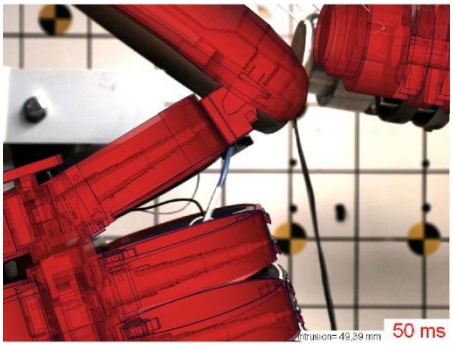

30 ms


30 ms


40 ms


40 ms


50 ms


50 ms

- For output of the EuroNCAP local rib deflections, DATABASE_HISTORY_NODE_LOCALS are defined. These nodes are included as an alternative to the output of the 2D IR-TRACCs. The nodes output the local x-, y- and z-deflection of the ribs. It must not be calculated from the resultant deflection and rotation of the 2D IR-TRACC.

  The nodes are:

Item	Node-ID	Label	Available components
shoulder rib	10751	shoulder rib deformation Local X/Y/Z	x-, y-, z-displacement
1. thorax rib	10752	1 thorax rib deformation Local X/Y/Z	x-, y-, z-displacement
2. thorax rib	10753	2 thorax rib deformation Local X/Y/Z	x-, y-, z-displacement
3. thorax rib	10754	3 thorax rib deformation Local X/Y/Z	x-, y-, z-displacement
1. abdomen rib	10755	1 abdomen rib deformation Local X/Y/Z	x-, y-, z-displacement
2. abdomen rib	10756	2 abdomen rib deformation Local X/Y/Z	x-, y-, z-displacement

- For dummy positioning the angles which are shown for Torso and Head are now global angles and no longer in respect to the Pelvis and Torso. So if the pelvis is rotated, they will also change.
  Due to this when the dummy is opened in Primer, two warning messages will occur that a coordinate systems does not belong to assembly 2 and 3.

- Positioning generator psg_v1.3 is improved. This is used to set up positioning pre simulations. Now it is possible also to rotate the neck backed bye pre-simulation. This was missing in v3.5.
  Furthermore we switched the method to pulling the assemblies bye springs and dampers to the right position. This is very similar to the Primer method and very robust.

- The Version 4.0 and higher of the WorldSID provides parameters to scale the friction of the joint off all limbs. As default a 1 g adjustment of the joints is included. The user is now able to increase ore decrease the friction values of the joints. The scale factors are used for the left and right hand side assemblies. So it is not possible to scale left and right assembly different.

Parameter name	Joint
Sfarmx	Scale factor arms local x-rotation
sfarmy	Scale factor arms local y-rotation
sffemr	Scale factor upper legs all directions
sfknee	Scale factor knees
sfankl	Scale factor ankle joins all directions

5.2 Release notes of WorldSID v3.5

- Geometric modifications:
  - Initial Arm position is set to EuroNCAP position
    - EuroNCAP Oblique Pole Side Impact Testing Protocol (Version 7.0 of June 2014):
      - 5.3.6.1 Place both arms at the first detent downward of the most upward detent that corresponds to a differential angle of 32° between rib angle sensor and the arm angle.
    - Rib angle sensor is 0° if the 2. and 3. thorax ribs are horizontal.
    - Arm must then positioned 32° downwards from the horizontal.
    - Tree File is adjusted to show -32° for arm position.
    - Outer shape of V3.5 compared to V3.0 has not changed, except the Arm position.
  - One additional Node is generated NID10000. This one has the same coordinate as the node 10501 which is located on the H-Point.
  - This is pone due to positioning issues with the psg of the WolrdSID50.

- Other modifications:
  - Due to a strange behavior of the Jacket in WSID v3.0 the Jacket is changed:
    - The solid material of the Jacket is improved.
    - The outer shell layer is changed from MAT-NULL to MAT_FABRIC with physical tension stiffness.

5.3 Release notes of WorldSID v3.0

- Geometric modifications:
  - The complete neoprene suit of the WorldSID is now meshed with solids
  - Arm foam and rubber mesh is disconnected from arm bone
  - 2D IR-TRACCs including new stop angles (SBL-E1)
  - New sacrum box data recorder in the pelvis (SBL-E1)

- Component modifications:
  - The arm component was improved
  - Neck model improvement
  - Shoulder rib component test in z-direction

- Other modifications:
  - The nitinol material of the rib bands now uses am *MAT_SHAPE_MEMORY. This should increase the overall stability and robustness of the dummy model

- Some load cell orientations were corrected to match the SAE standard: upper and lower neck, shoulder, lumbar spine, pubic, sacro iliac and femur load cells
- Improvement of the pelvis flesh model to avoid high hourglass energies
- Improvement of the hole dummy definitions to reduce time step dependency of the model
- Parameter tpref to switch on/off the foam reference geometry of the thorax pad
- More robustness against variation of time step size
- New positioning procedure

5.4 Release Notes of WorldSID v2.0

- The new sled tests are now validated in a first loop. So the interaction of different parts is adjusted and validated.
- First observations show very hard movement of the ribs in local z-direction. To investigate in this behavior there are planed new pendulum tests on the shoulder of the WorldSID.
- The validation of the single component tests of Version 1.0 is not changed. All single components of the WorldSID v2.0 are still the same.
- The WorldSID v2.0 fulfils still all available calibration tests.

5.5 Release Notes of WorldSID v1.0

- The WorldSID model v1.0 is the first commercial available PDB WorldSID.
- The geometry and mass of the model are based on the data of ISO 15830 part 1 to 4.
- All important materials have been tested and used to generate corresponding material models.
- All available component tests are validated for the WorldSID v1.0
- The WorldSID v1.0 fulfills all available calibration tests.

6. Limitations and Further Work

The current release of the WorldSID has been validated by using material, component, dummy certification and sled tests. First experiences of full car simulations are included to the model.

The model is validated in use of the depicted tests in this Manual. The validation is done every time under physical aspects and in use of all know how which was available to this point in time.

To carry on improving the model response and the usability we appreciate all users' feedback.

7. Material Tests

Material tests on all major foams, rubber like materials and plastics have been performed. The specimens were taken from components of the WorldSID or from blocks provided by FTSS. The material test samples are depicted below.

Figure 21: Material test samples of WorldSID

The following types of tests were performed: Static tension tests, dynamic tension tests, static compression tests, and dynamic compression tests. These tests were chosen to obtain material data that could be used with very small adaptations for material *MAT_FU_CHANG_FOAM and *MAT_SIMPLIFIED_RUBBER for foam and rubber parts, respectively.

The following materials were tested:

- pelvis rubber foam
- upper arm rubber foam
- upper leg rubber
- lower leg rubber
- shoe rubber
- pubic rubber buffer
- lumbar spine rubber
- all neck rubber materials (three different)
- vinyl (head skin)
- lower arm foam
- thorax pad foam (Ensolite)
- rib material (Nitinol)
- blue rib damping material
- plastics iliac wings
- arm bone
- head bone

The emphasis was on static and dynamic tension and compression tests. For the rubber like materials, the compression tests were also performed with a lateral obstructed expansion.

The strain rates used for the foam and rubber materials were:

Test	Type	Strain rate	Lateral expansion
1	Tension	0.001 1/s (static)	free
2	Tension	0.1 1/s	free
3	Tension	20 1/s	free
4	Tension	100 1/s	free
5	Tension	400 1/s	free
6	Compression	0.001 1/s (static)	obstructed
7	Compression	0.001 1/s (static)	free
8	Compression	0.1 1/s	free
9	Compression	20 1/s	free
10	Compression	100 1/s	free
11	Compression	400 1/s	free

Table 30: Strain rates used for material tests

8. Performance

8.1 Component tests

Selected components of the WorldSID are tested in special defined component tests. The target of these tests is to have a fine validated component in a load range which can also be observed in a full car crash like the oblique pole of the FMVSS 214 new.

The tested components are:

- Head-neck unit
- Half arm
- Different ribs of the thorax and abdomen
- Lumbar spine
- Iliac wing

The description of the single component tests and the performance is given in the following chapters.

8.1.1 Head-neck test

This test is built to validate the neck unit in use of the mounted head assembly. The test setup is depicted in the figure below. The loads on the sled are defined to get signals which are similar to the neck signals in a full car crash.

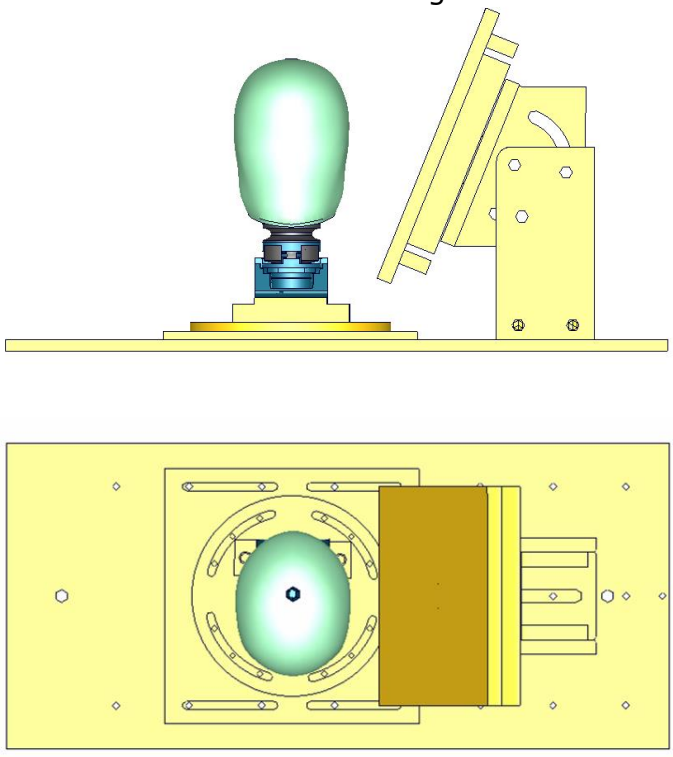


Figure 22: Head-neck test setup - 90 degree, side and top view

The oblique plate is adapted only as a guide for the neck in the higher pulses. Two different pulses are tested for a 90 degree configuration as depicted in the previous figure and the same two pulses for a 75 degree configuration of the component. The configurations are listed in the table below.

Test	Load angle	Pulse
1	90 degree	20 g triangular pulse
2	90 degree	35 g triangular pulse
3	75 degree	20 g triangular pulse
4	75 degree	35 g triangular pulse

Table 31: Test configurations of head-neck test

Results of 90 degree, 20g configuration:

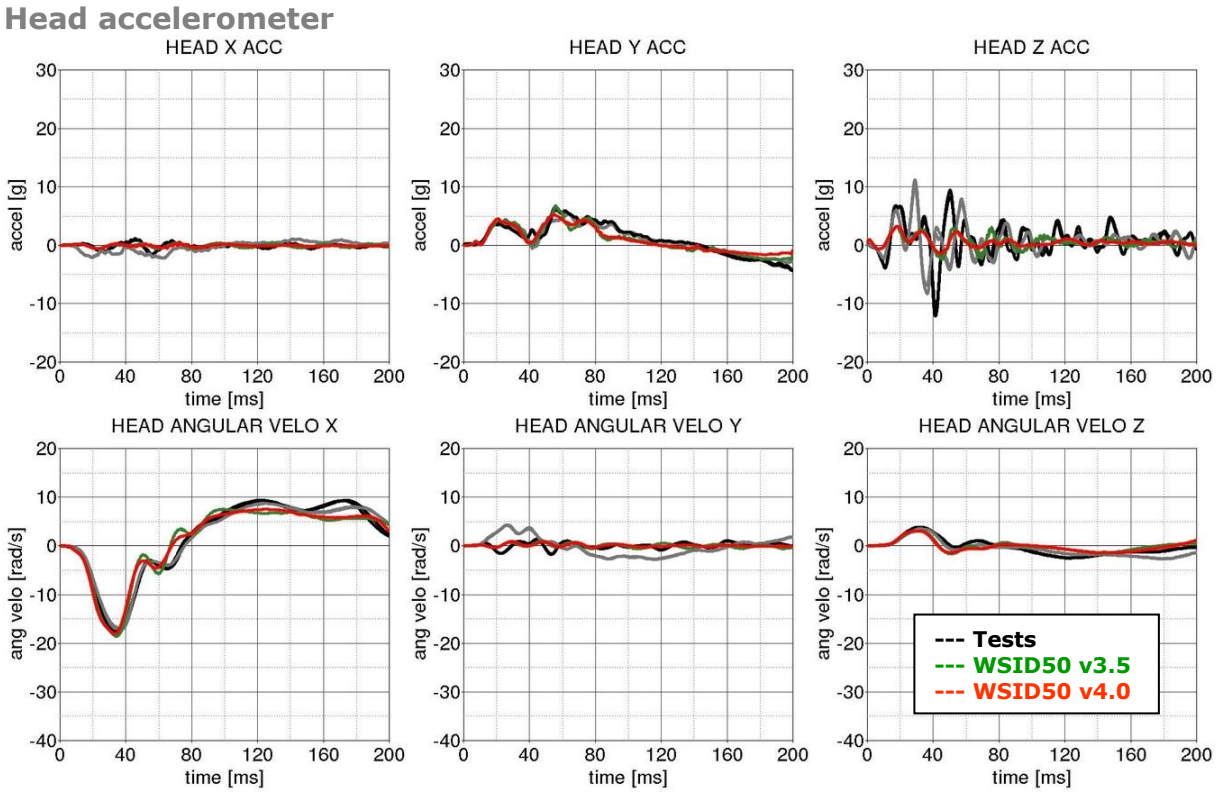


Figure 23: Result of head-neck test -- 20g, 90 degree (Head acceleration)

Upper neck load cell

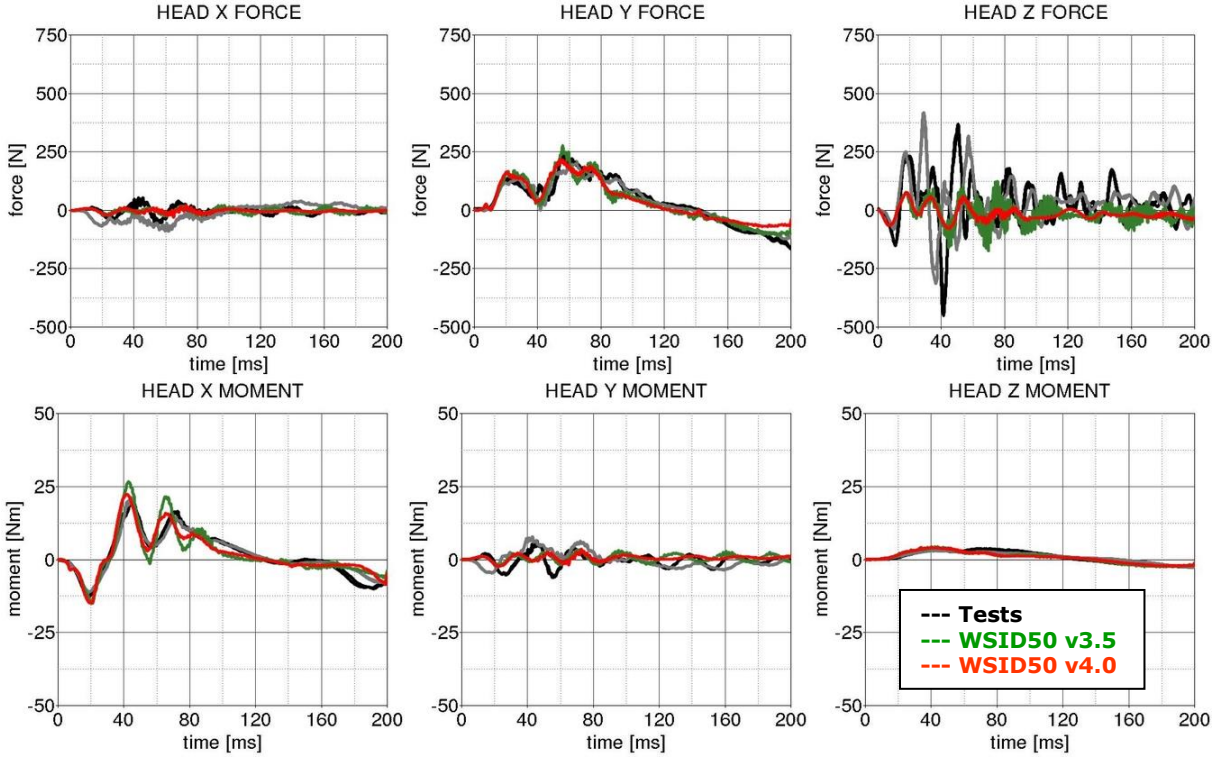


Figure 24: Result of head-neck test -- 20g, 90 degree (Upper neck forces and moments)

Lower neck load cell

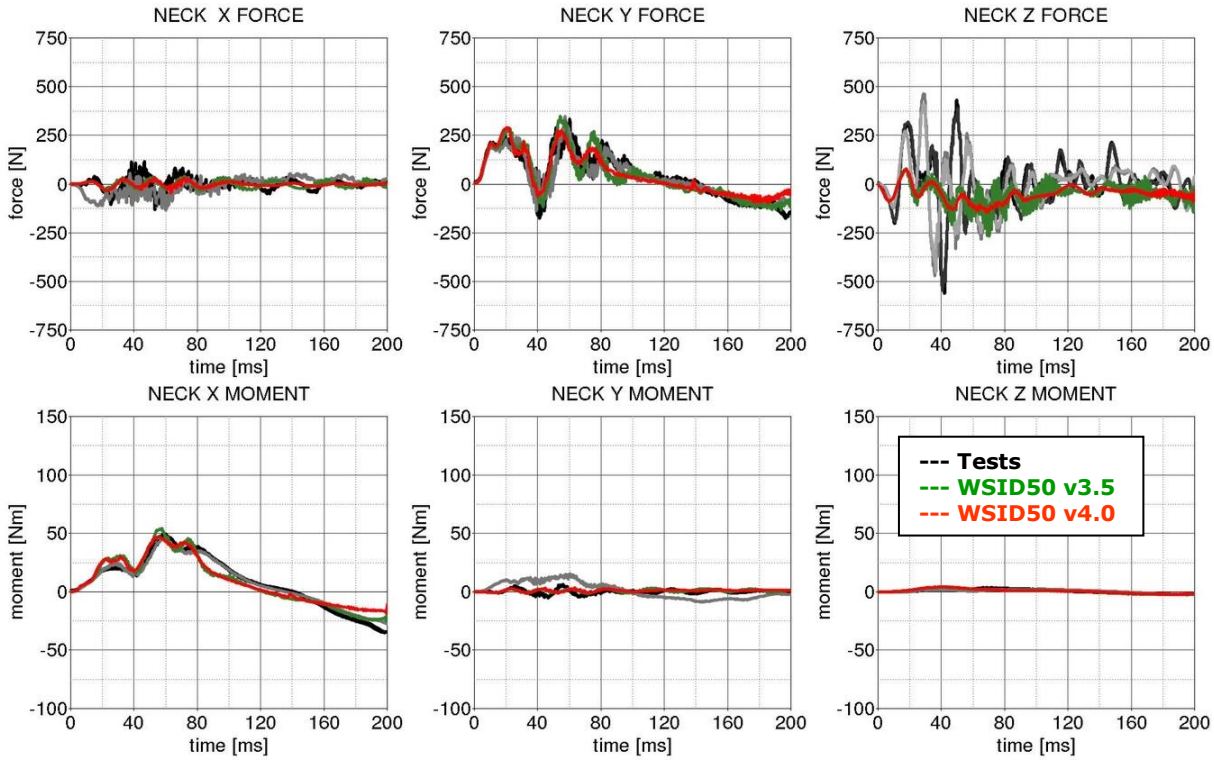


Figure 25: Result of head-neck test -- 20g, 90 degree (Lower neck forces and moments)

Results of 90 degree, 35g configuration:

Head accelerometer

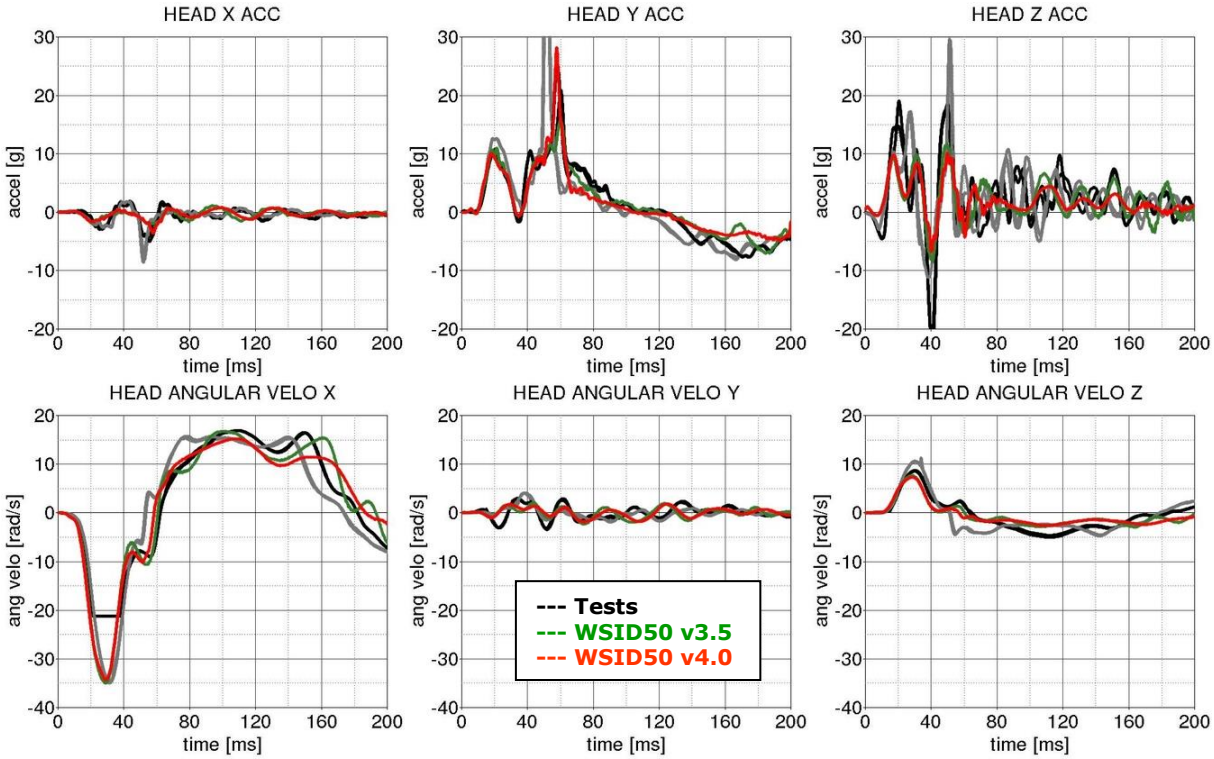


Figure 26: Result of head-neck test -- 35g, 90 degree (Head acceleration)

Upper neck load cell

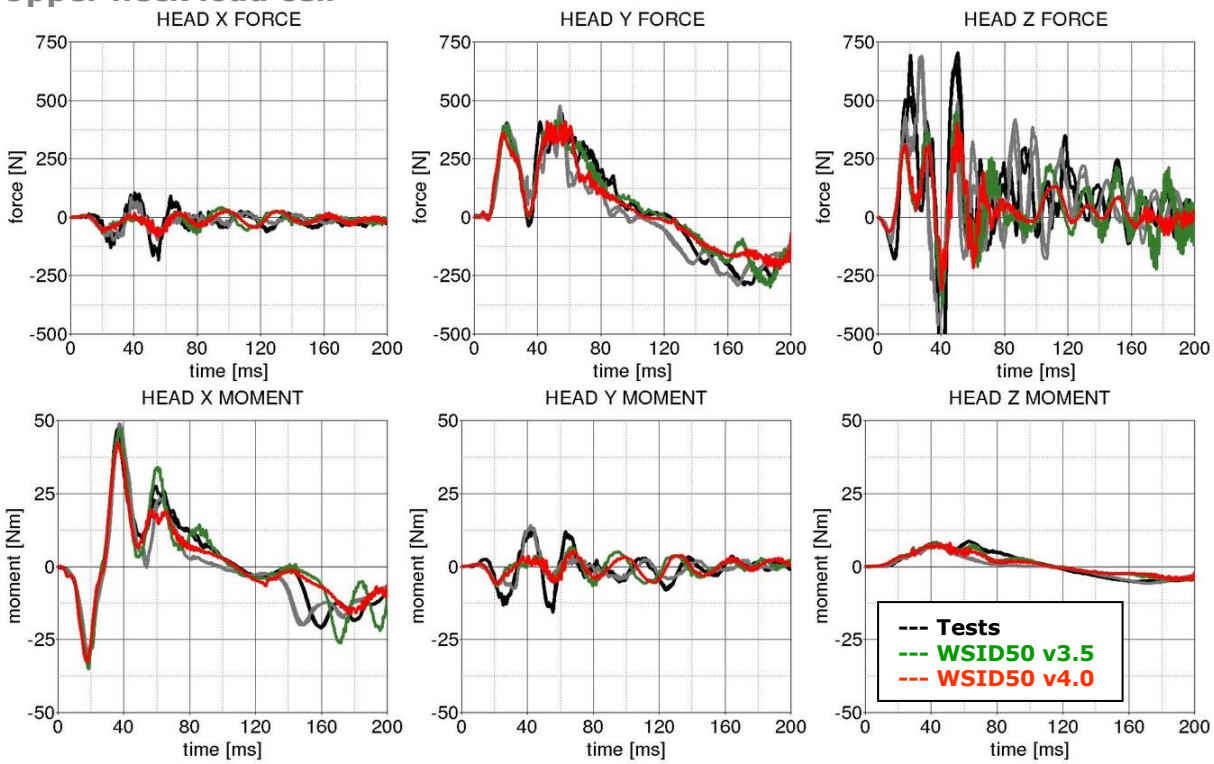


Figure 27: Result of head-neck test -- 35g, 90 degree (Upper neck forces and moments)

Lower neck load cell

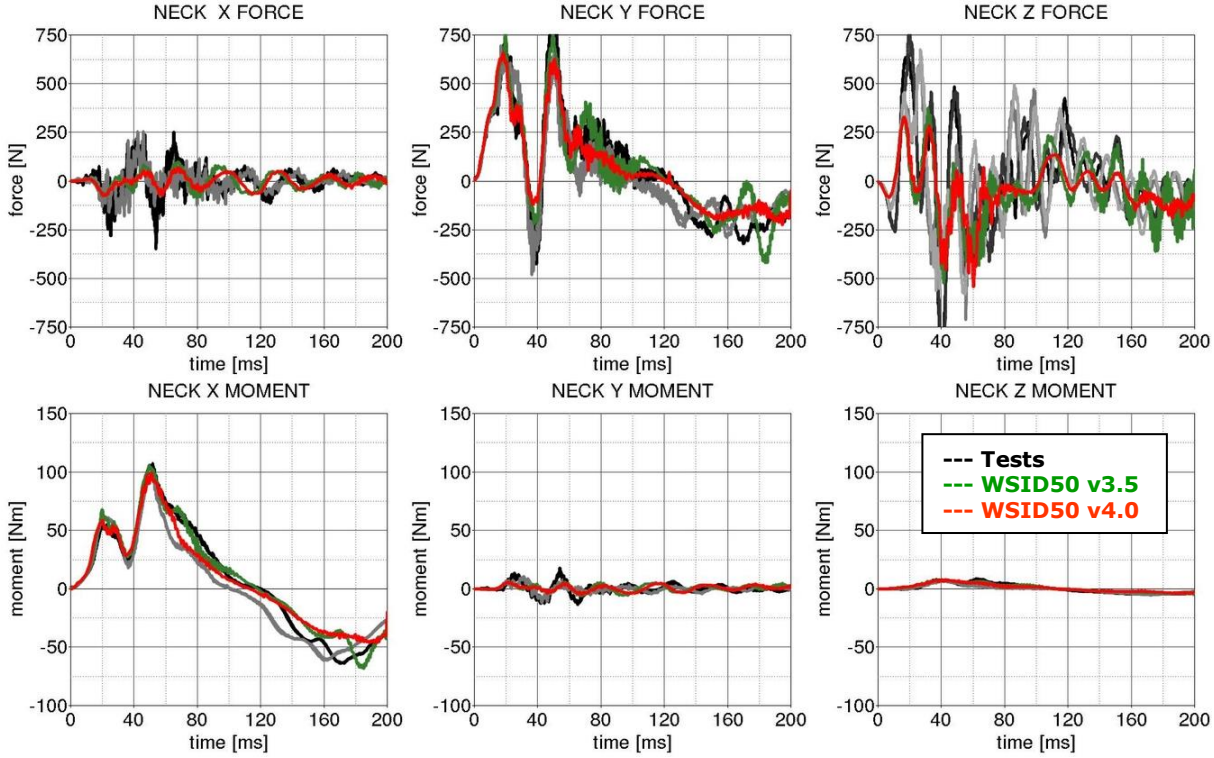


Figure 28: Result of head-neck test -- 35g, 90 degree (Lower neck forces and moments)

Results of 75 degree, 20g configuration:

Head accelerometer

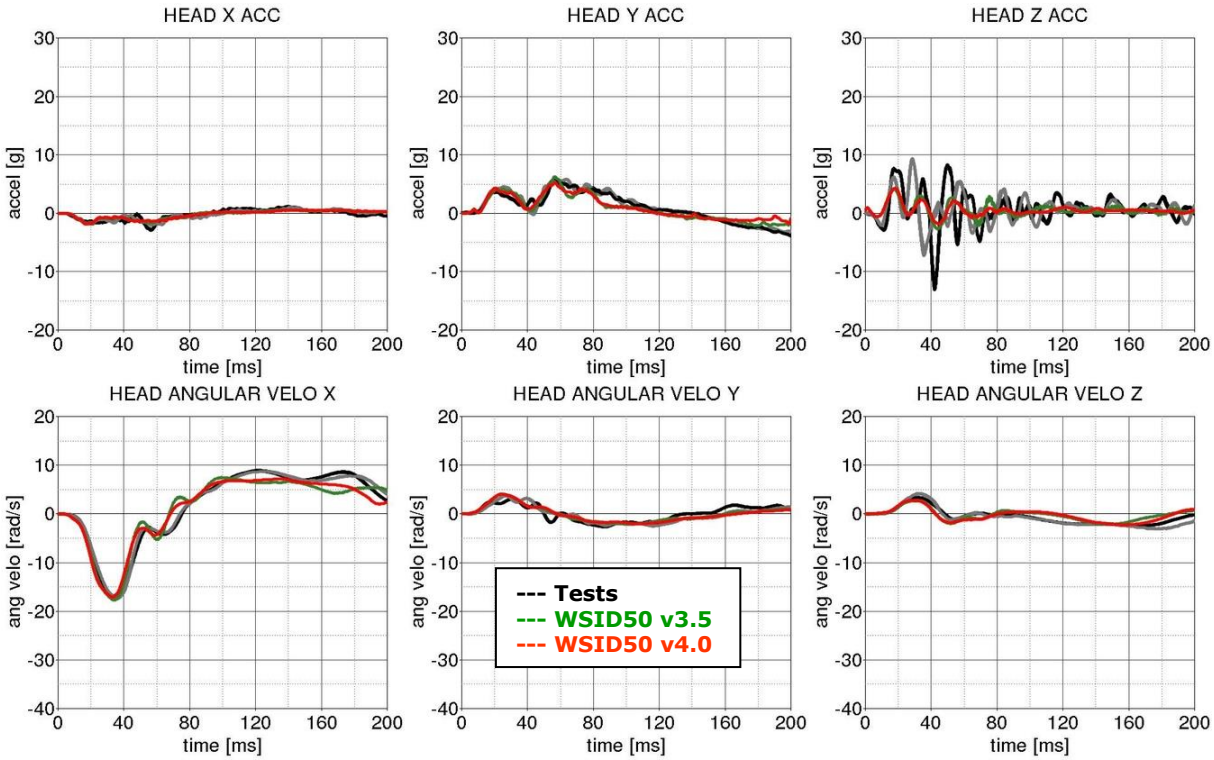


Figure 29: Result of head-neck test -- 20g, 75 degree (Head acceleration)

Upper neck load cell

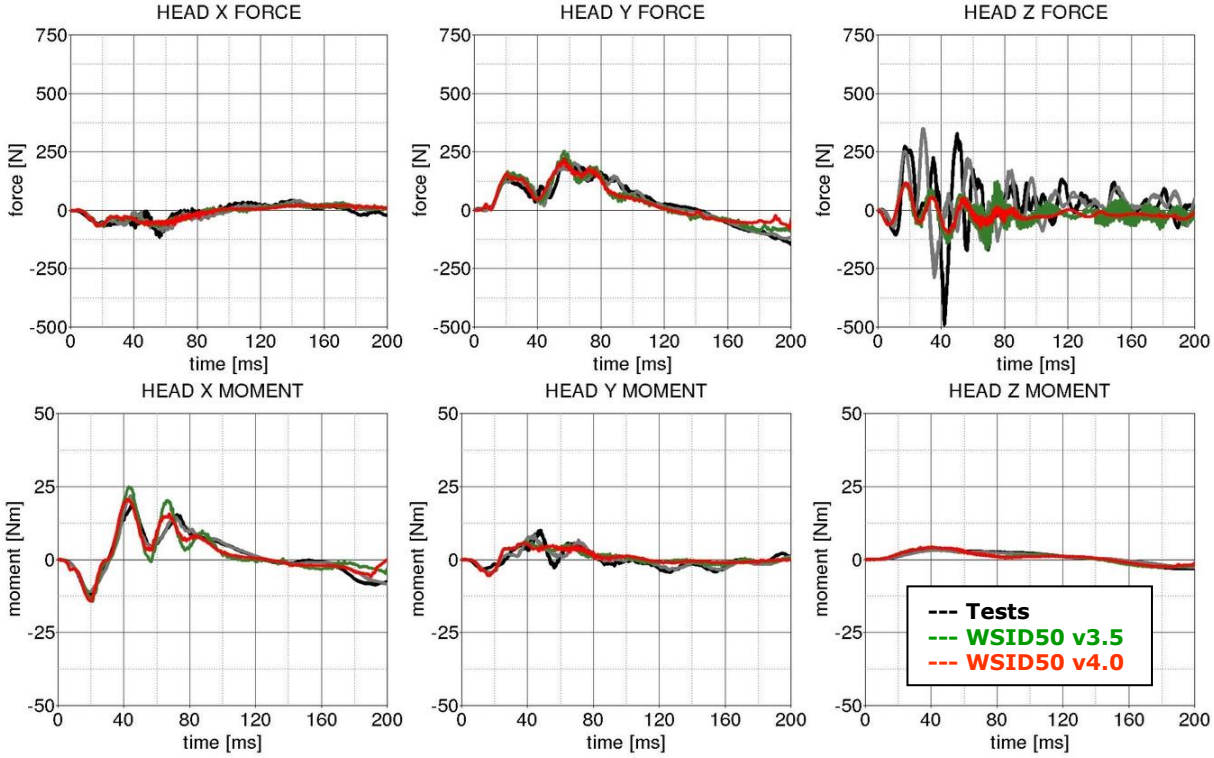


Figure 30: Result of head-neck test -- 20g, 75 degree (Upper neck forces and moments)

Lower neck load cell

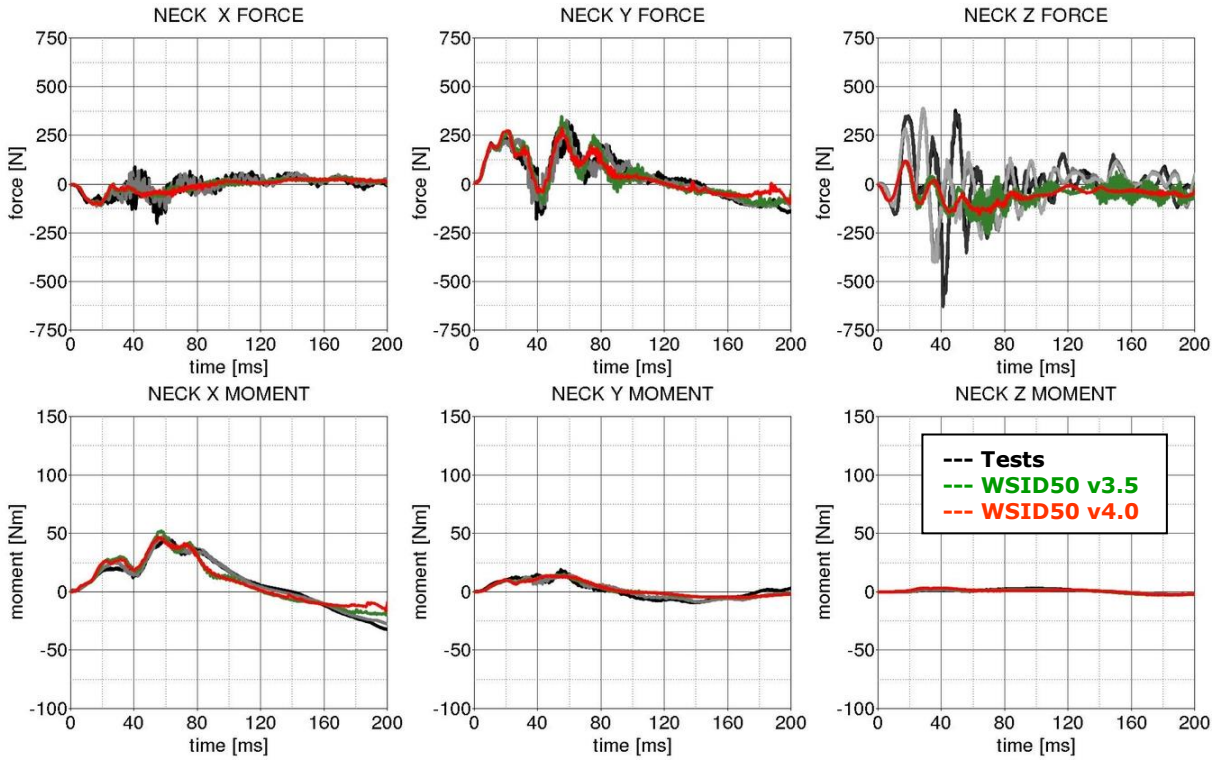


Figure 31: Result of head-neck test -- 20g, 75 degree (Lower neck forces and moments)

Results of 75 degree, 35g configuration:

Head accelerometer

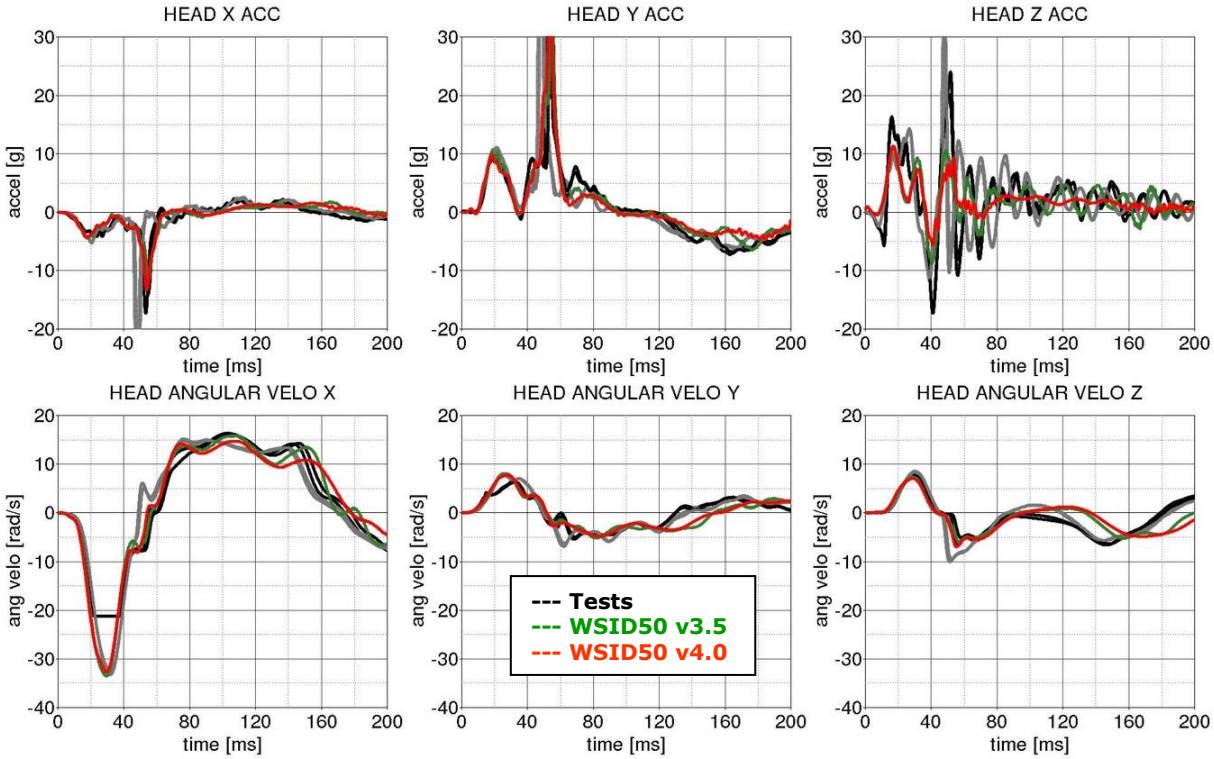


Figure 32: Result of head-neck test -- 35g, 75 degree (Head acceleration)

Upper neck load cell

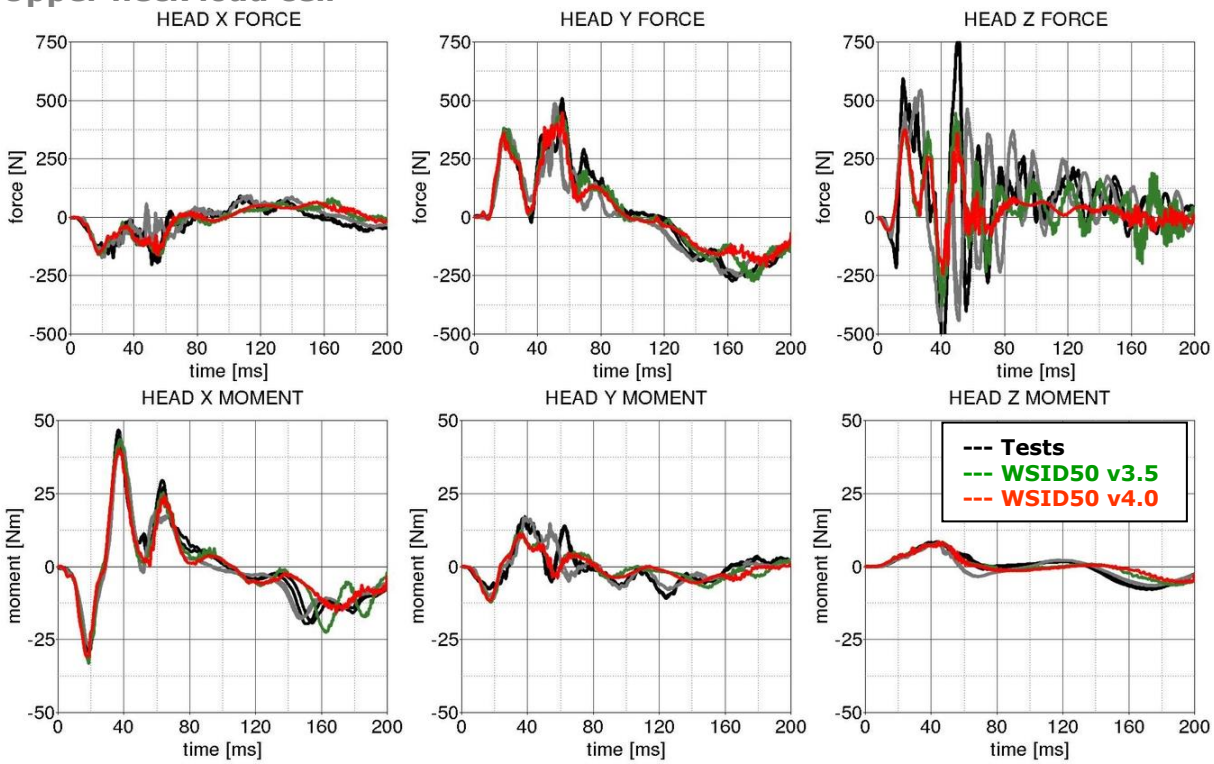


Figure 33: Result of head-neck test -- 35g, 75 degree (Upper neck forces and moments)

Lower neck load cell

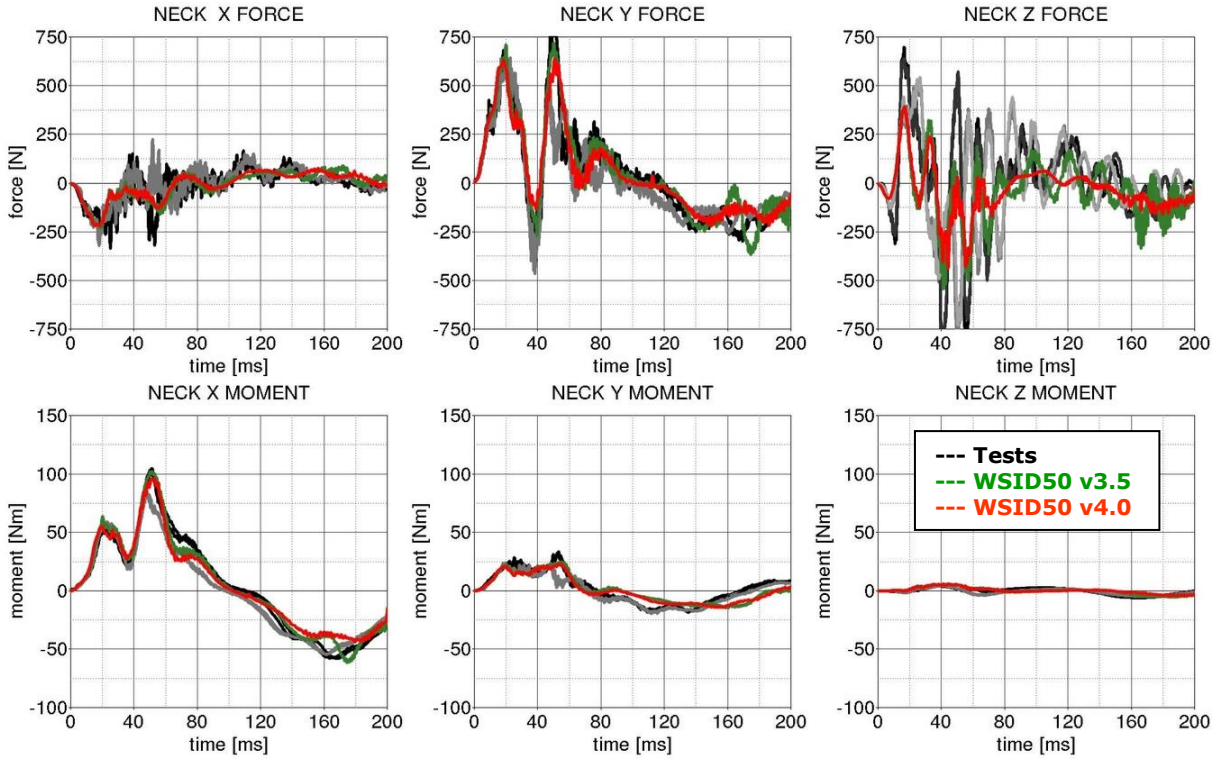


Figure 34: Result of head-neck test -- 35g, 75 degree (Lower neck forces and moments)

8.1.2 Half arm test

The arm is mounted on the test box using the original shoulder load cell. In most of the tests, the notch of the arm is in the 40 degree position. The load cell is then rotated so that the arm in each test is in a vertical position. For a different notch of the arm adjustment, only the shoulder load cell is rotated. The figure below shows the three pendulum positions used for the arm tests. In Table 32 all test setup configurations are listed.

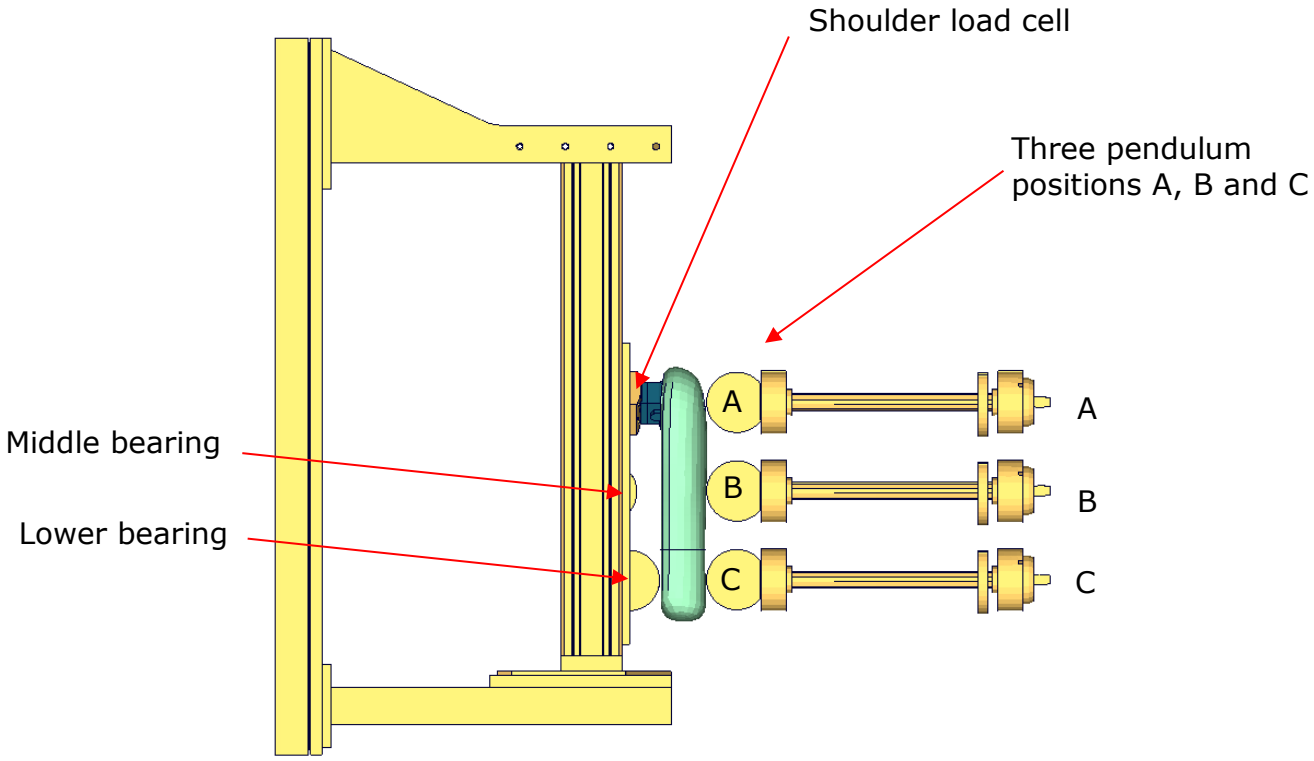


Figure 35: Half arm test setup with all pendulum positions

Test	Shoulder load cell angle	Target point	Velocities
1	48 degree	A	2 m/s and 4 m/s
2	48 degree	B	2 m/s and 4 m/s
3	48 degree	C	2 m/s and 4 m/s
4	8 degree	B	2 m/s and 4 m/s
5	8 degree / middle bearing modified	B	4 m/s and 6 m/s

Table 32: Test configurations for half arm test

Test number 5 is done by using a reduced distance between the middle bearing and the arm. Target is that the arm hits the middle bearing after bending.

The results of all tests are shown in the following figures:

Results - Target point A, 2 m/s velocity, 48 degree load cell position

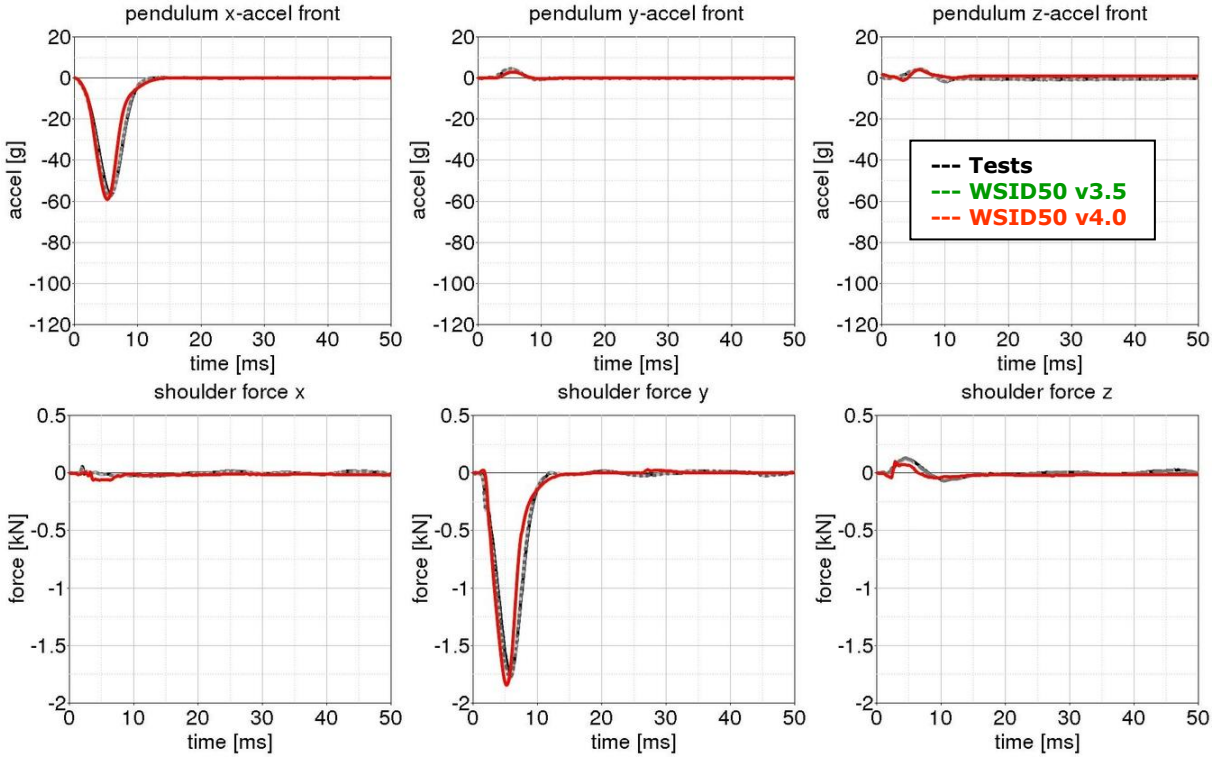


Figure 36: Results - target point A, 2 m/s velocity, 48 degree load cell position

Results - Target point A, 4 m/s velocity, 48 degree load cell position

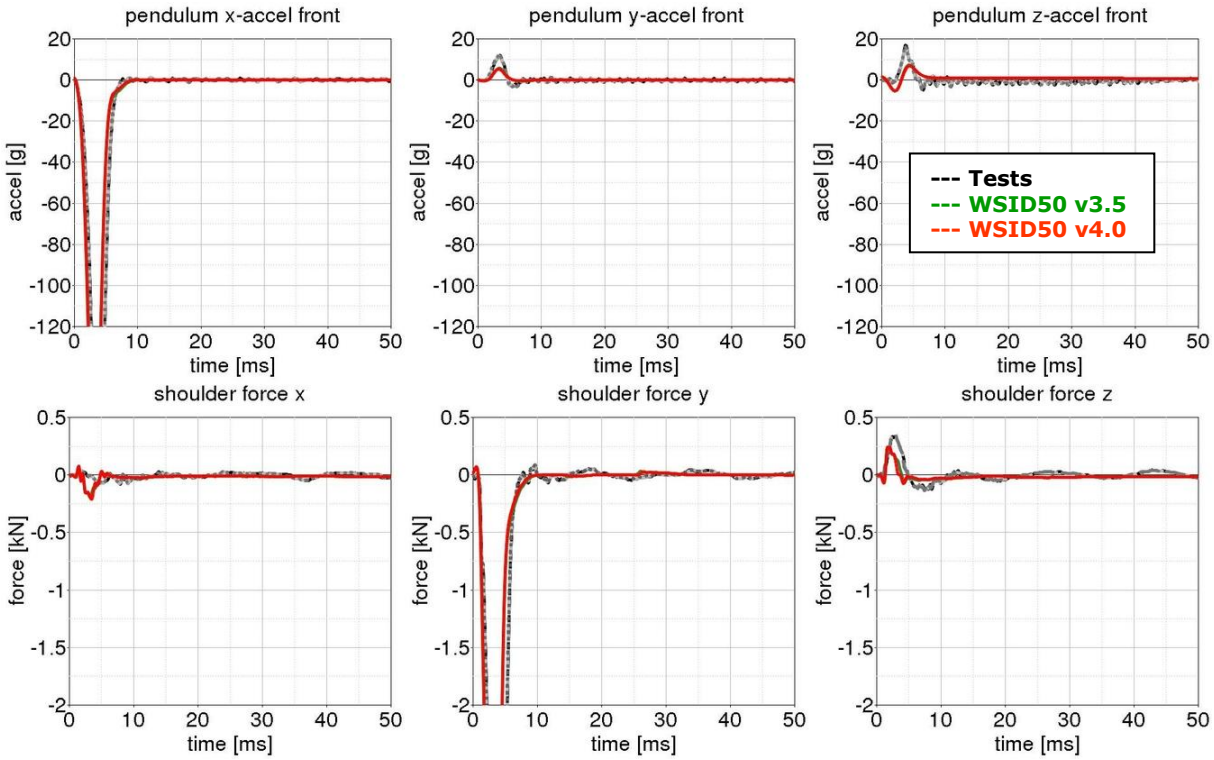


Figure 37: Results - Target point A, 4 m/s velocity, 48 degree load cell position

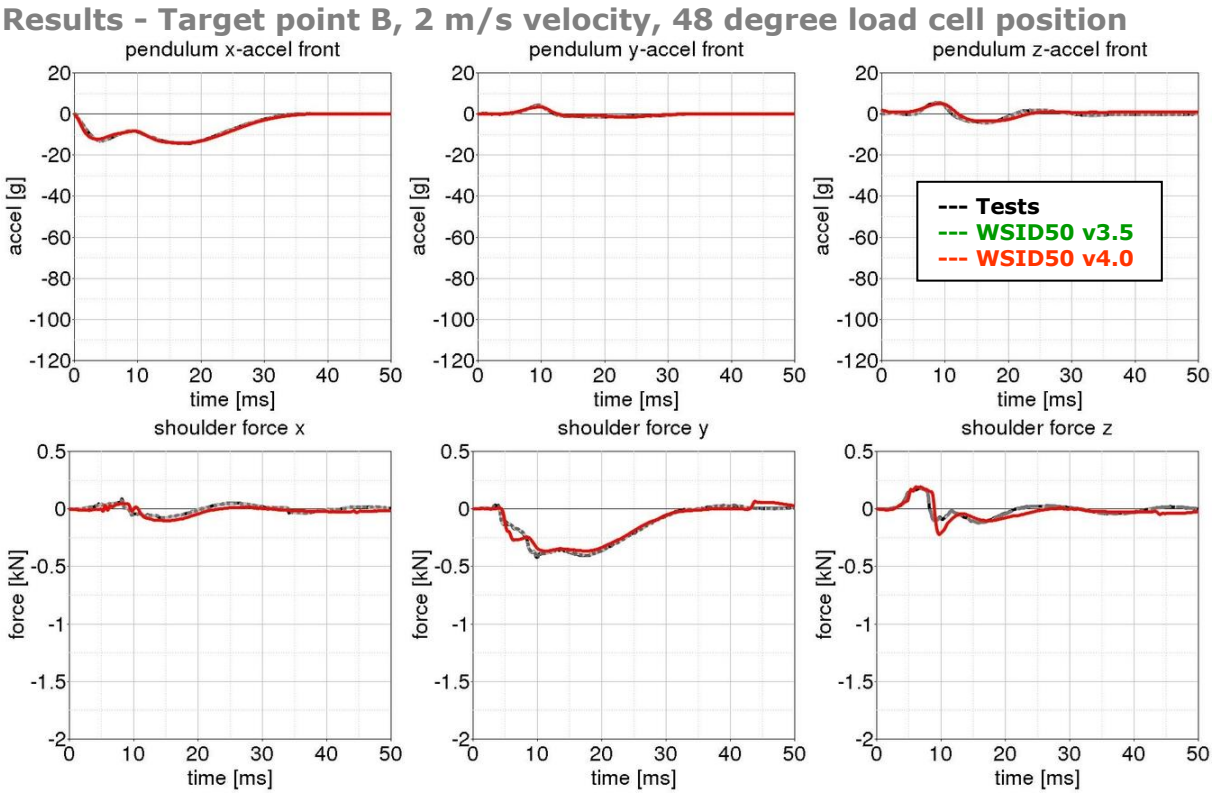


Figure 38: Results - Target point B, 2 m/s velocity, 48 degree load cell position

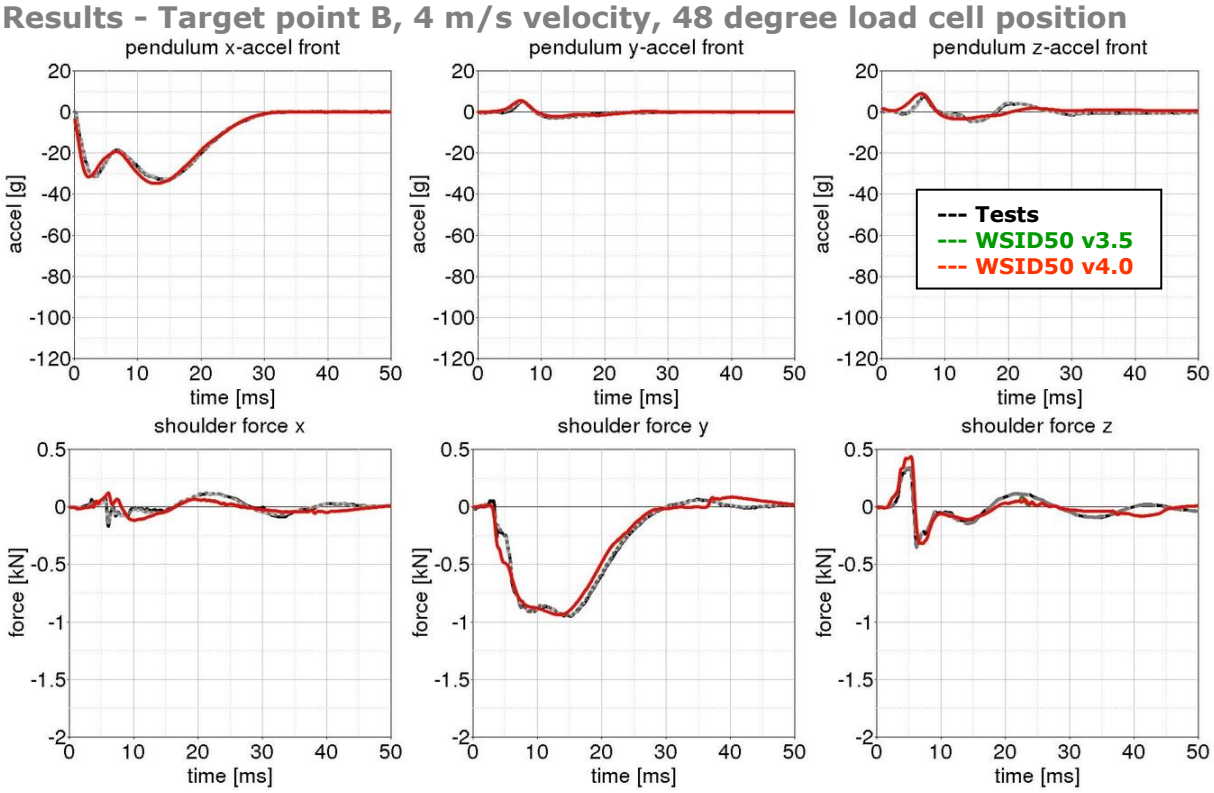


Figure 39: Results - Target point B, 4 m/s velocity, 48 degree load cell position

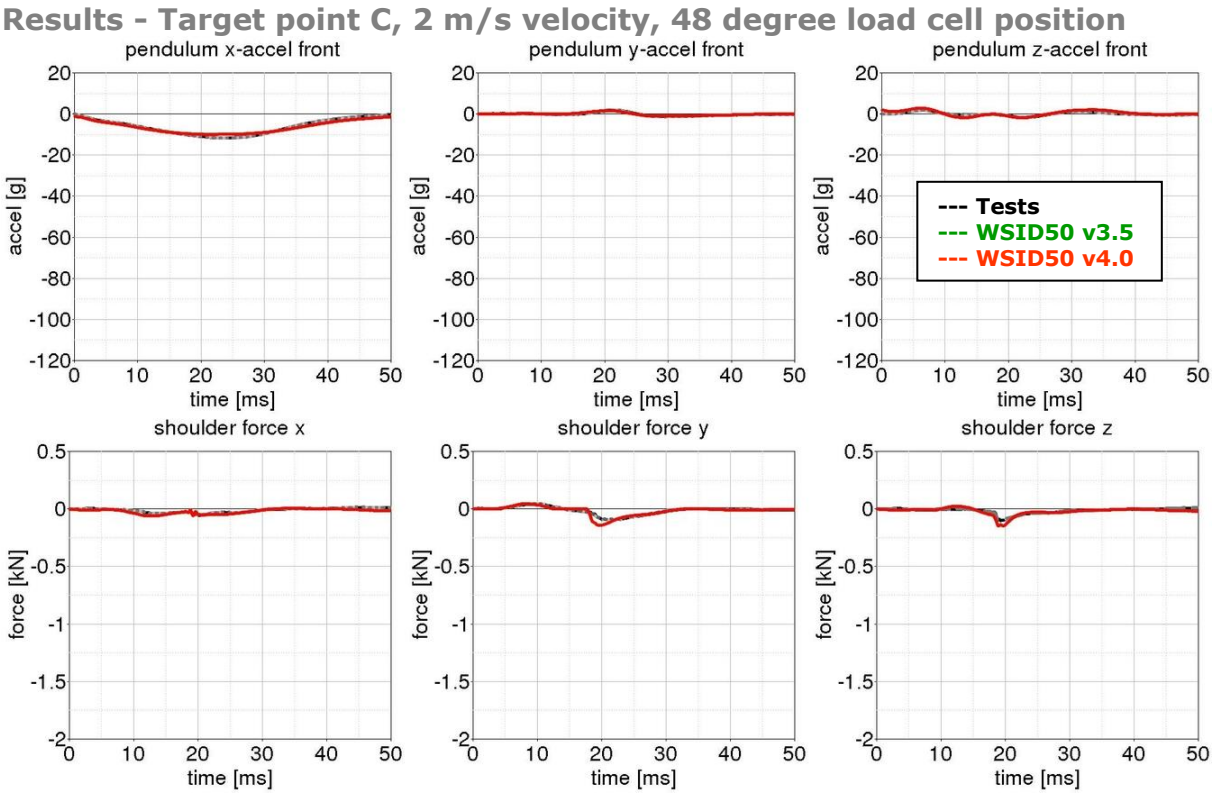


Figure 40: Results - Target point C, 2 m/s velocity, 48 degree load cell position

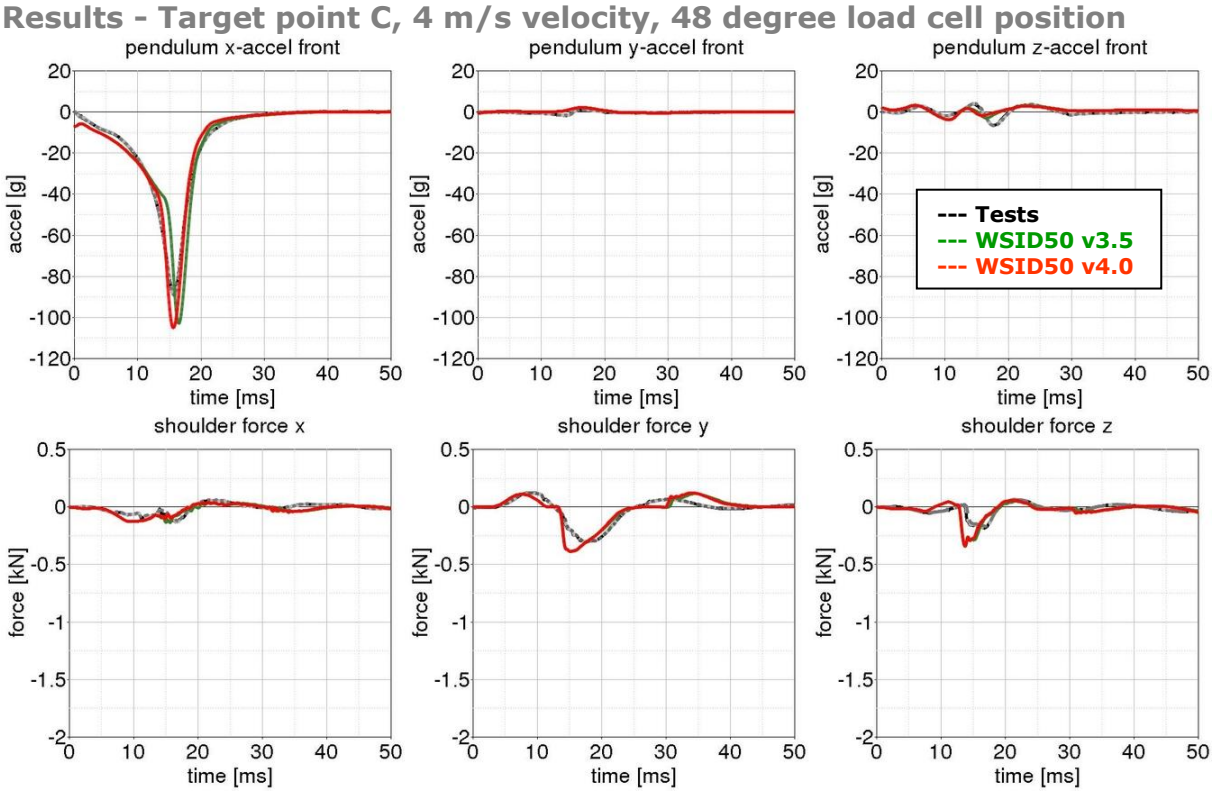


Figure 41: Results - Target point C, 4 m/s velocity, 48 degree load cell position

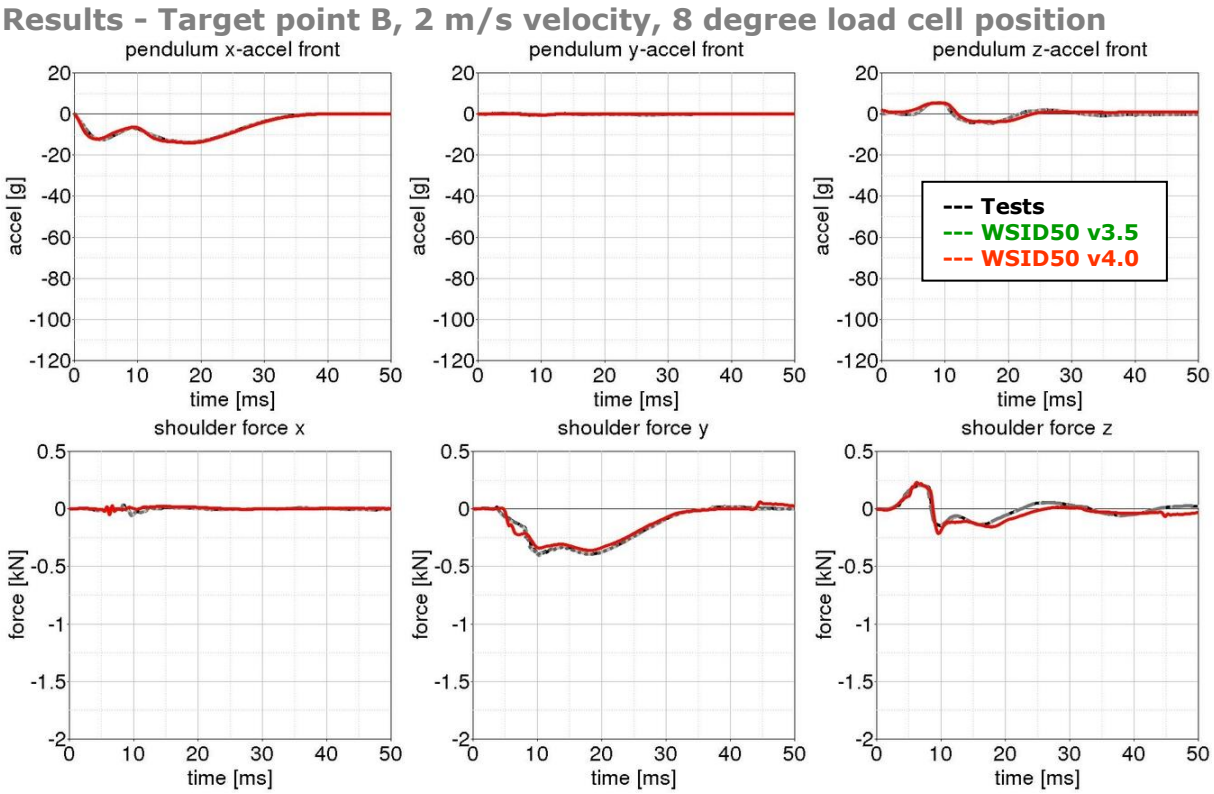


Figure 42: Results - Target point B, 2 m/s velocity, 8 degree load cell position

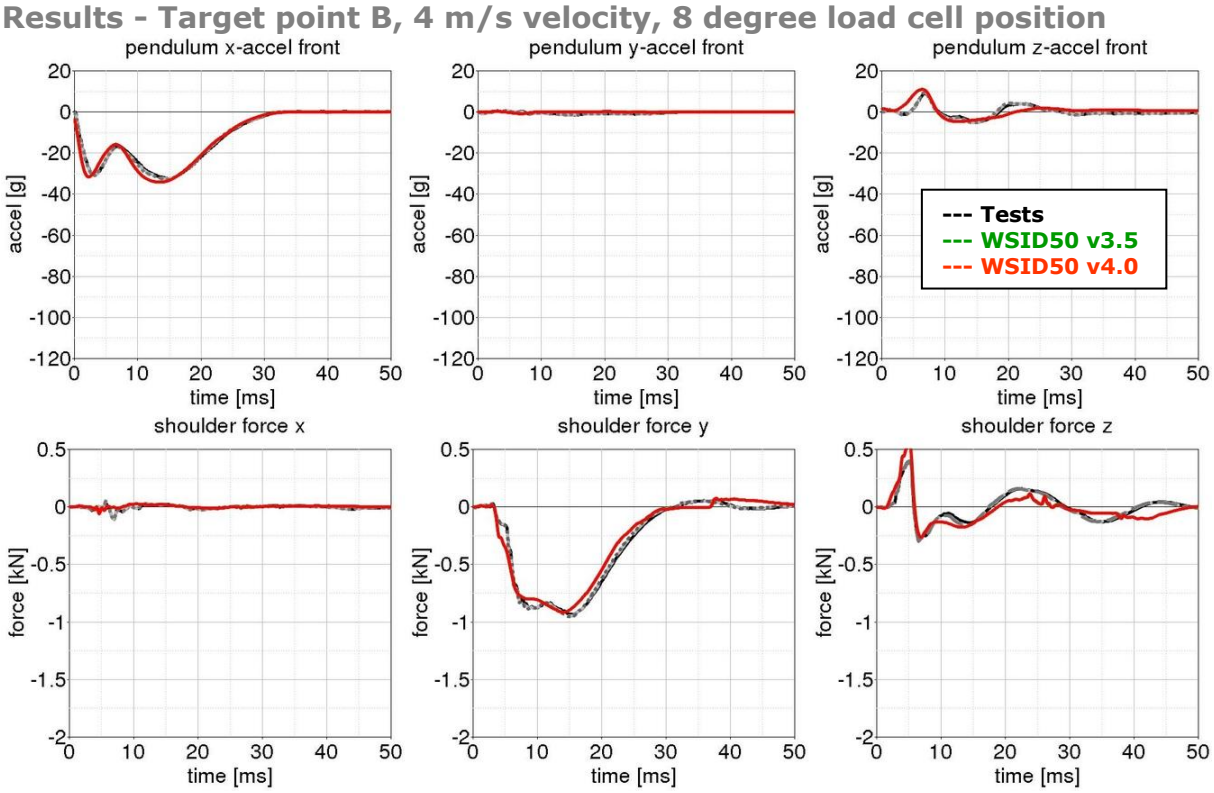


Figure 43: Results - Target point B, 4 m/s velocity, 8 degree load cell position

Results - Target point B, 4 m/s velocity, 48 degree load cell position and modified middle bearing

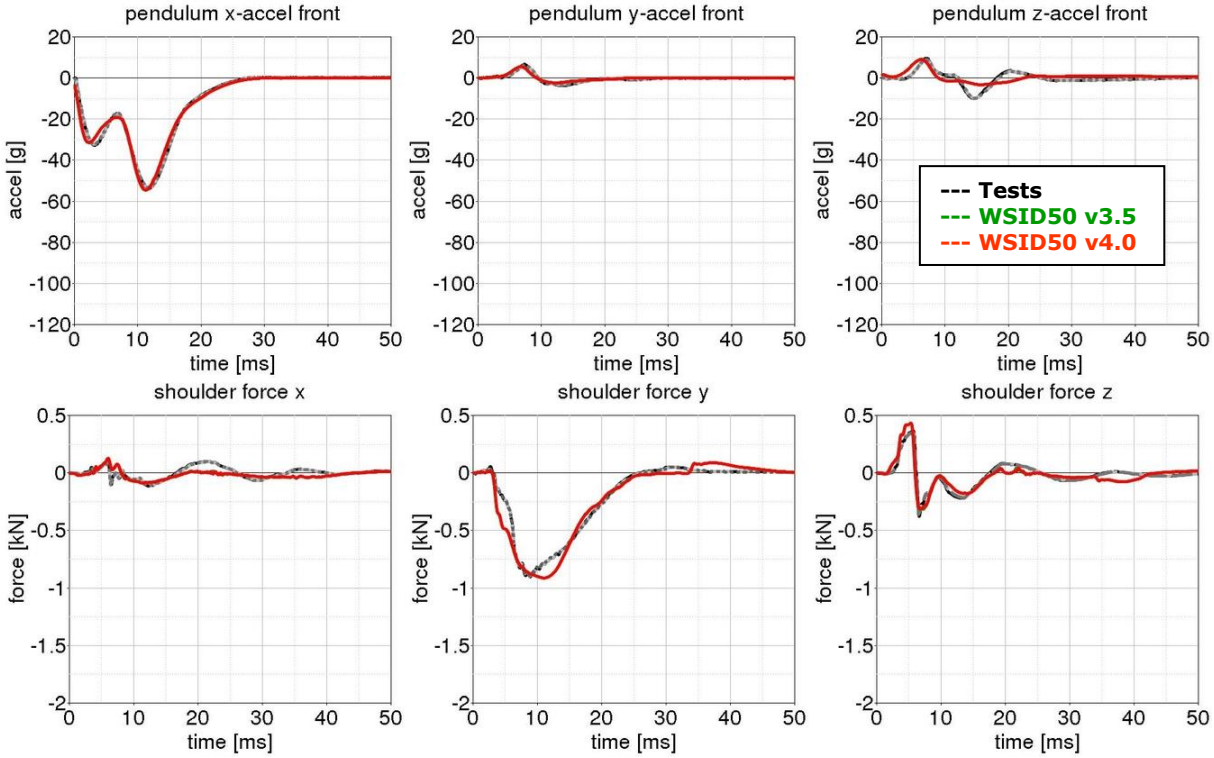


Figure 44: Results - Target point B, 4 m/s velocity, 8 degree load cell position, modified middle bearing

Results - Target point B, 6 m/s velocity, 48 degree load cell position and modified middle bearing

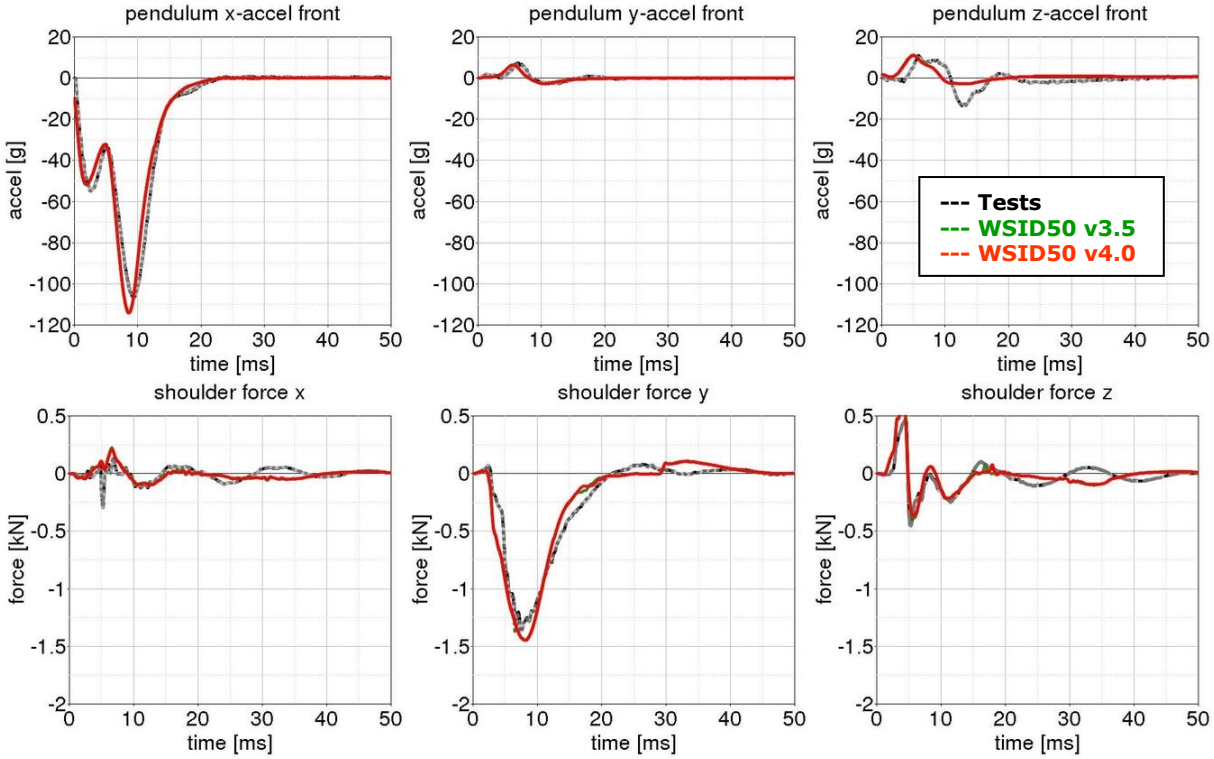


Figure 45: Results - Target point B, 6 m/s velocity, 8 degree load cell position, modified middle bearing

8.1.3 Rib test

For the validation of the rib module of the WorldSID, many different tests have been performed. One single rib consists of two rib bands - an inner and an outer band. On the inner side of the inner band a blue damping material is tied. All ribs are built in a similar way. The difference in the shoulder, thorax and abdomen ribs are in the geometry and in the thickness of the damping material. The rib module is shown in the figure below:

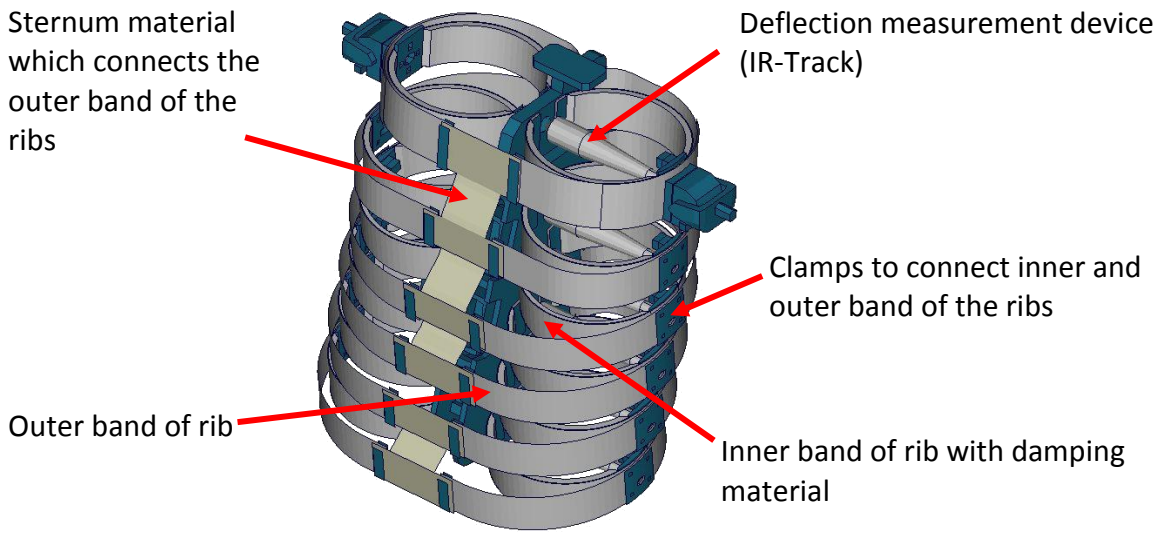


Figure 46: Thorax construction of WorldSID

8.1.3.1 Inner rib band

The inner rib bands with damping material of the shoulder, the third thorax and second abdomen rib are tested. A pendulum test is performed with two different velocities on the single rib band as depicted below.

Shoulder rib:

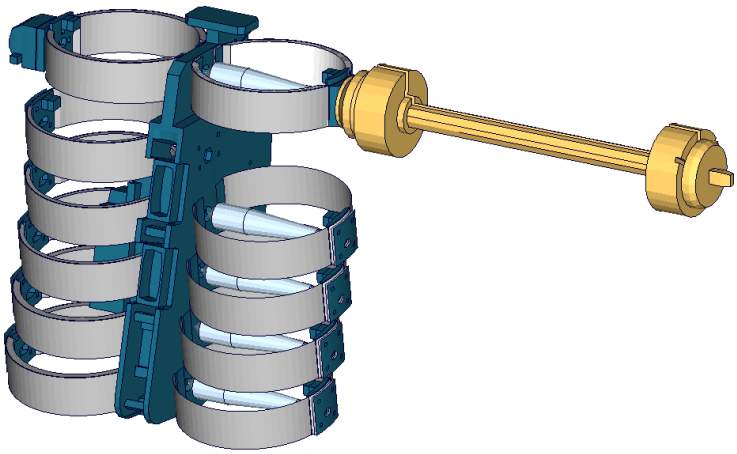


Figure 47: Shoulder rib test on inner band with damping material

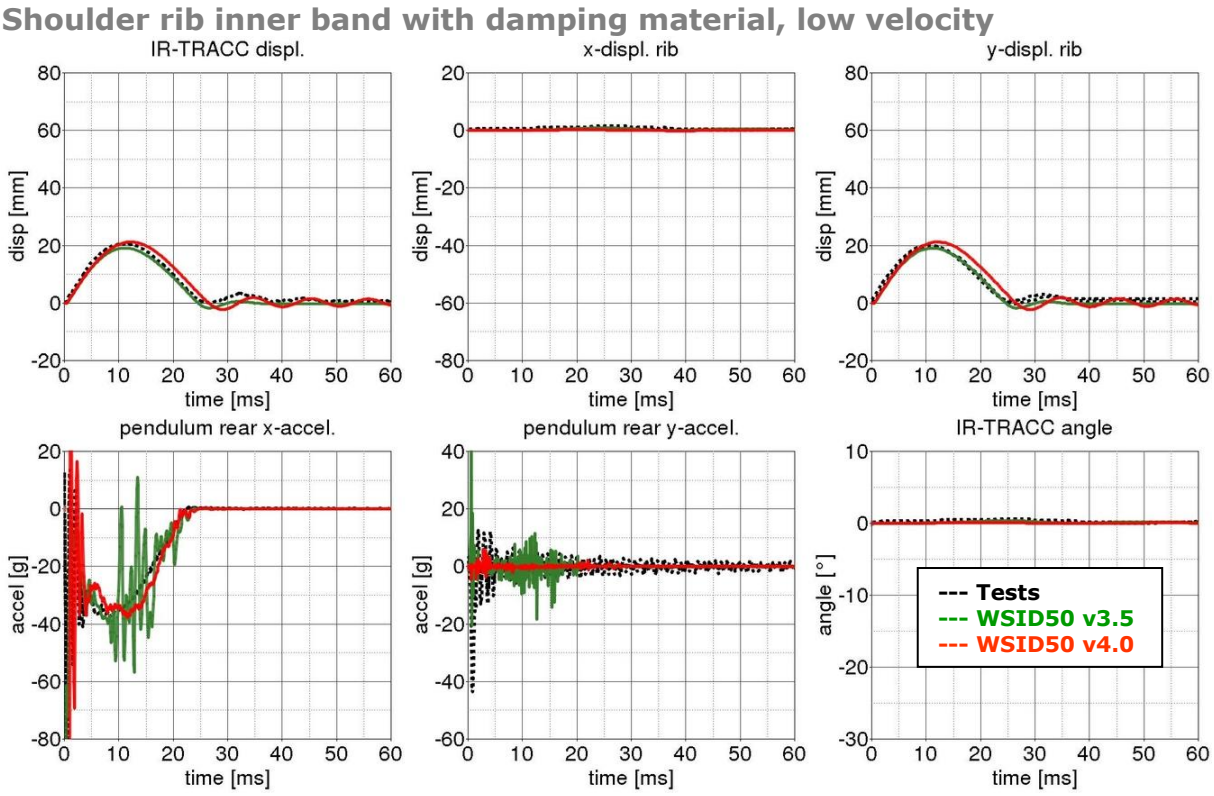


Figure 48: Shoulder rib test on inner band with damping material, low velocity

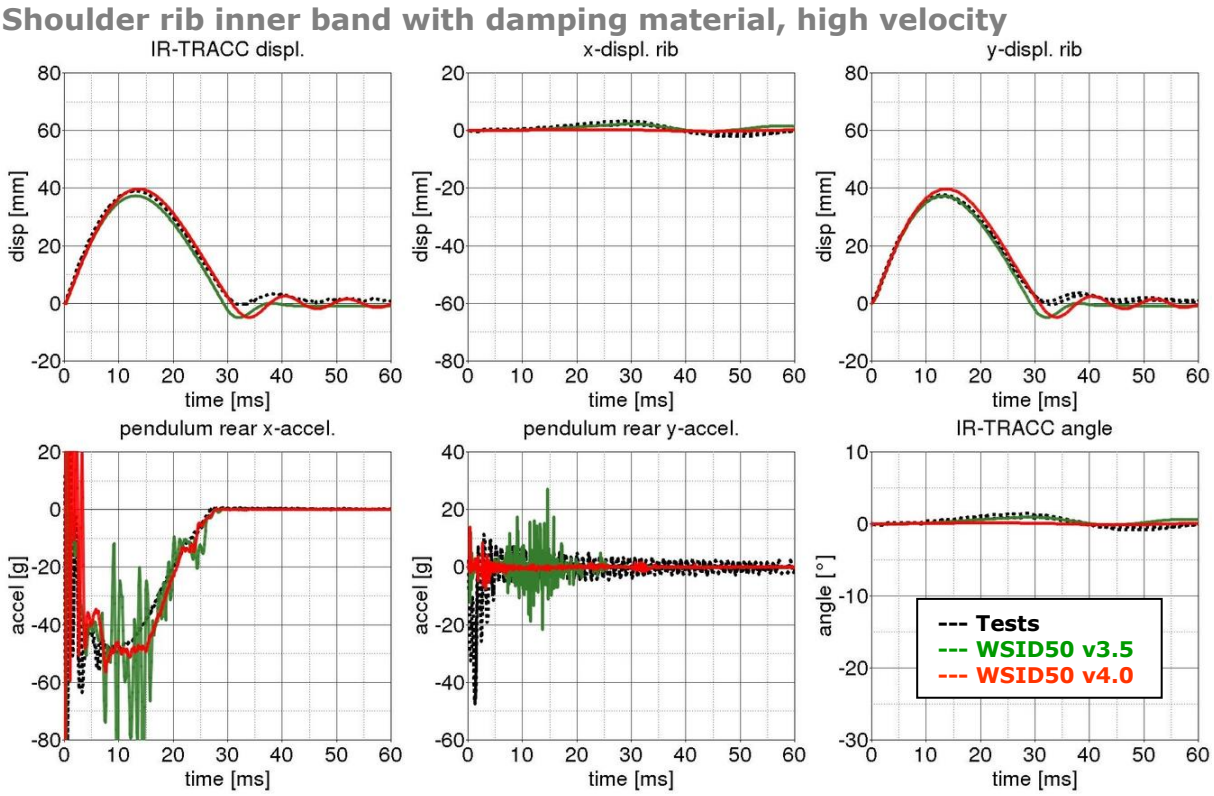


Figure 49: Shoulder rib test on inner band with damping material, high velocity

Third thorax rib:

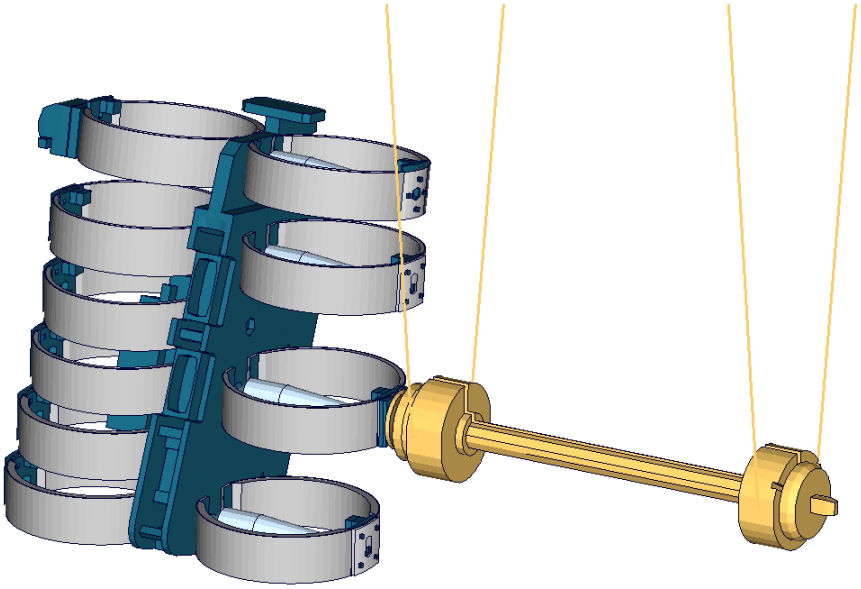


Figure 50: Third thorax rib test on inner band with damping material

Third thorax rib inner band with damping material, low velocity

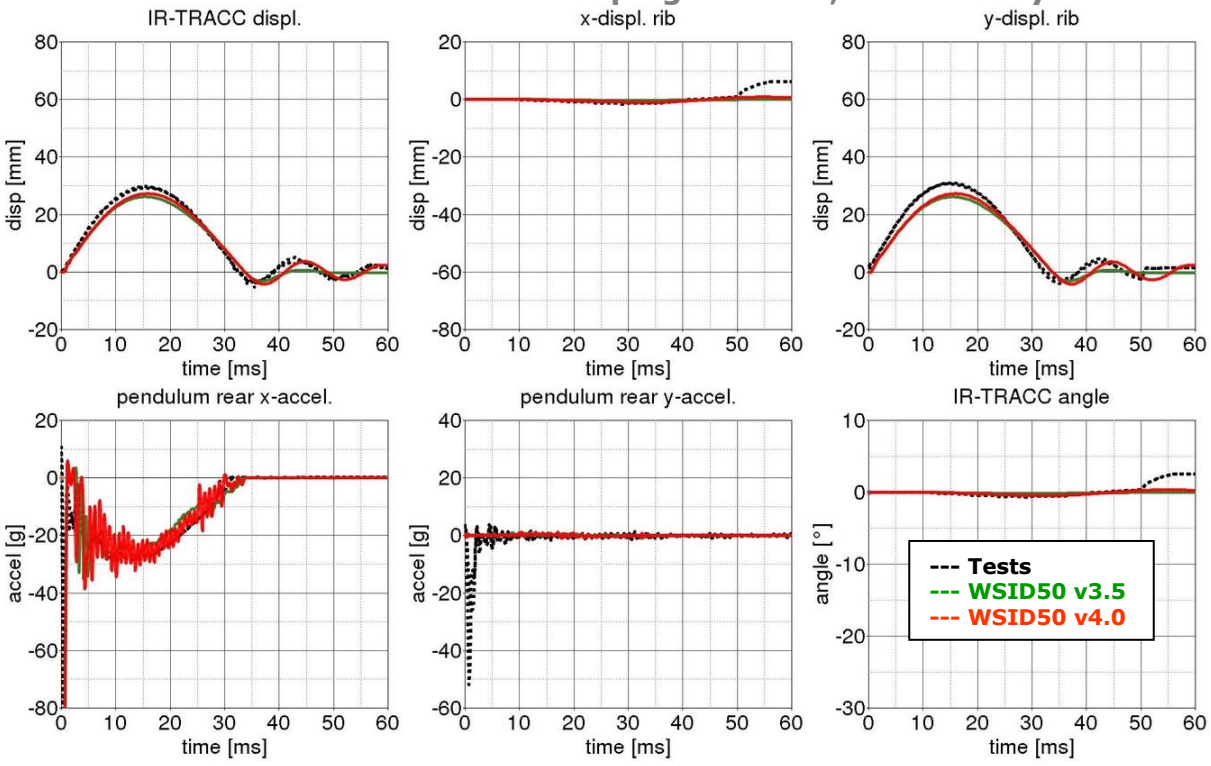


Figure 51: Shoulder rib test on inner band with damping material, low velocity

Third thorax rib inner band with damping material, high velocity

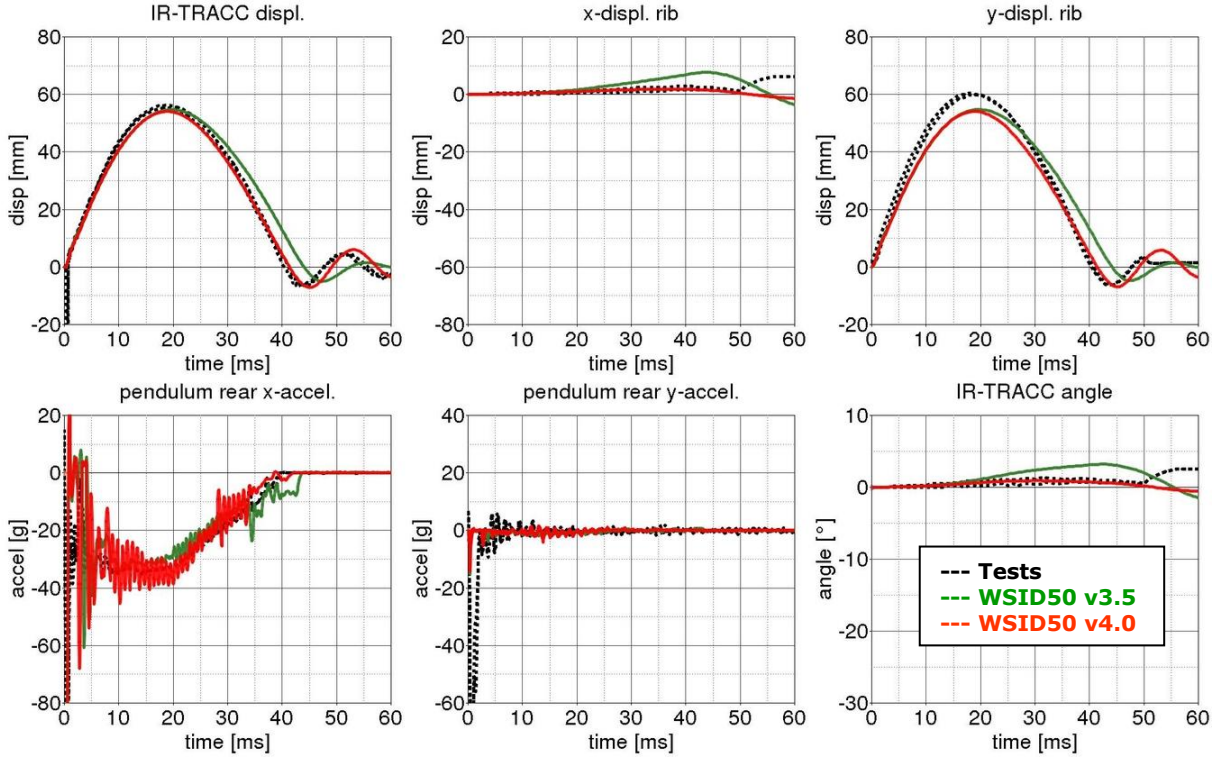


Figure 52: Shoulder rib test on inner band with damping material, high velocity

Second abdomen rib:

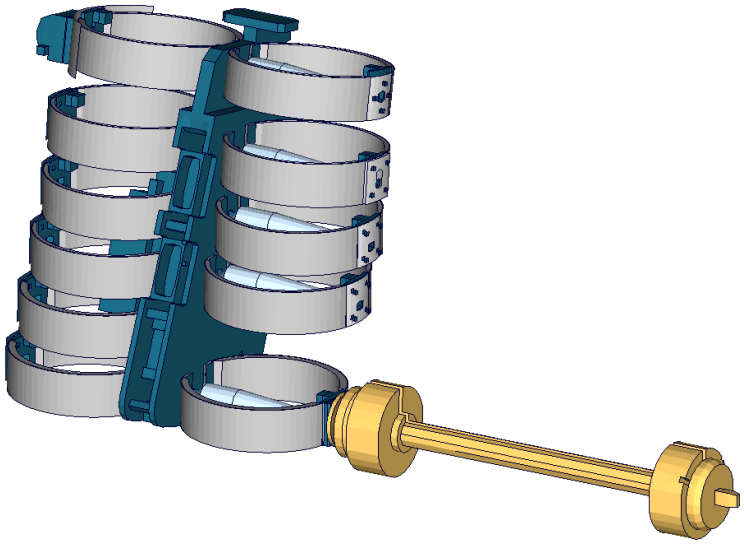


Figure 53: Second abdomen rib test on inner band with damping material.

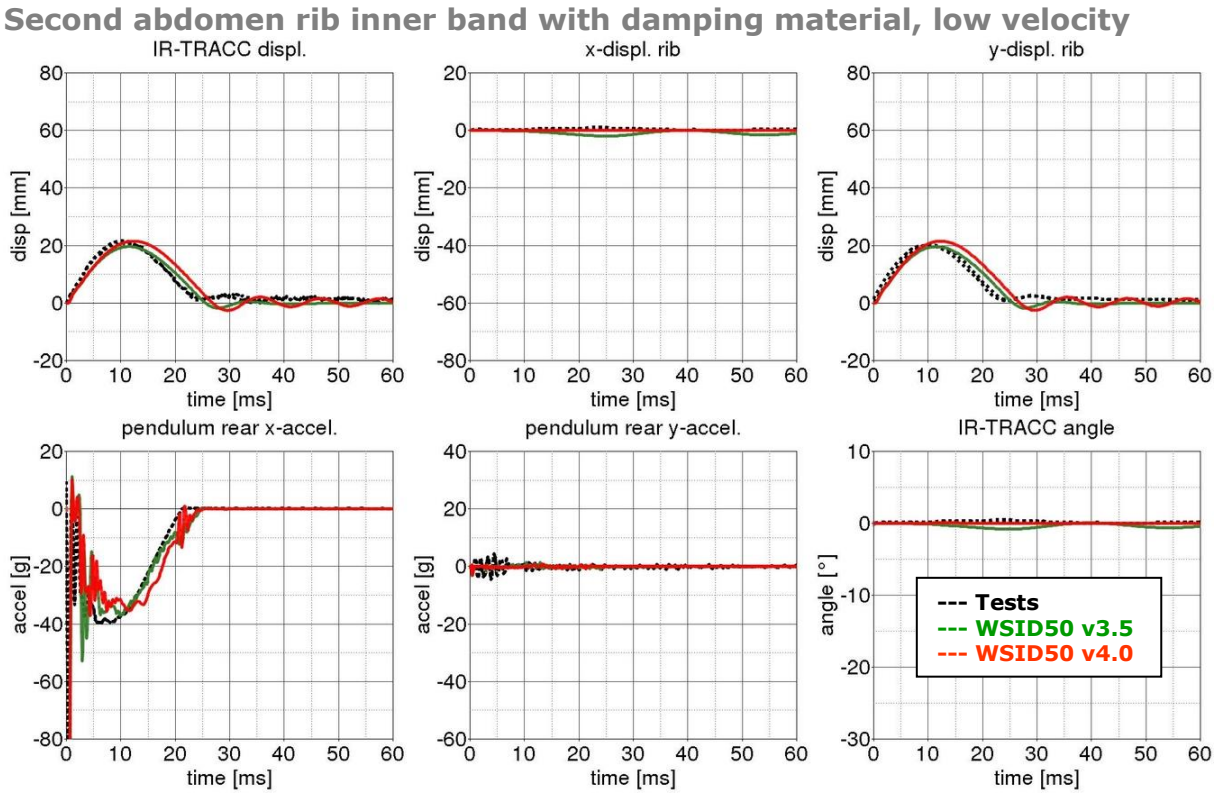


Figure 54: Second abdomen rib test on inner band with damping material, low velocity

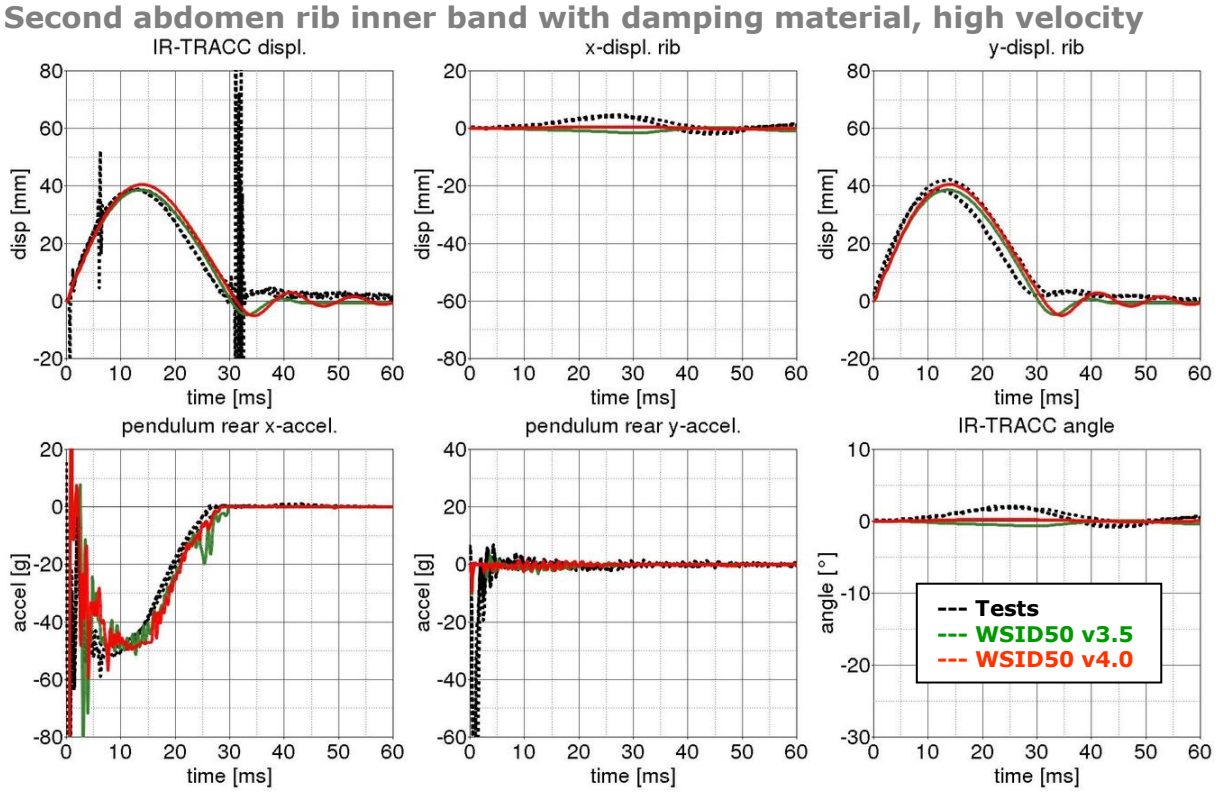


Figure 55: Second abdomen rib test on inner band with damping material, high velocity

8.1.3.2 Outer rib band

The outer rib band is tested in a similar way. A fully assembled thorax assembly is used and only the ribs above and below the tested rib are disassembled. The tested ribs are:

- Shoulder rib
- First thorax rib
- Third thorax rib
- Second abdomen rib

Each rib is tested with two velocities except the first thorax rib, where three different pendulum speeds are used.

The test is used to validate the behavior of the complete rib modules including the sternum materials.
Furthermore two different masses are used for the pendulum; hence there are four different test configurations for each single rib.

Shoulder rib:

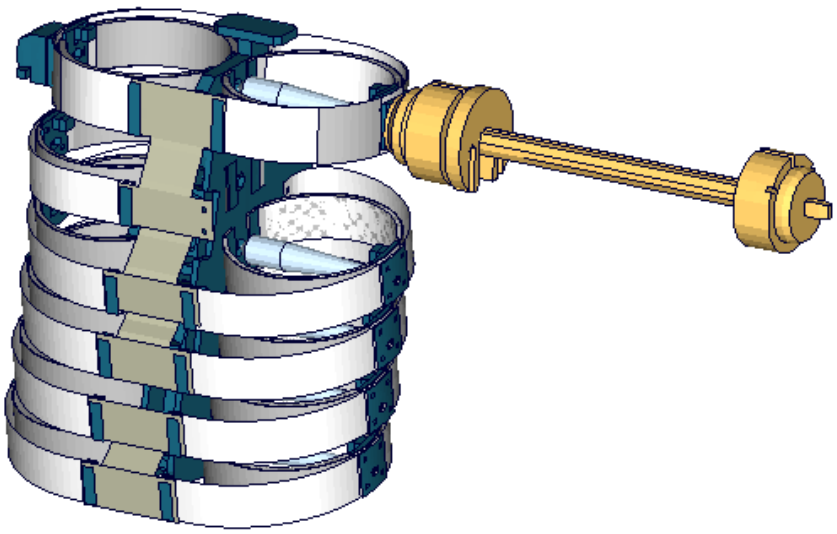


Figure 56: Shoulder rib outer band test

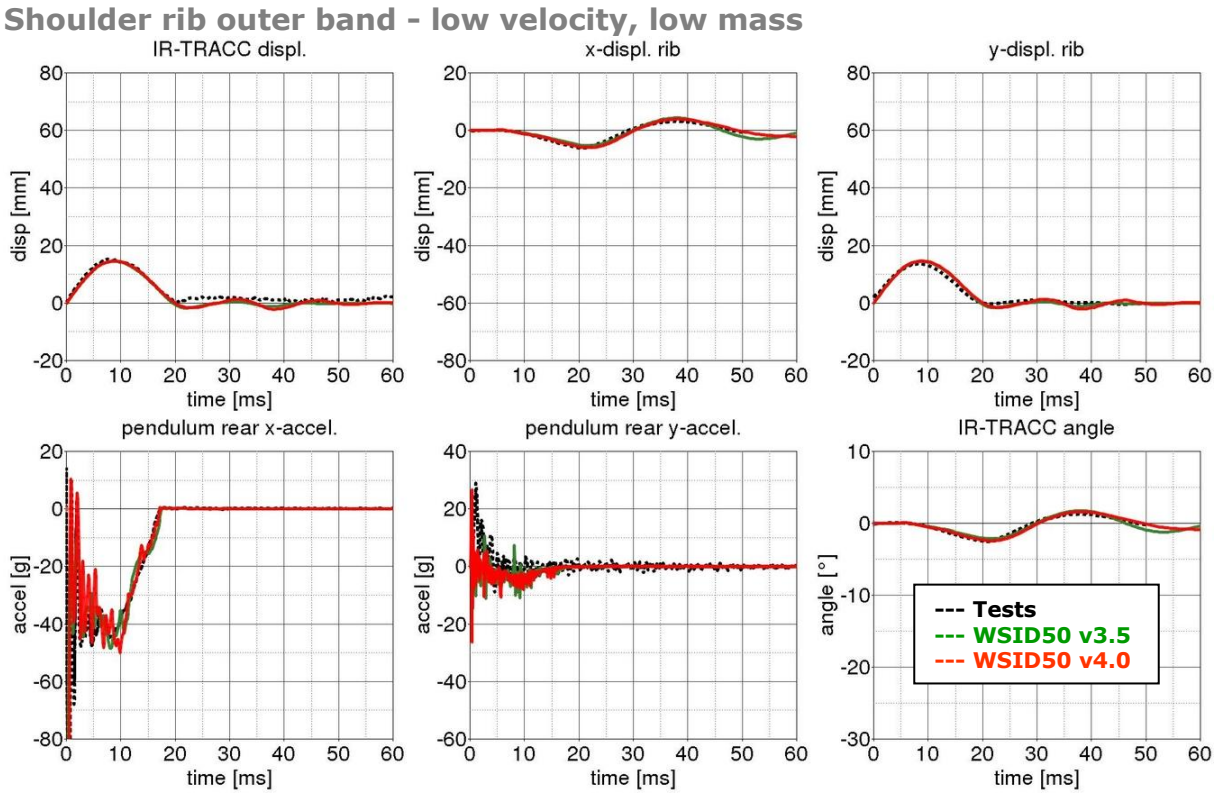


Figure 57: Shoulder rib test on outer band - low velocity and low mass

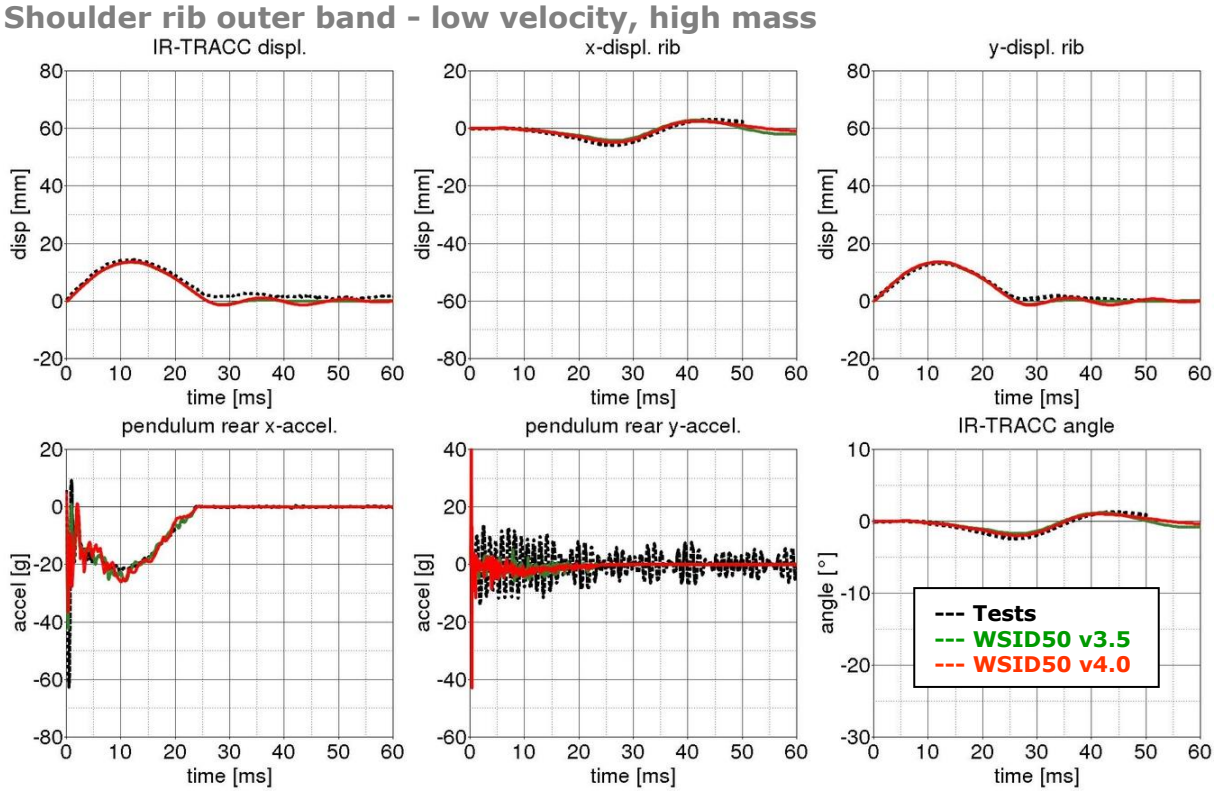


Figure 58: Shoulder rib test on outer band - low velocity and high mass

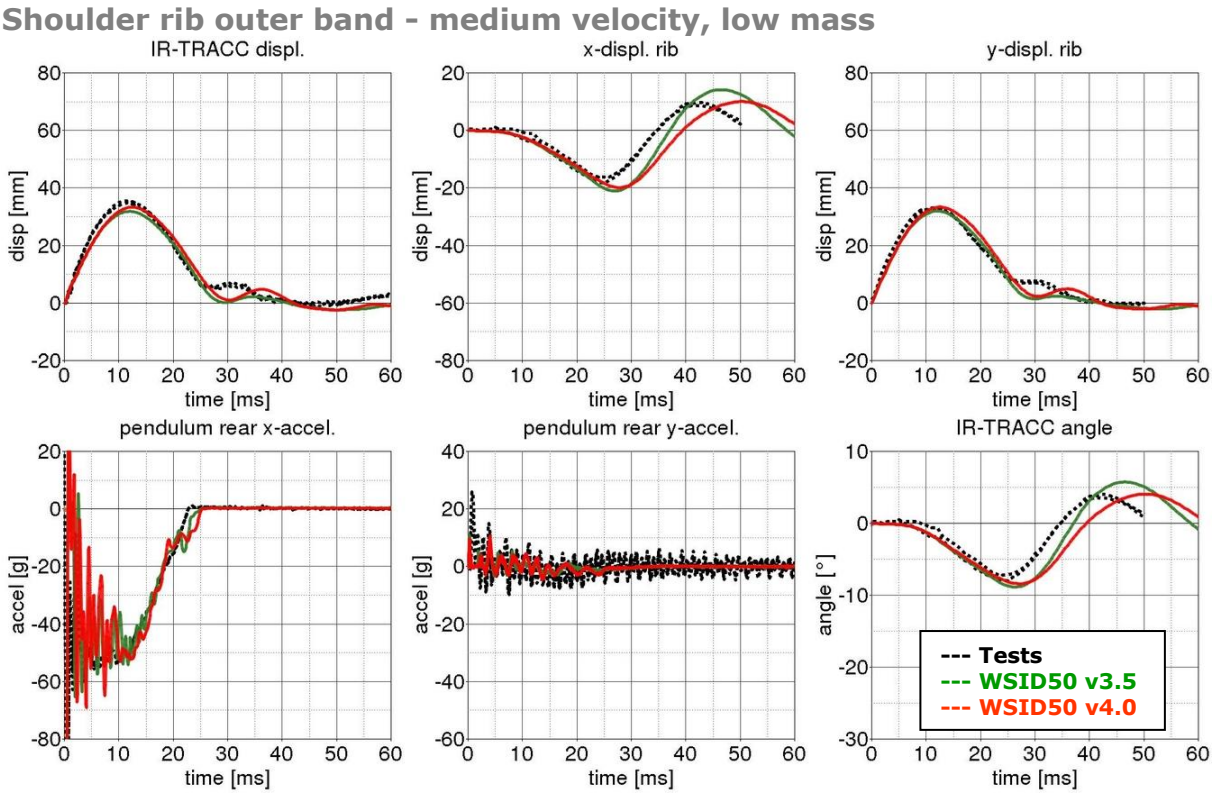


Figure 59: Shoulder rib test on outer band - low velocity and low mass

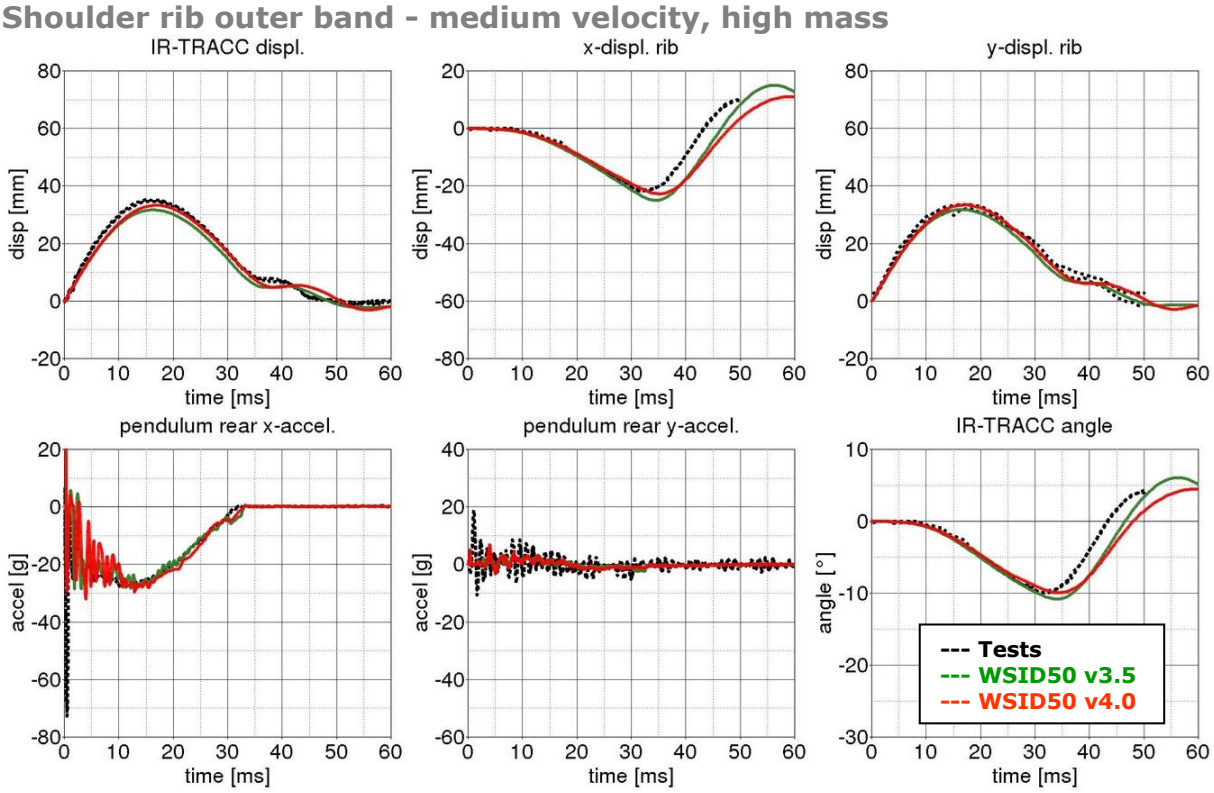


Figure 60: Shoulder rib test on outer band - low velocity and high mass

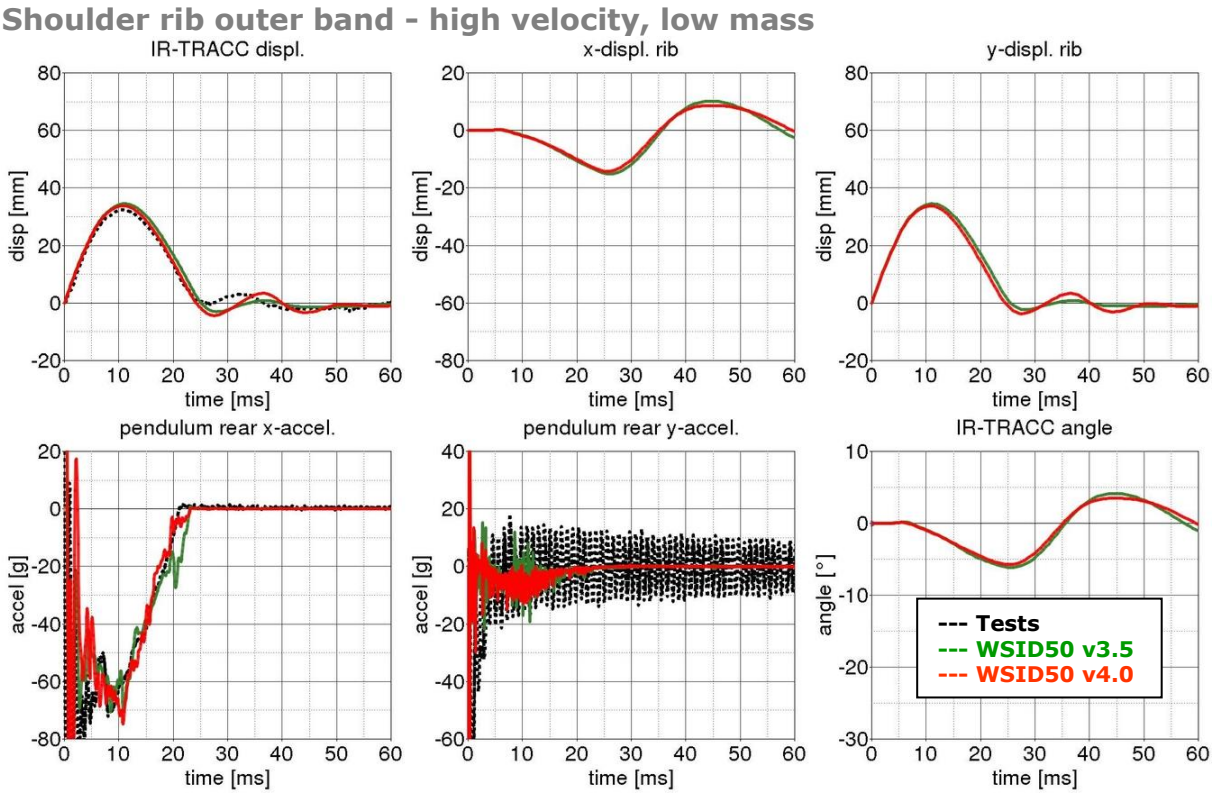


Figure 61: Shoulder rib test on outer band - high velocity and low mass

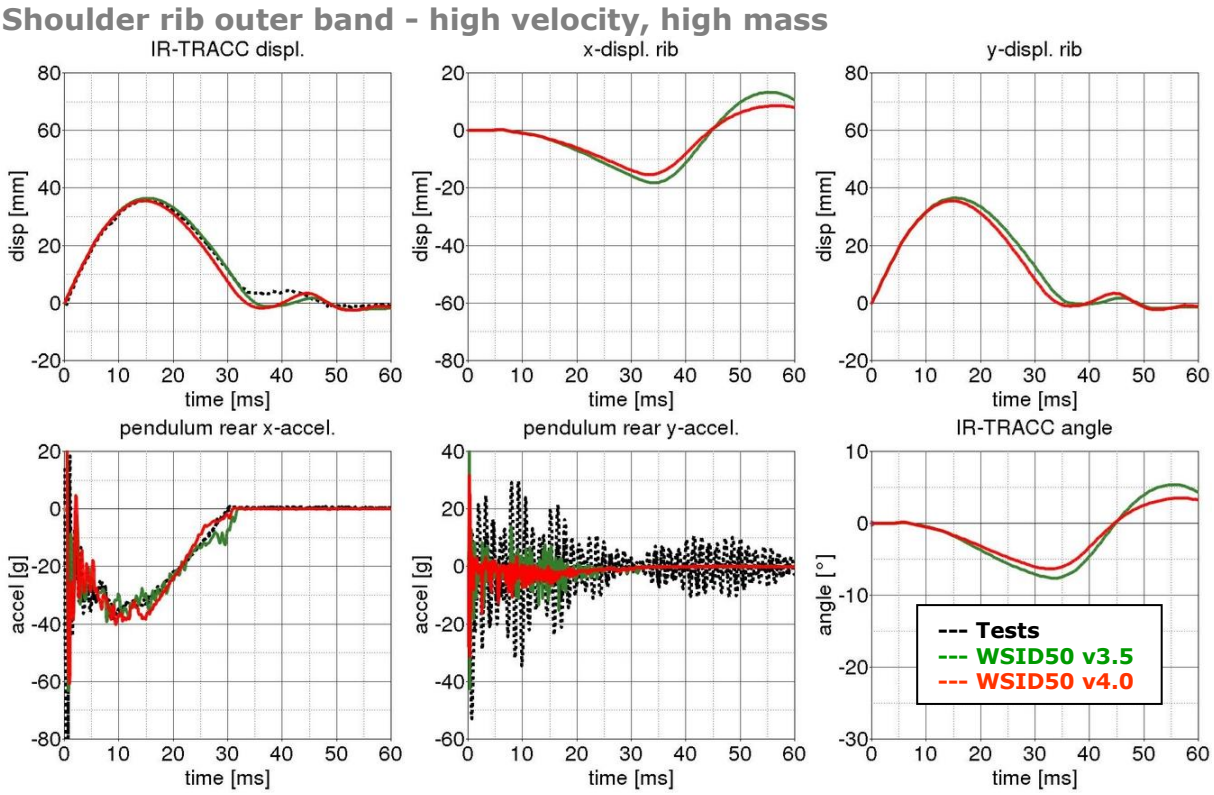


Figure 62: Shoulder rib test on outer band - high velocity and high mass

First thorax rib:

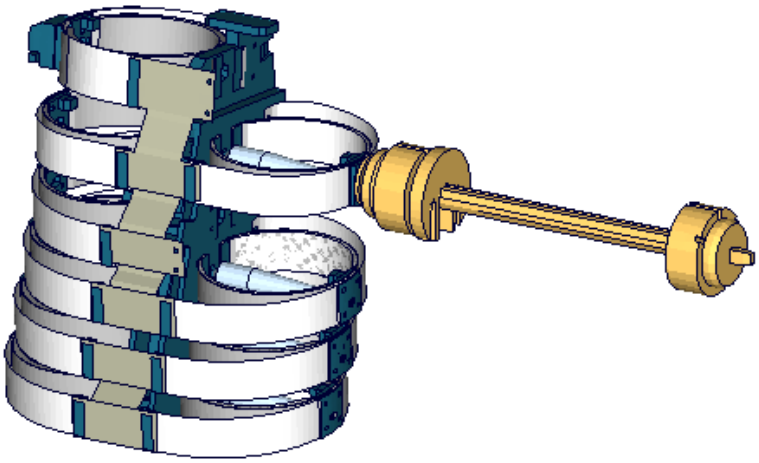


Figure 63: First thorax rib outer band test

First thorax rib outer band - low velocity, low mass

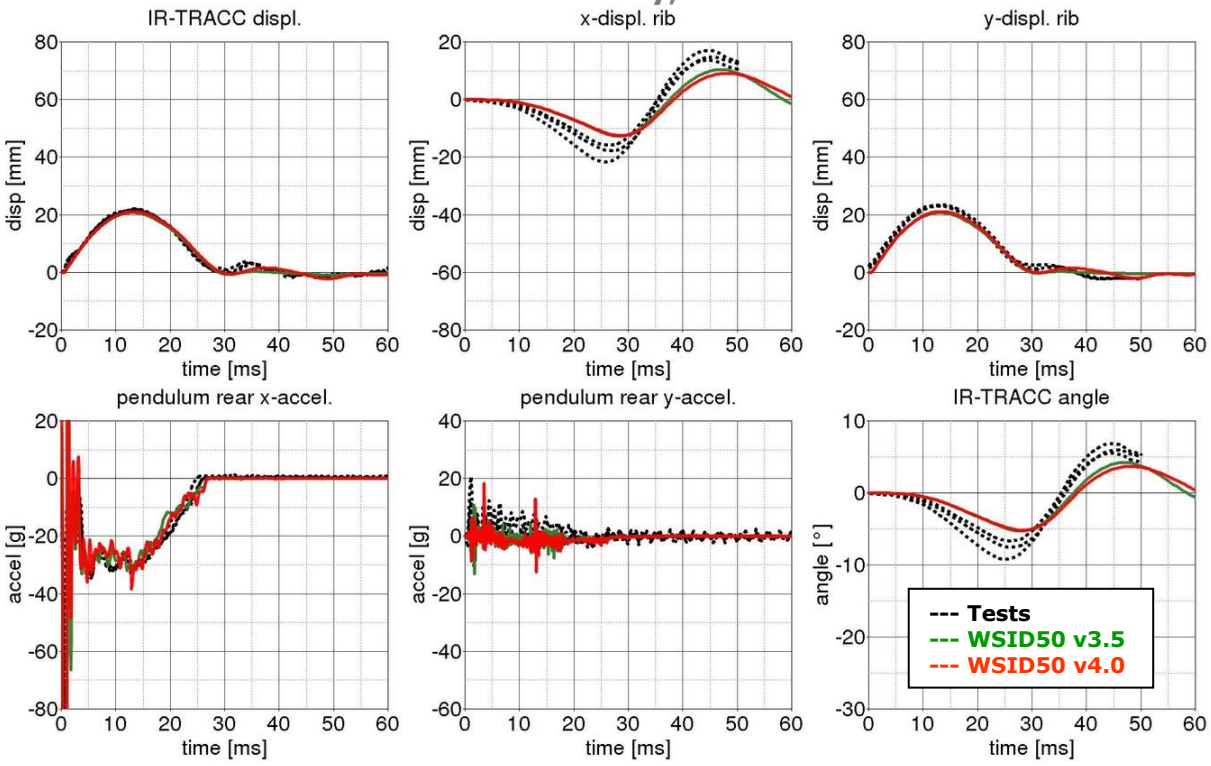


Figure 64: First thorax rib test on outer band - low velocity and low mass

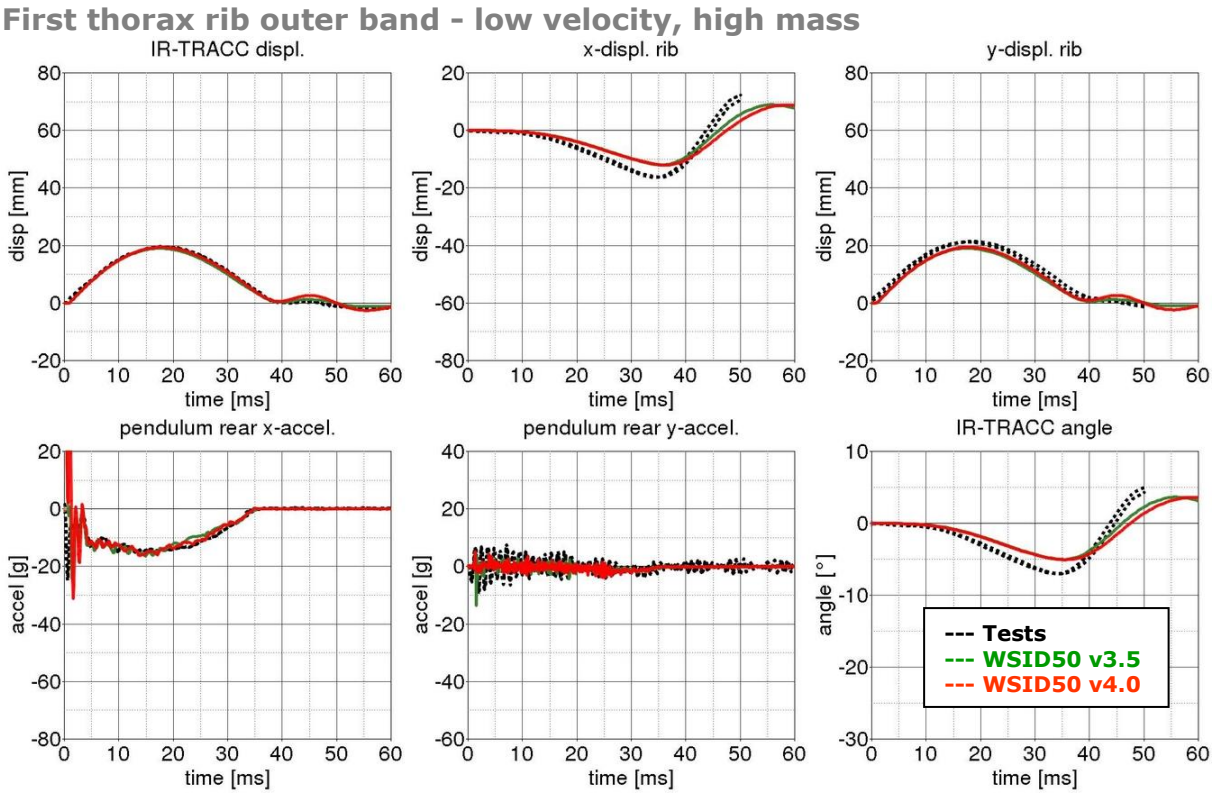


Figure 65: First thorax rib test on outer band - low velocity and high mass

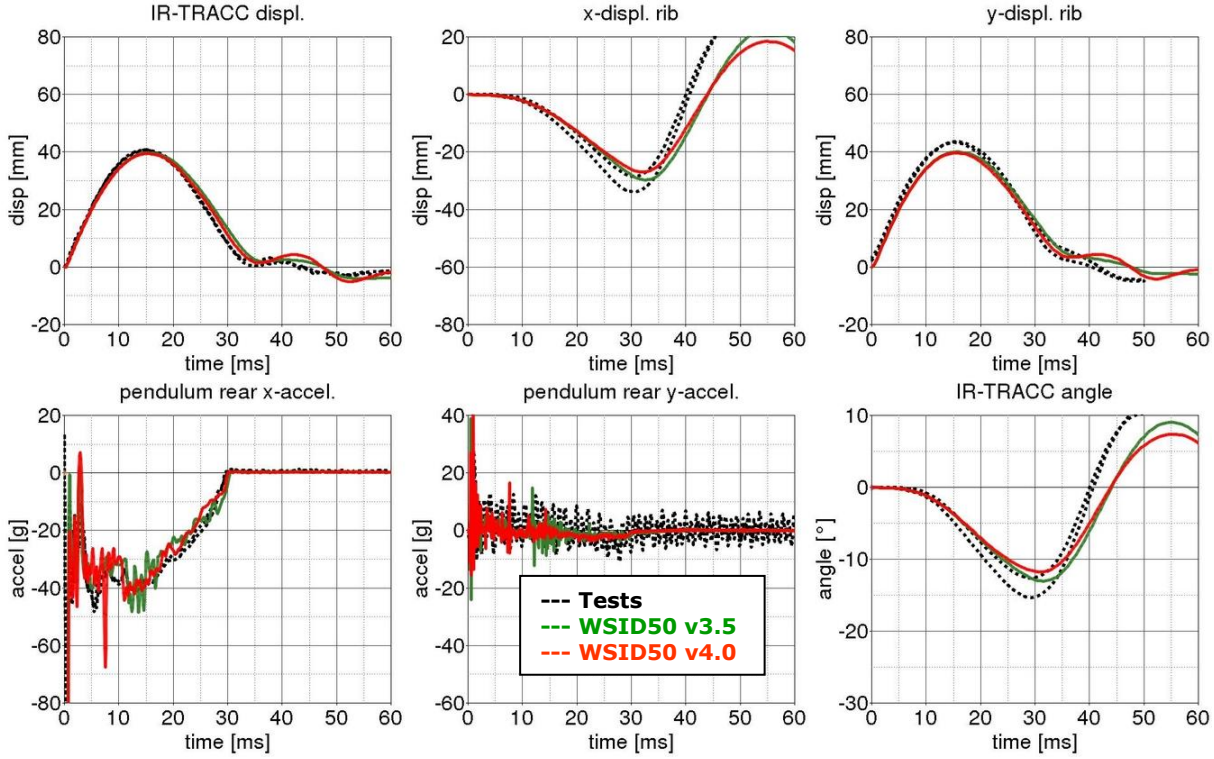


Figure 66: First thorax rib test on outer band - middle velocity and low mass

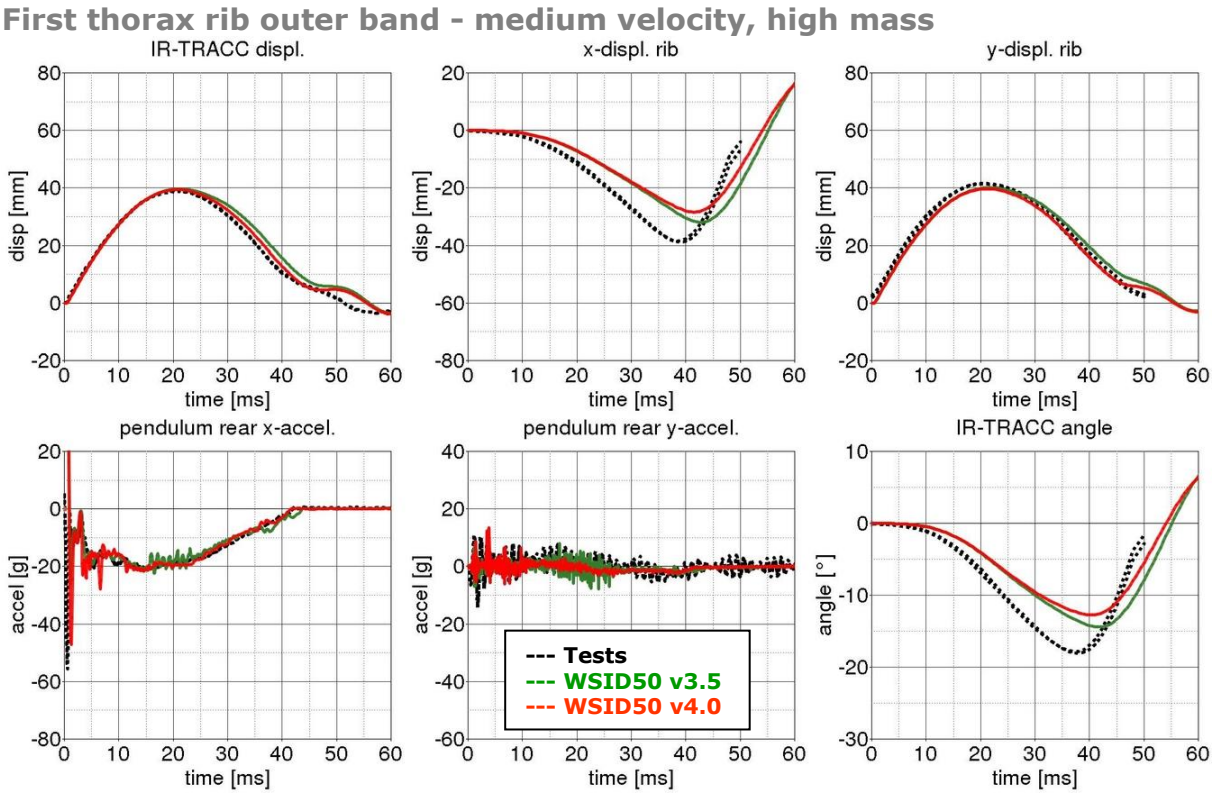


Figure 67: First thorax rib test on outer band - middle velocity and high mass

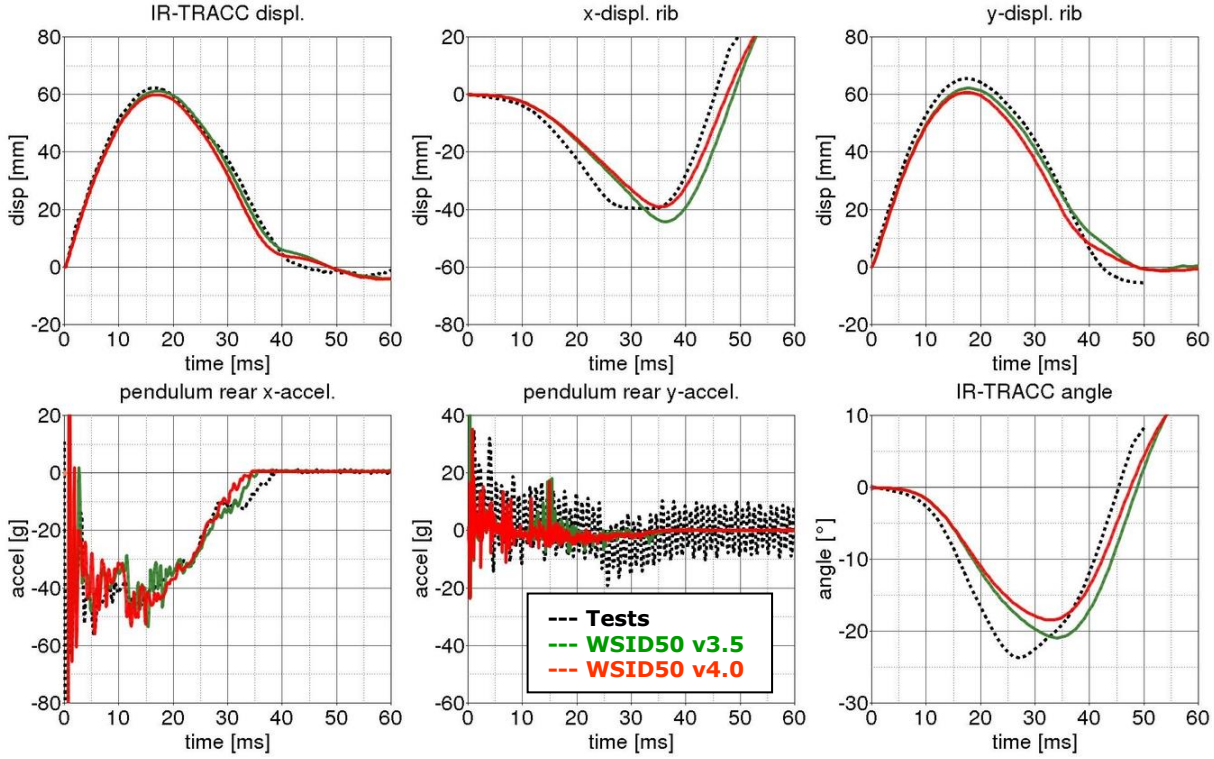


Figure 68: First thorax rib test on outer band - high velocity and low mass

First thorax rib outer band - high velocity, high mass

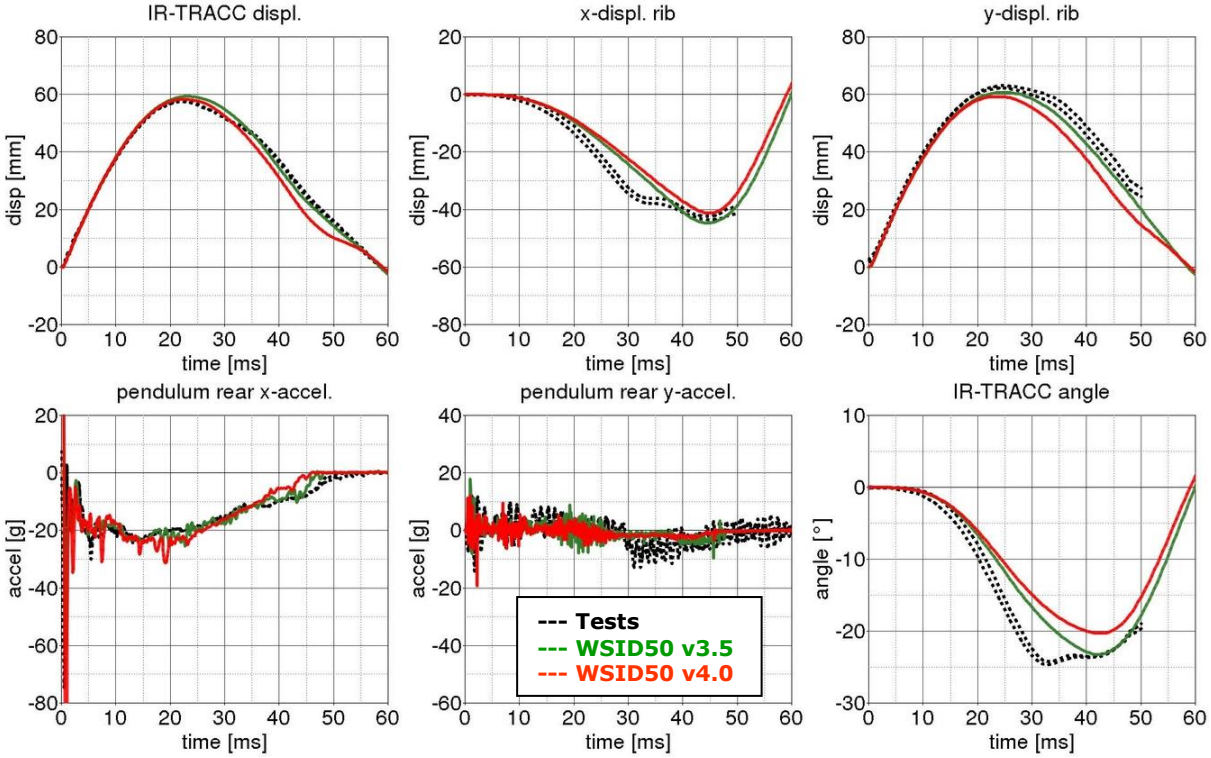


Figure 69: First thorax rib test on outer band - high velocity and high mass

Third thorax rib:

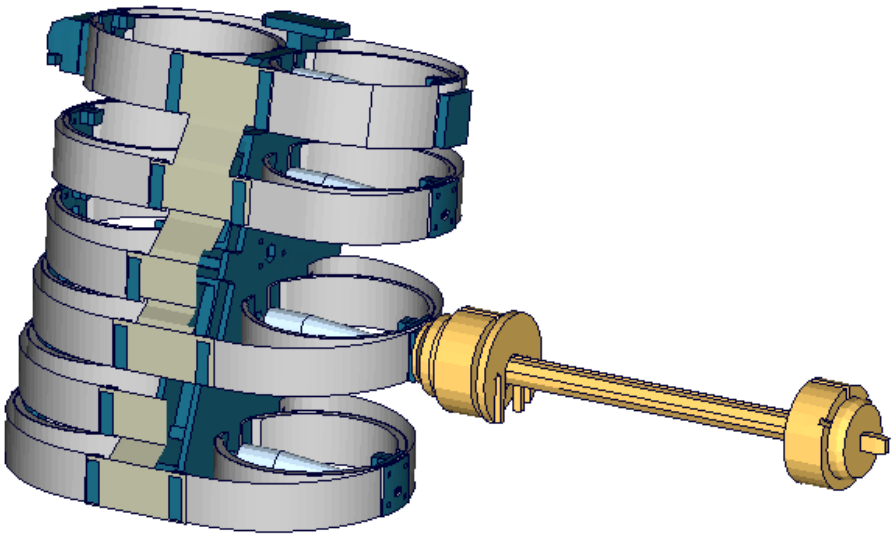


Figure 70: Third thorax rib outer band test

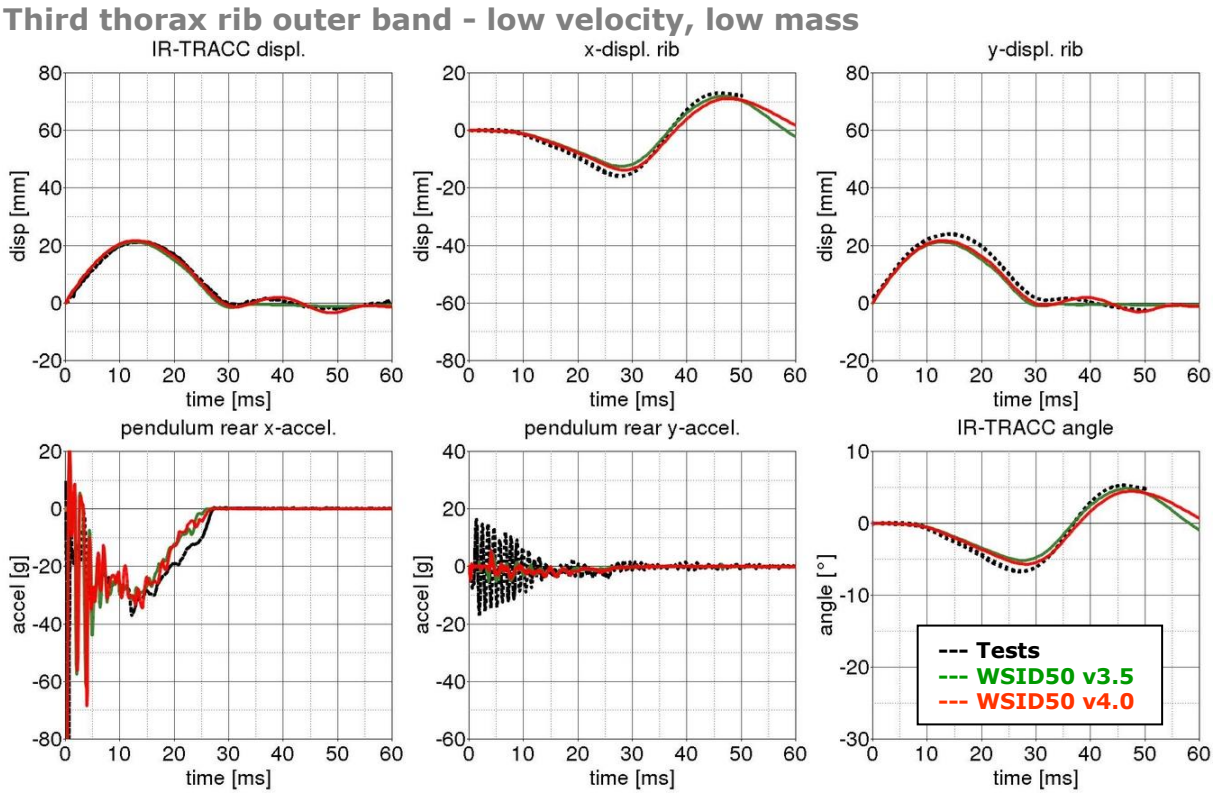


Figure 71: Third thorax rib test on outer band - low velocity and low mass

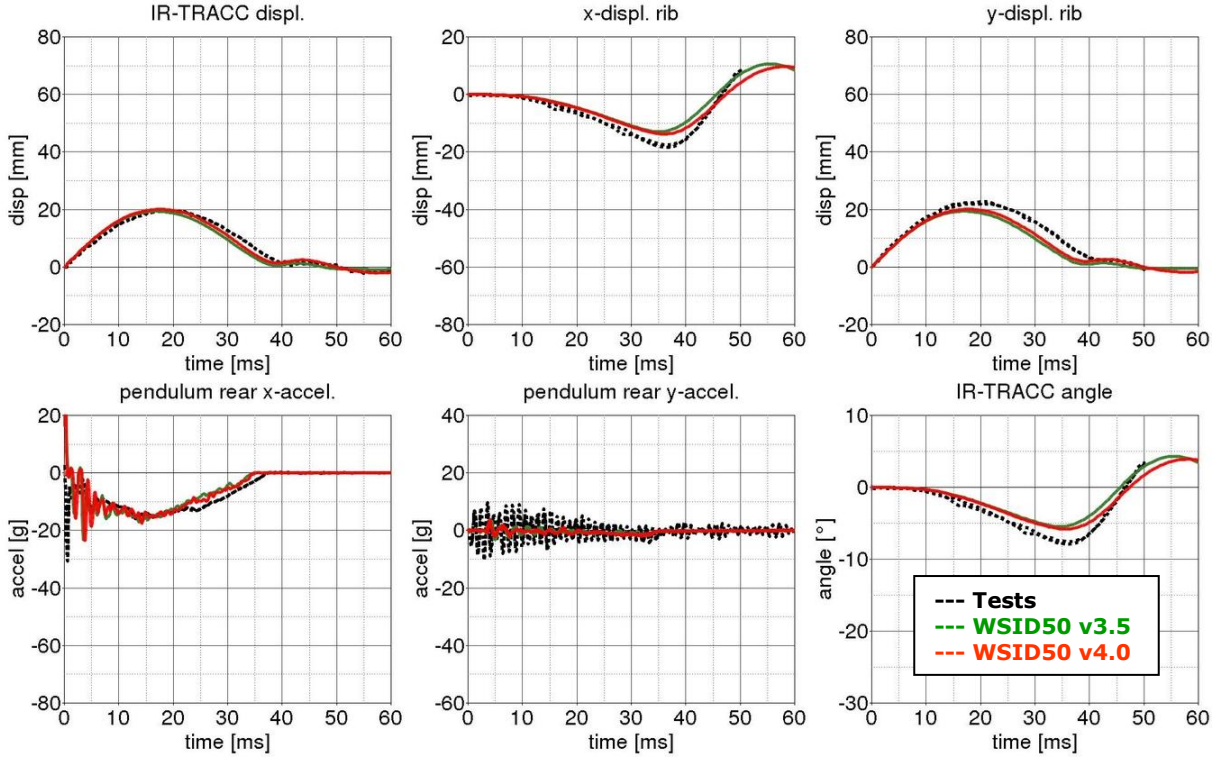


Figure 72: Third thorax rib test on outer band - low velocity and high mass

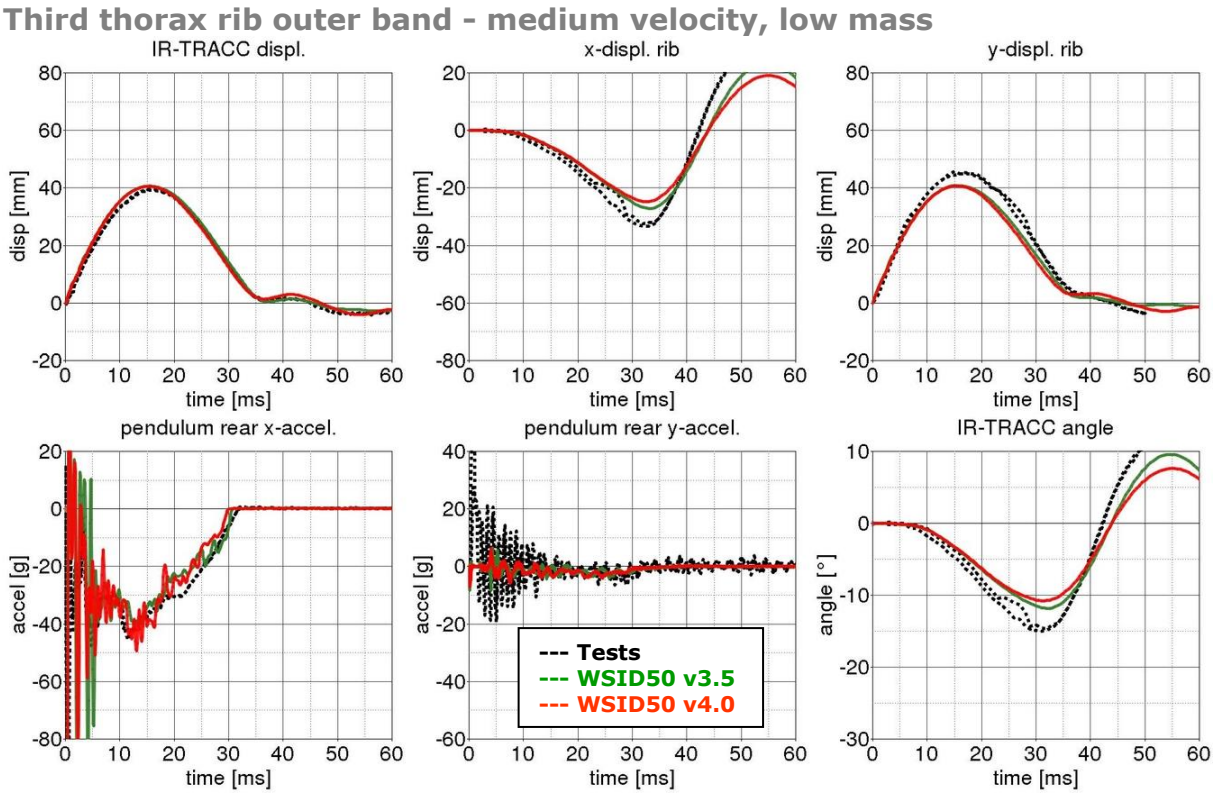


Figure 73: Third thorax rib test on outer band - medium velocity and low mass

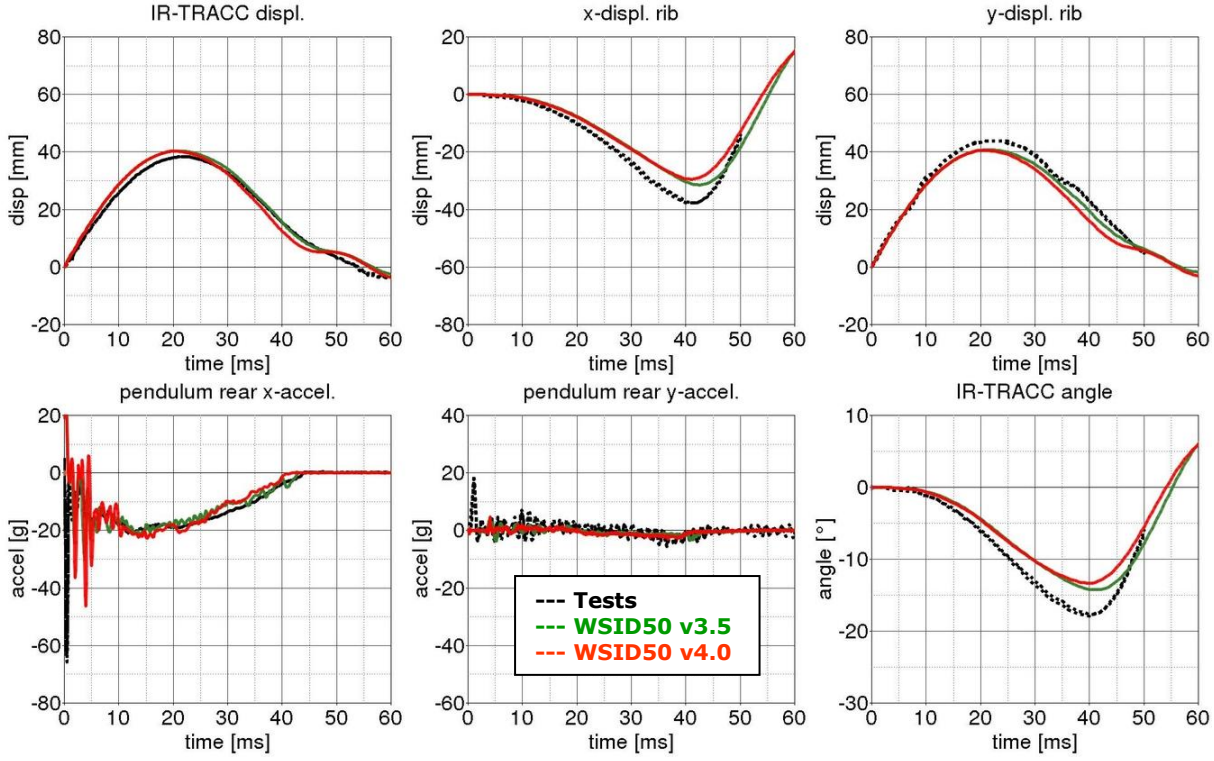


Figure 74: third thorax rib test on outer band - medium velocity and high mass

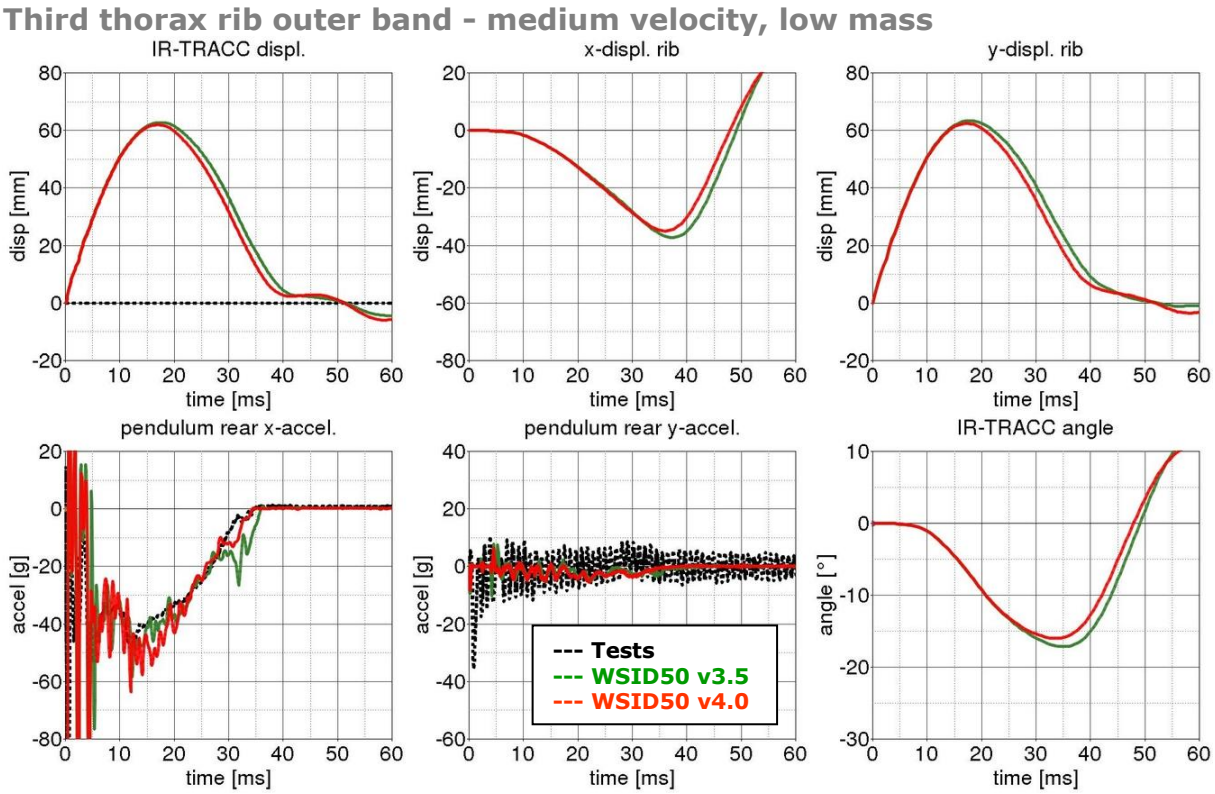


Figure 75: Third thorax rib test on outer band - high velocity and low mass

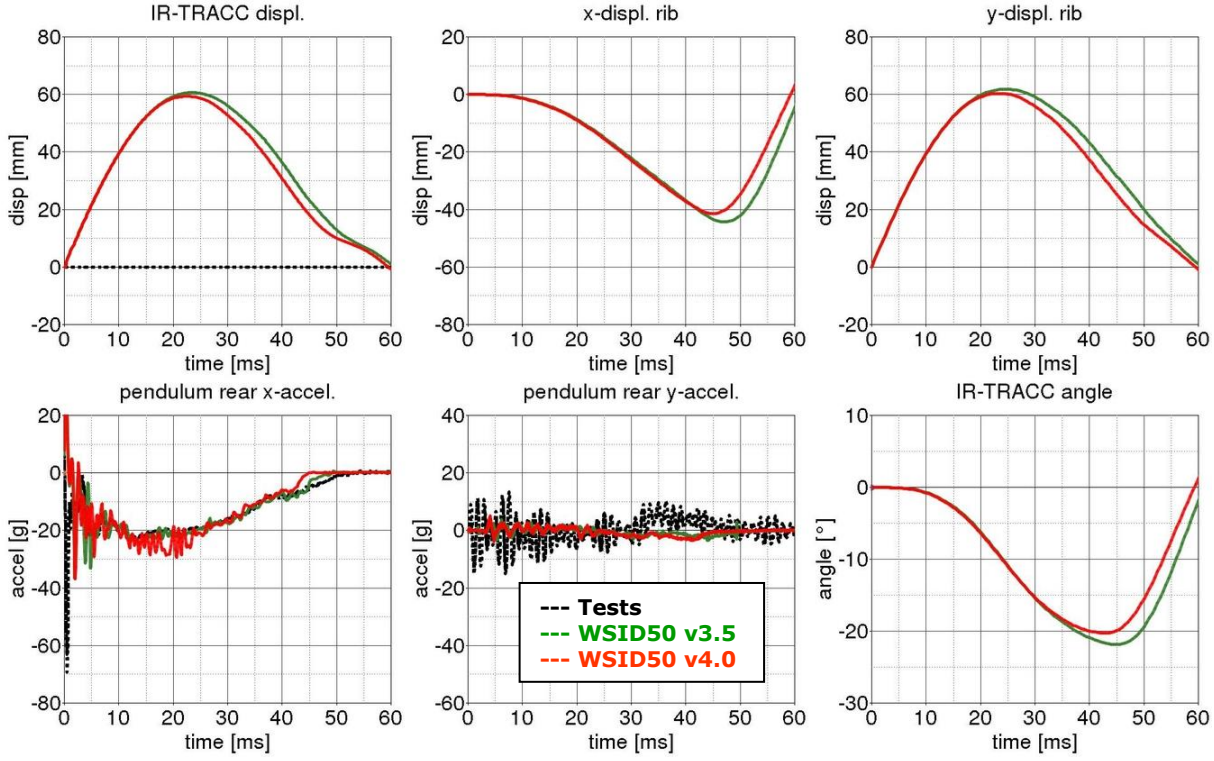


Figure 76: third thorax rib test on outer band - high velocity and high mass

Second abdomen rib:

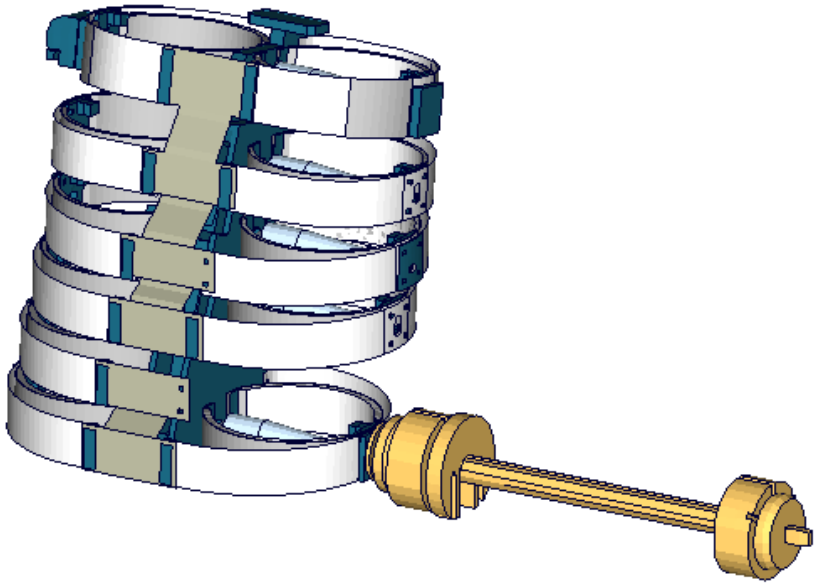


Figure 77: Second abdomen rib outer band test

Second abdomen rib outer band - low velocity, low mass

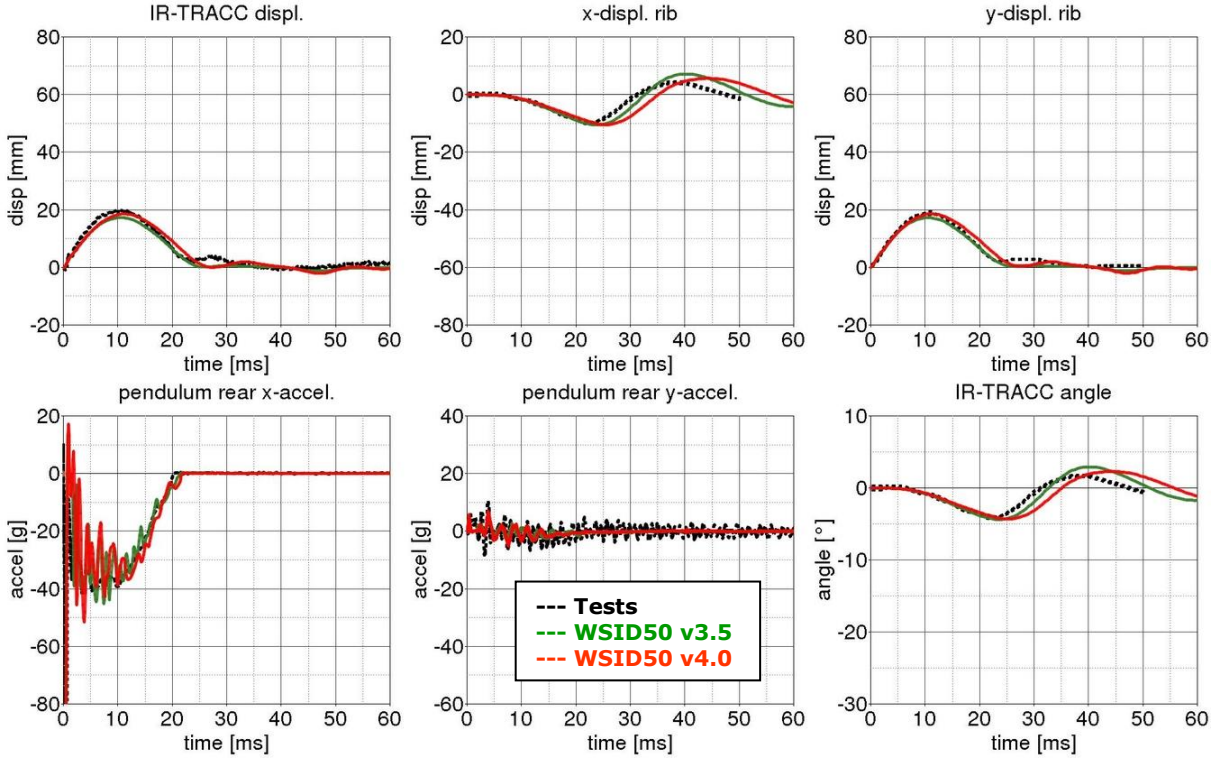


Figure 78: Second abdomen rib test on outer band - low velocity and low mass

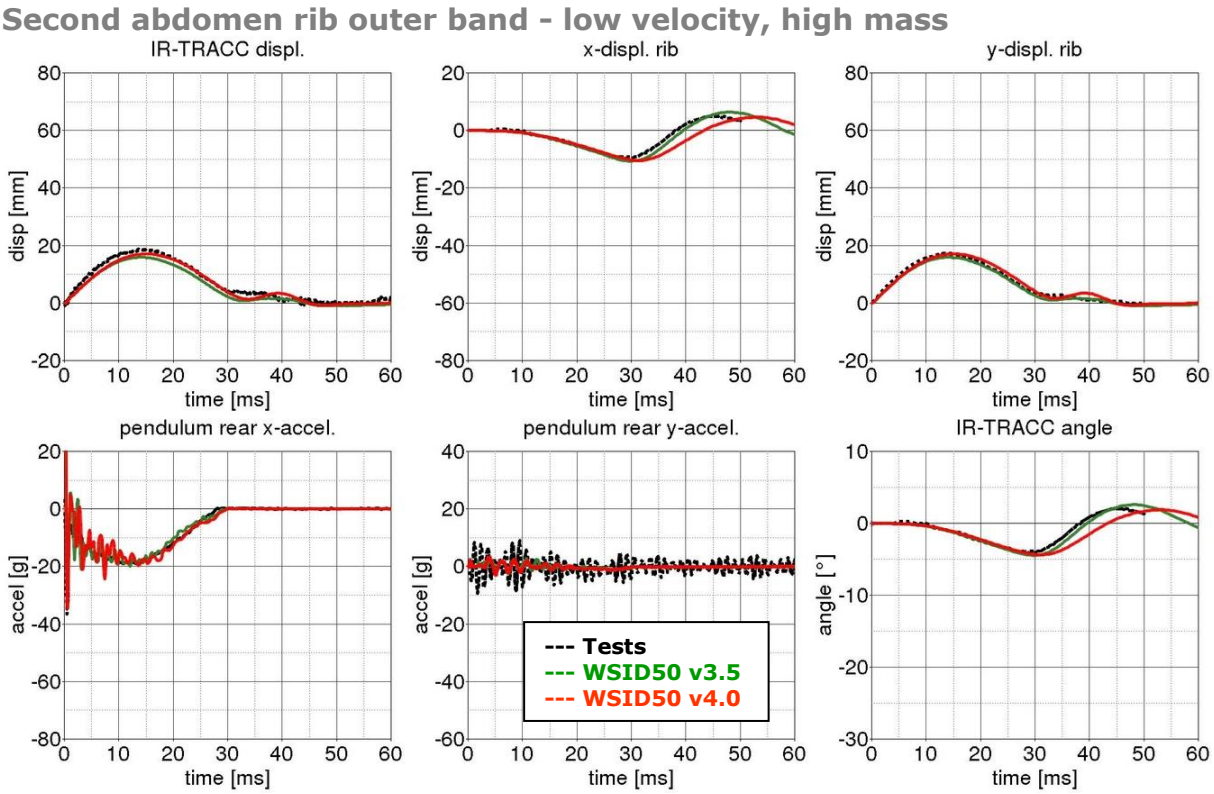


Figure 79: Second abdomen rib test on outer band - low velocity and high mass

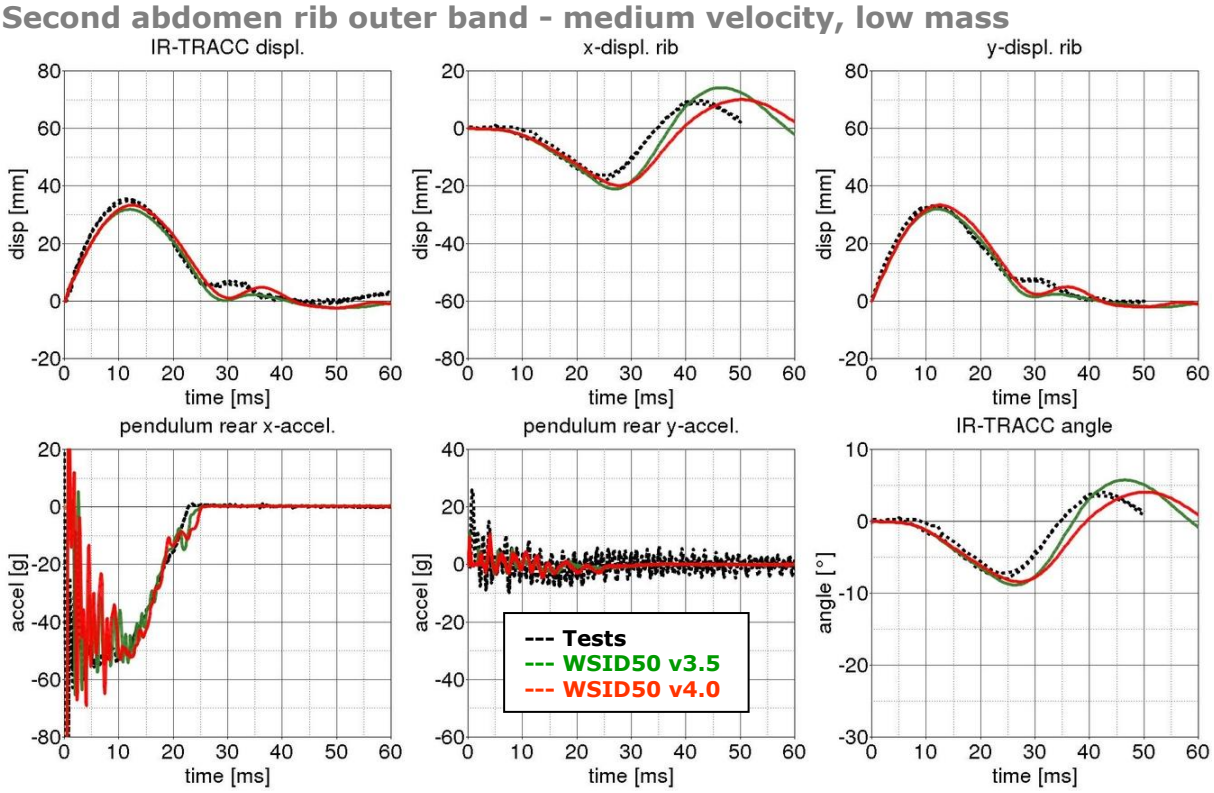


Figure 80: Second abdomen rib test on outer band - high velocity and low mass

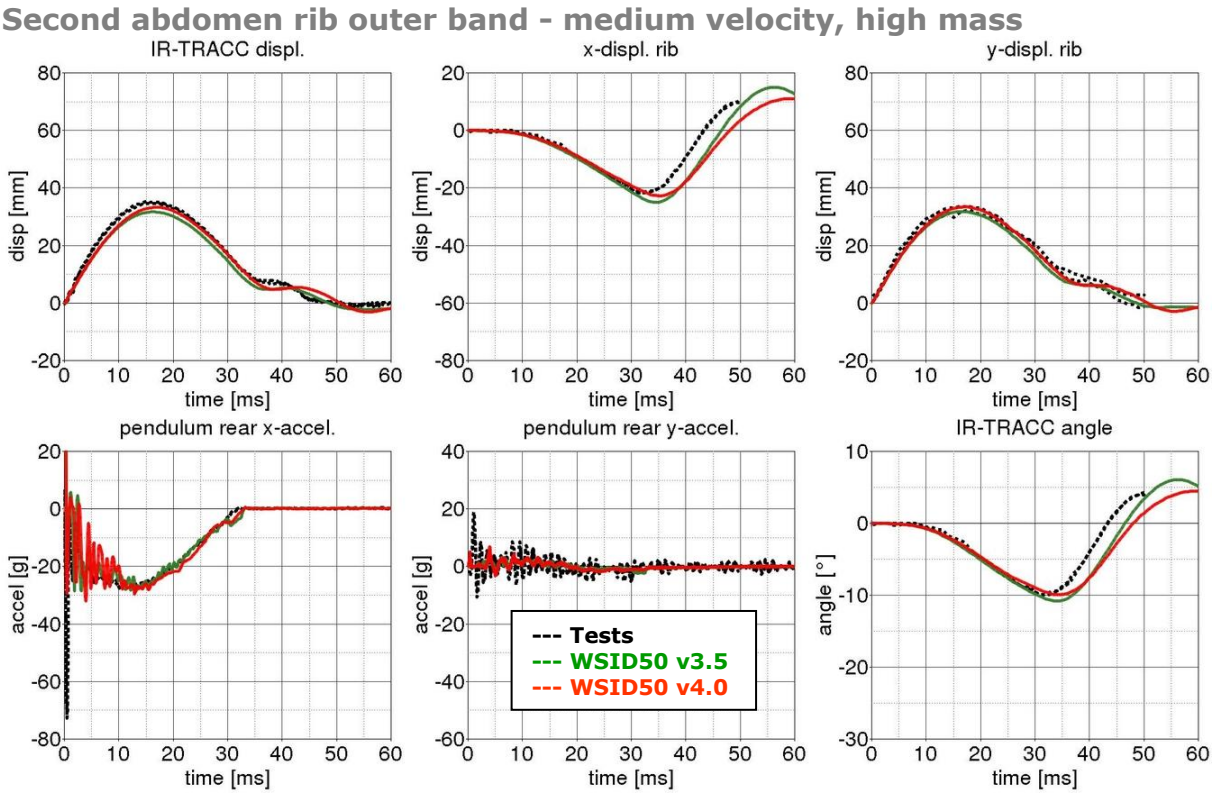


Figure 81: Second abdomen rib test on outer band - high velocity and high mass

8.1.3.3 Outer rib band vertical pendulum test

Since the release v3.5 there are additional test for the shoulder rib in vertical direction. With these tests the WorldSID model can be fine tuned to capture the ribs vertical movement due to an impact.

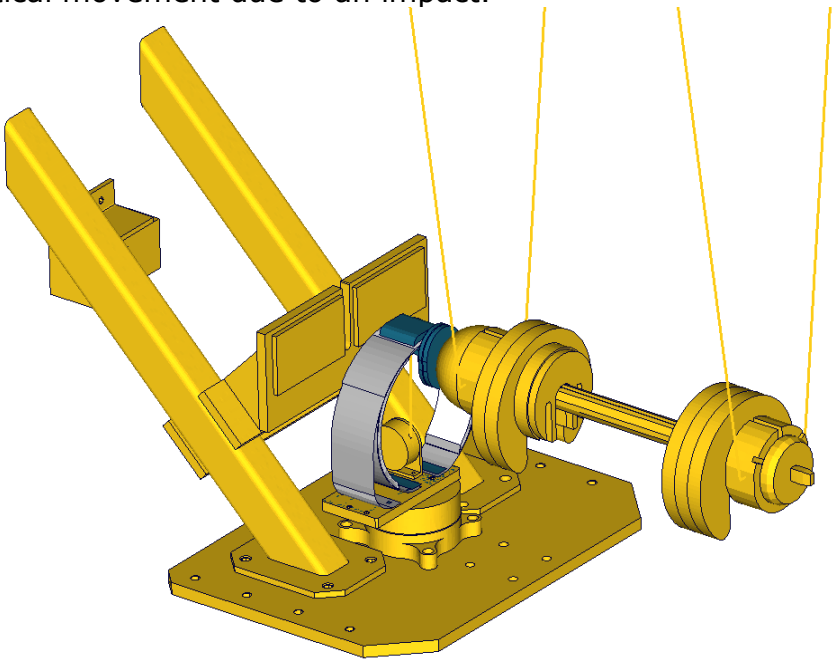


Figure 82: shoulder rib tests in z-direction

Shoulder rib outer band z-direction - low velocity

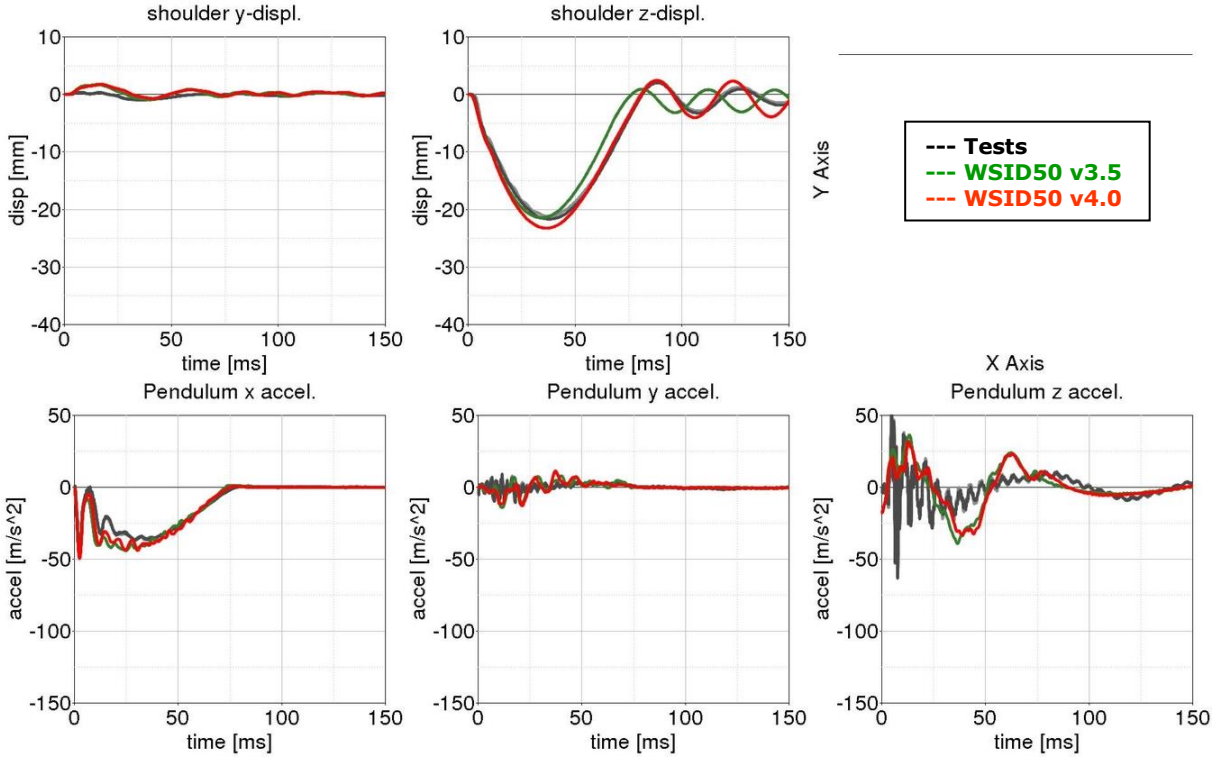


Figure 83: shoulder rib test on outer band z-direction – low velocity

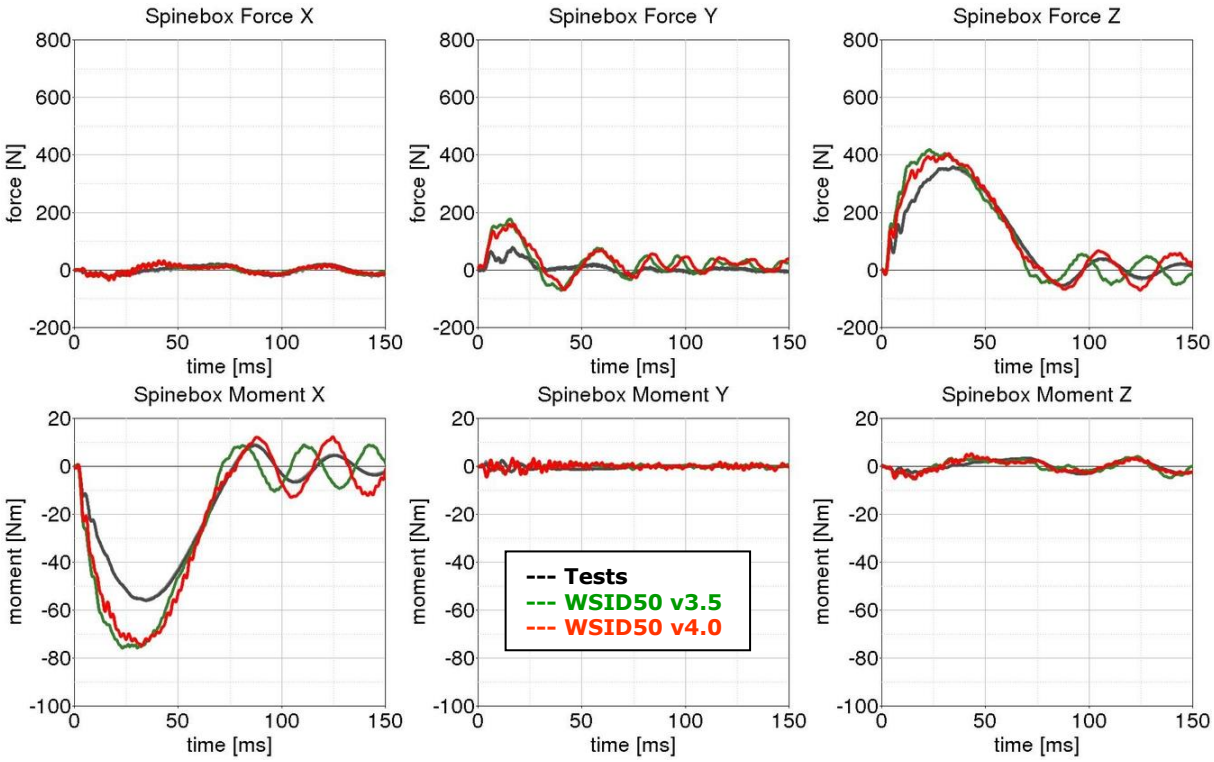


Figure 84: shoulder rib test on outer band z-direction – low velocity

Shoulder rib outer band z-direction - medium velocity

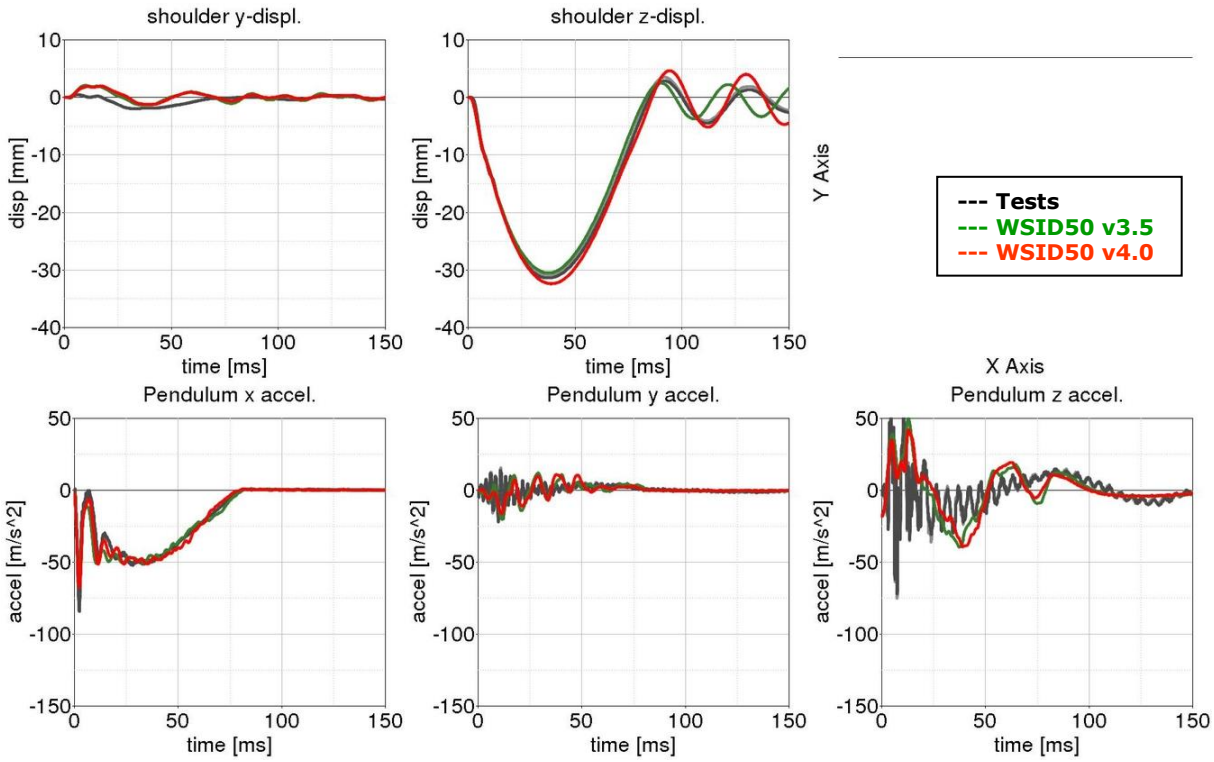


Figure 85: shoulder rib test on outer band z-direction – medium velocity

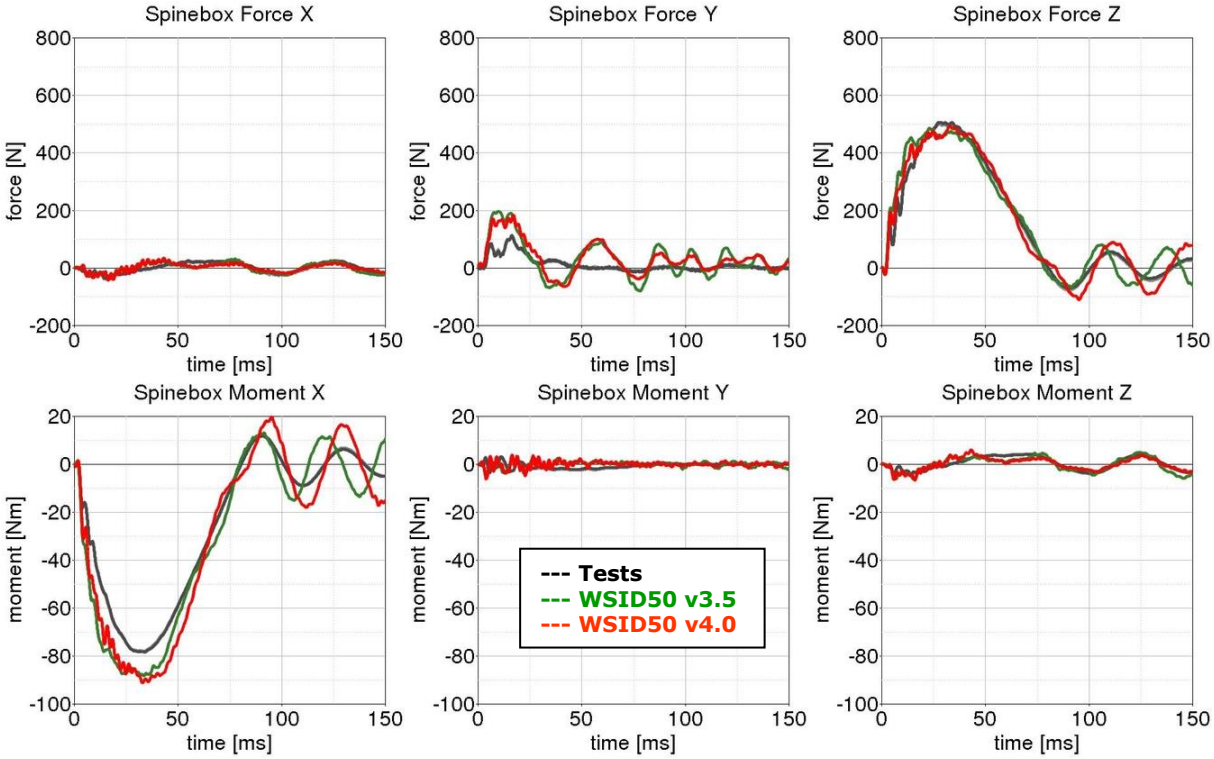


Figure 86: shoulder rib test on outer band z-direction – medium velocity

Shoulder rib outer band z-direction - high velocity

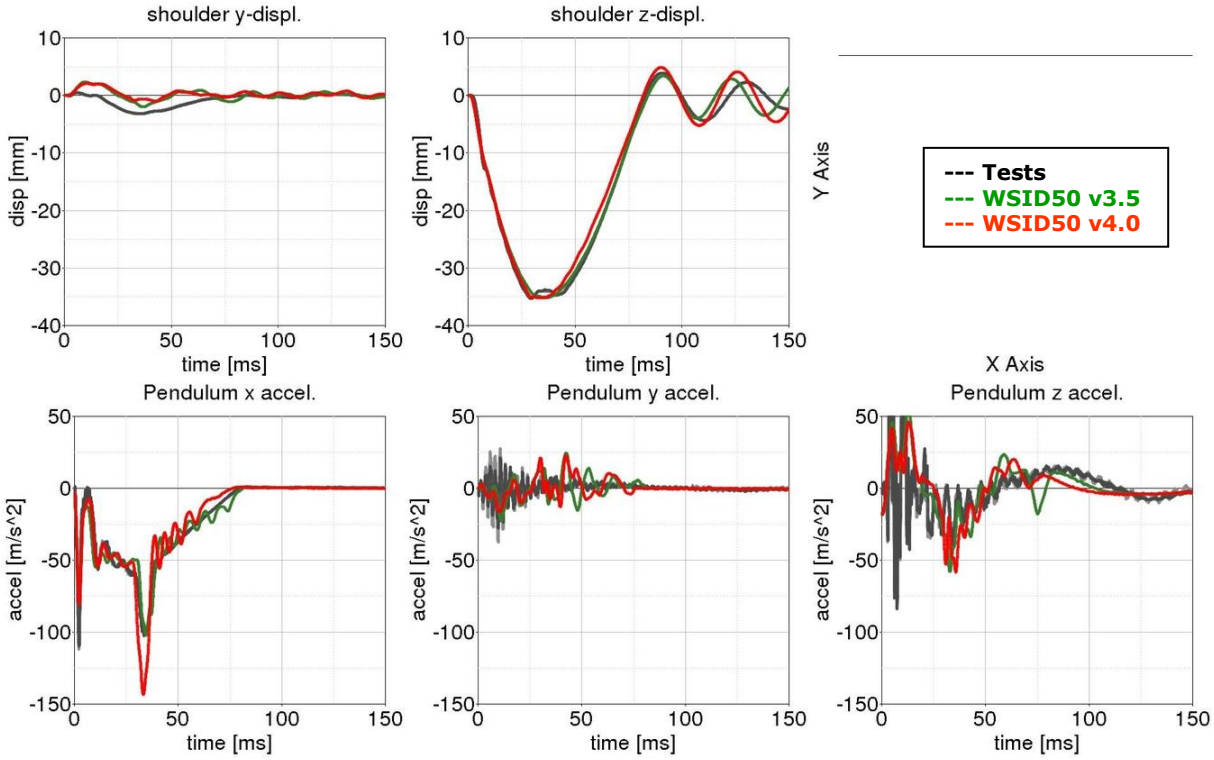


Figure 87: shoulder rib test on outer band z-direction – high velocity

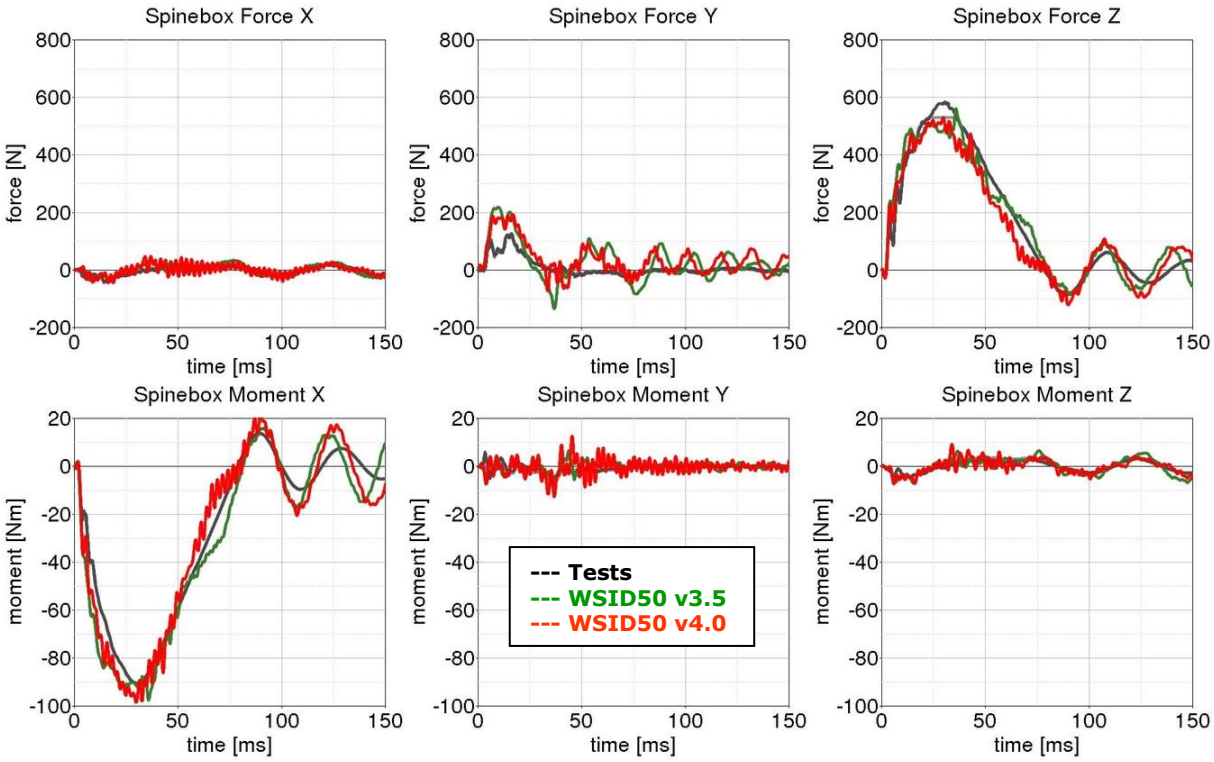


Figure 88: shoulder rib test on outer band z-direction – high velocity

8.1.3.4 Outer rib band with arm

Since the release v3.5 there are additional test for the shoulder rib with the assembled arm. These tests where performed with different pendulum velocities and two different impact angles.

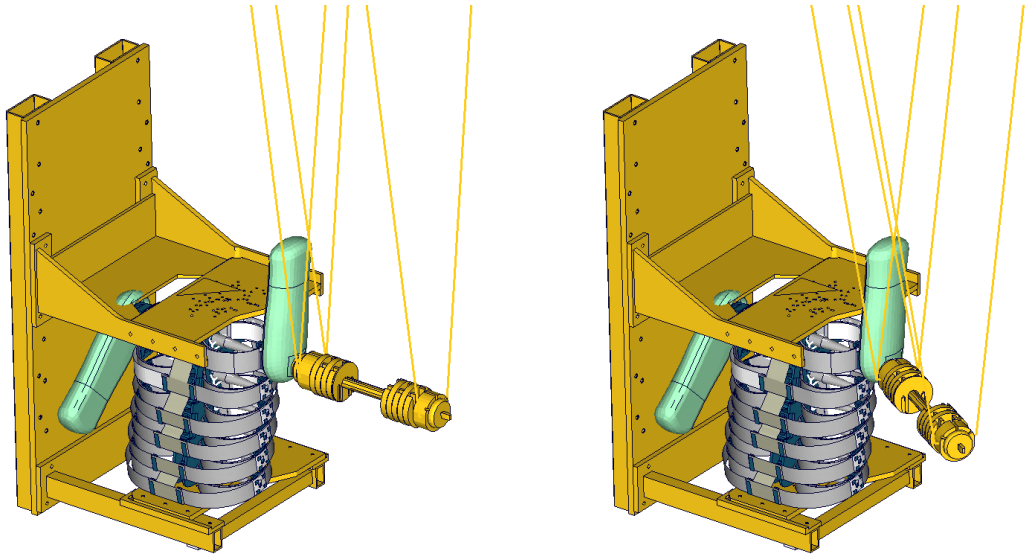


Figure 89: shoulder rib tests with arm (90° on the right and 60° on the left)

Shoulder rib outer band with arm - low velocity, 90°

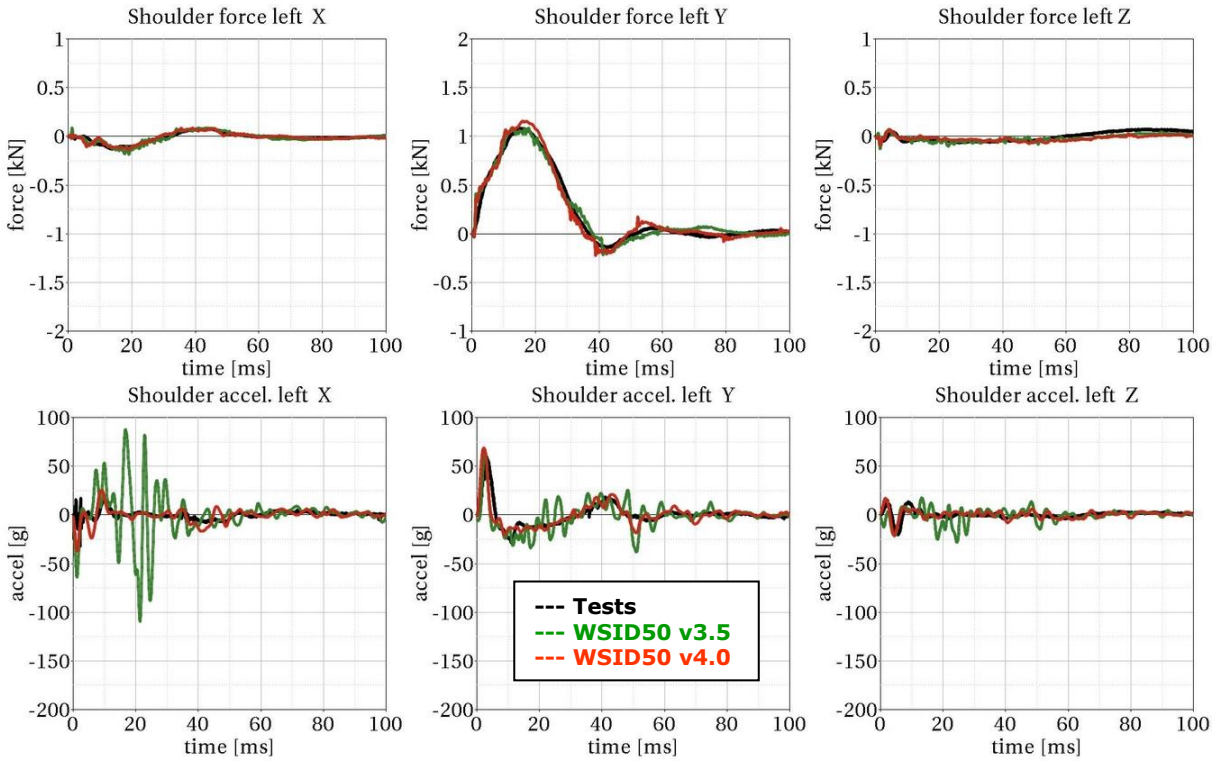


Figure 90: shoulder rib test on outer band with arm – low velocity, 90°

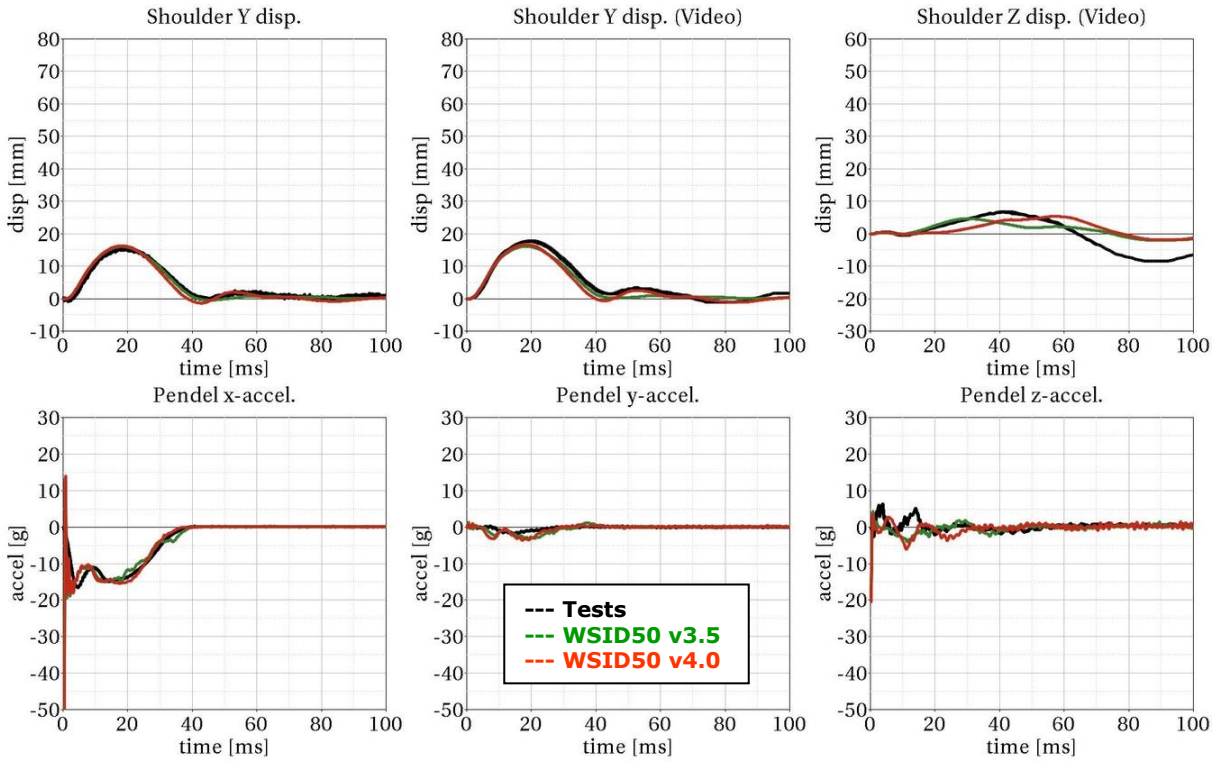


Figure 91: shoulder rib test on outer band with arm – low velocity, 90°

Shoulder rib outer band with arm - high velocity, 90°

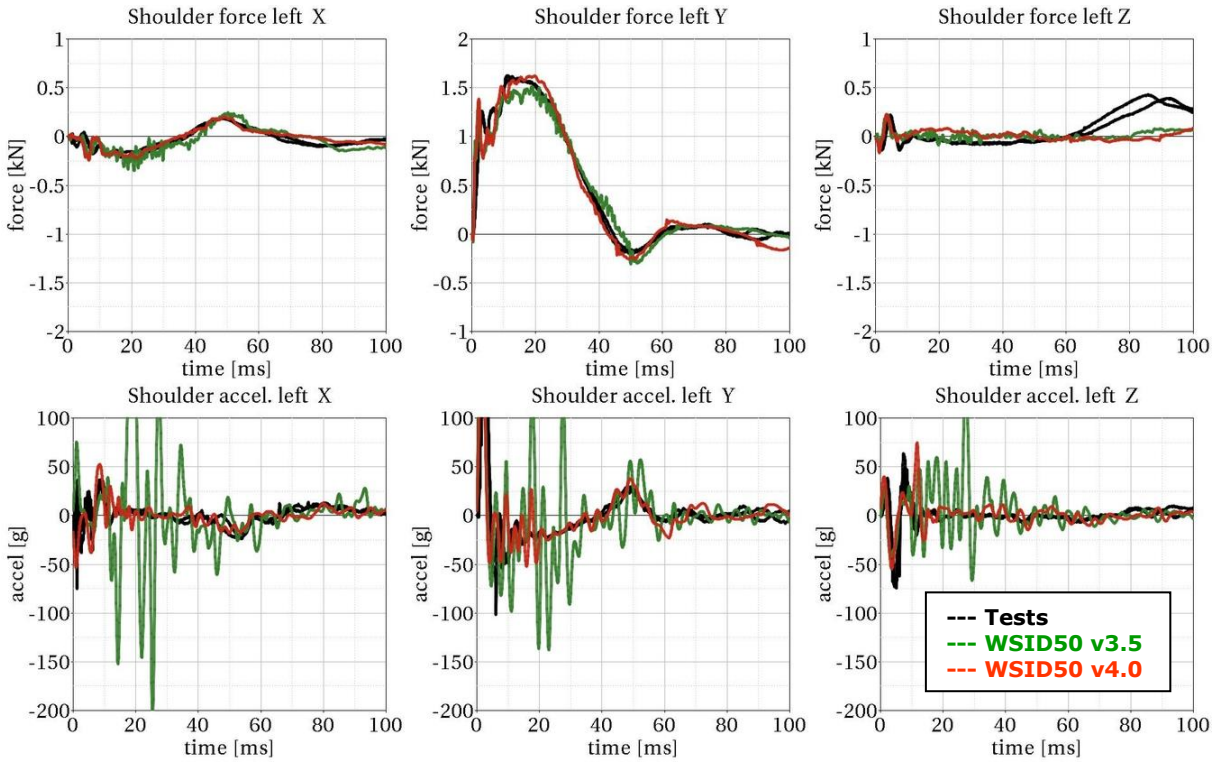


Figure 92: shoulder rib test on outer band with arm - high velocity, 90°

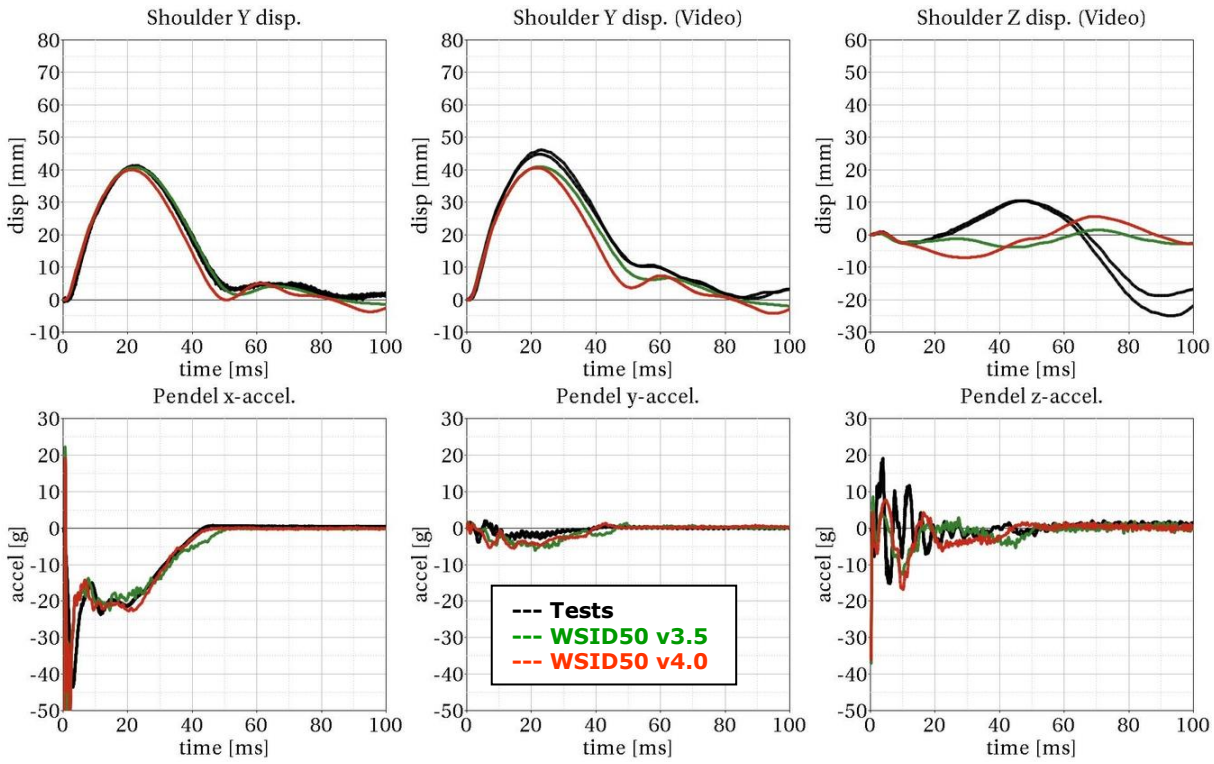


Figure 93: shoulder rib test on outer band with arm - high velocity, 90°

Shoulder rib outer band with arm - low velocity, 60°

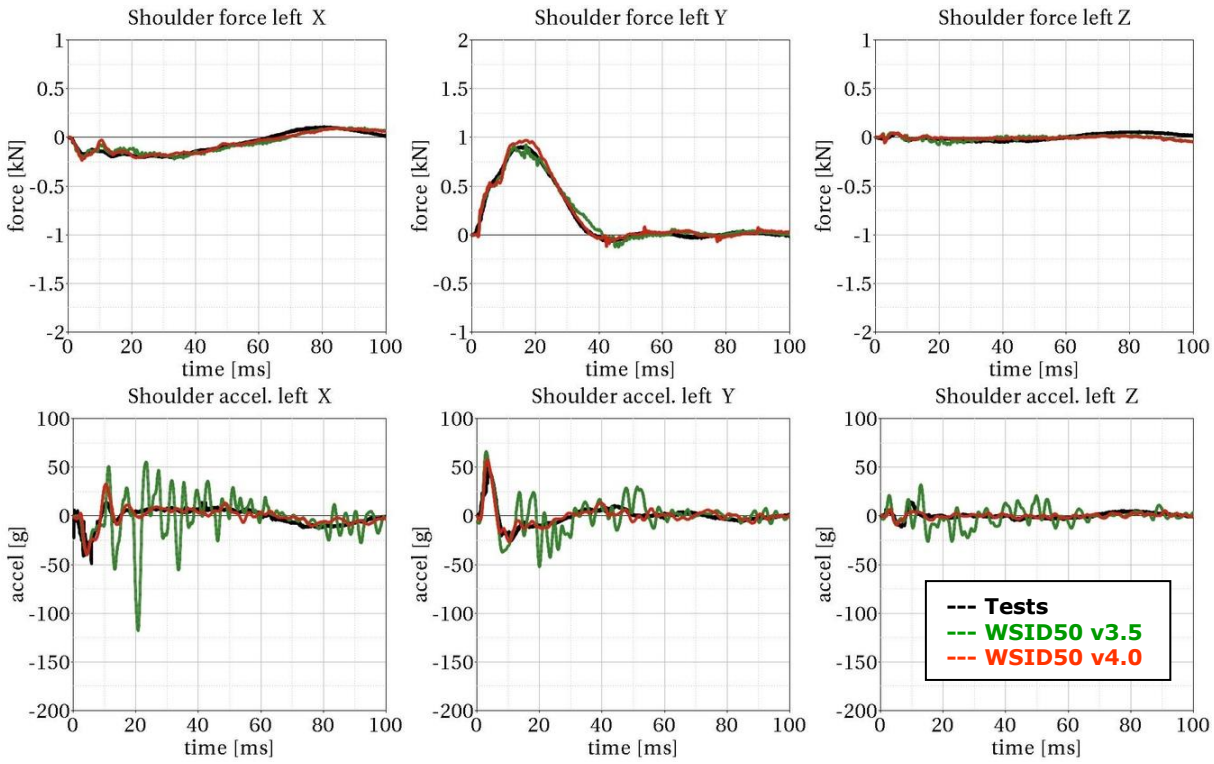


Figure 94: shoulder rib test on outer band with arm – low velocity, 60°

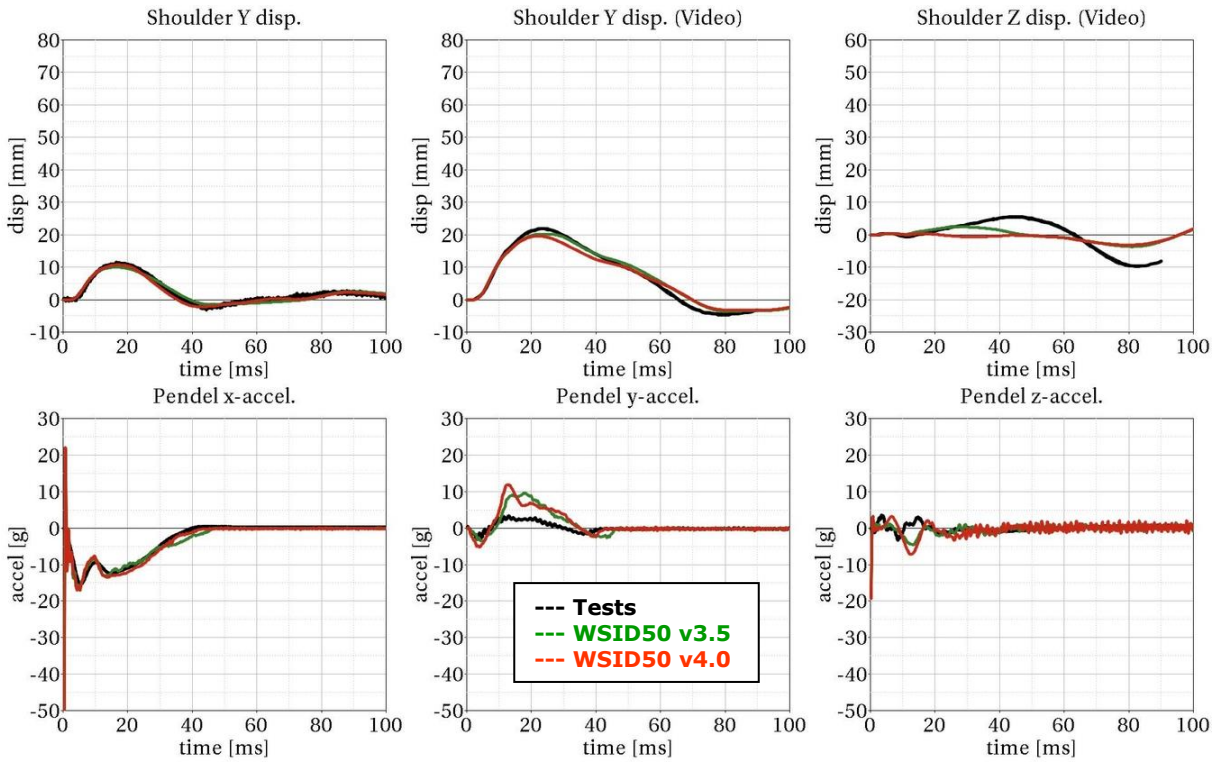


Figure 95: shoulder rib test on outer band with arm – low velocity, 60°

Shoulder rib outer band with arm - high velocity, 60°

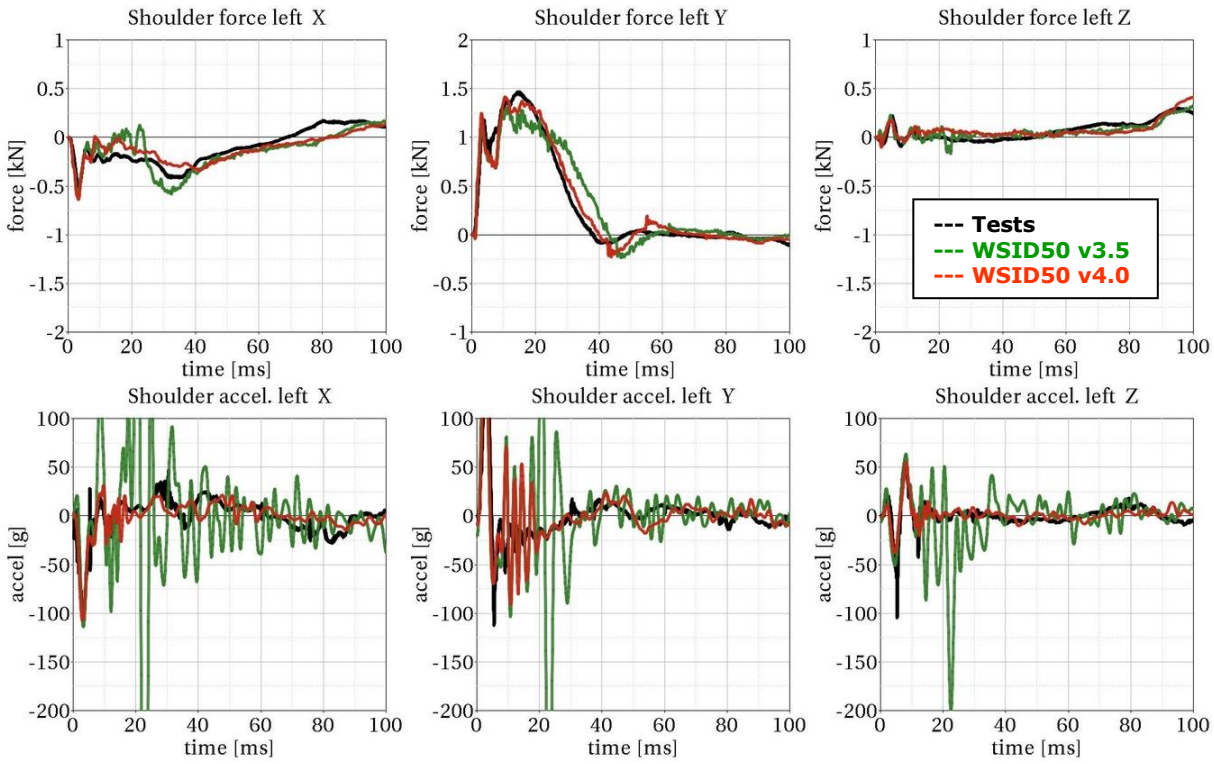


Figure 96: shoulder rib test on outer band with arm - high velocity, 60°

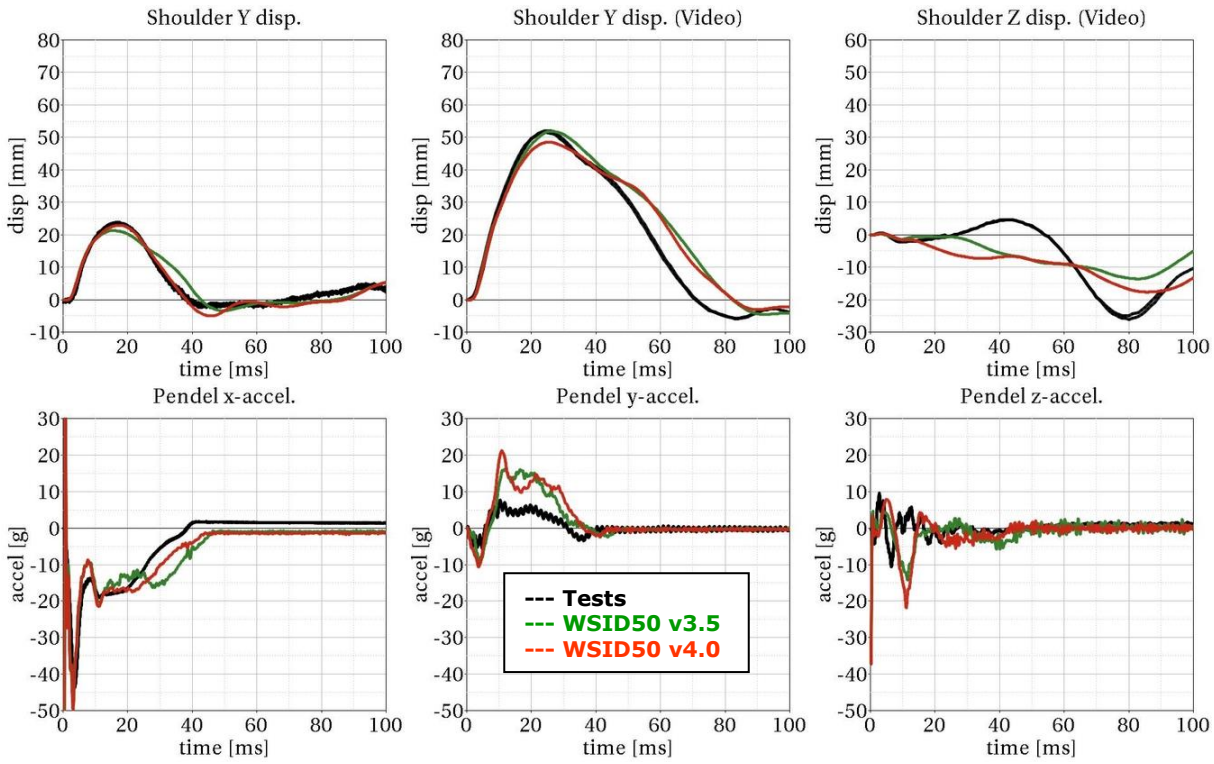


Figure 97: shoulder rib test on outer band with arm - high velocity, 60°

8.1.3.5 Outer rib band vertical pendulum test with arm

Since the release v3.5 there are additional test for the shoulder rib in oblique z-direction with assembled arm.

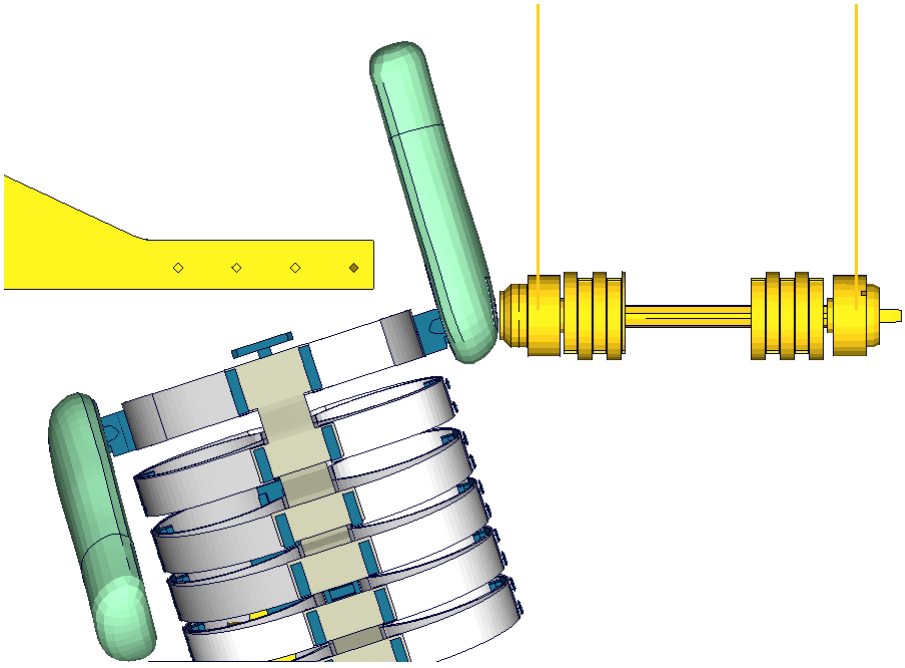


Figure 98: shoulder rib tests in oblique z-direction with arm

Shoulder rib test oblique z-direction with arm - low velocity

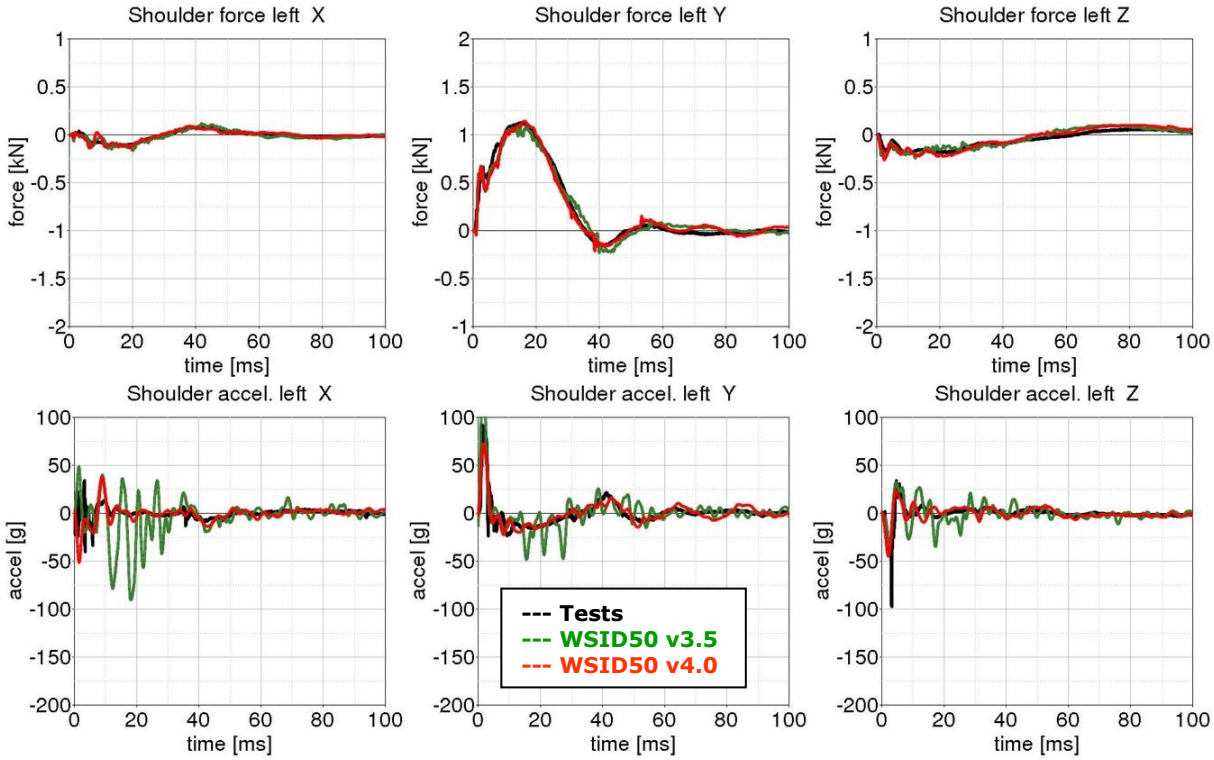


Figure 99: shoulder rib test oblique z-direction with arm – low velocity

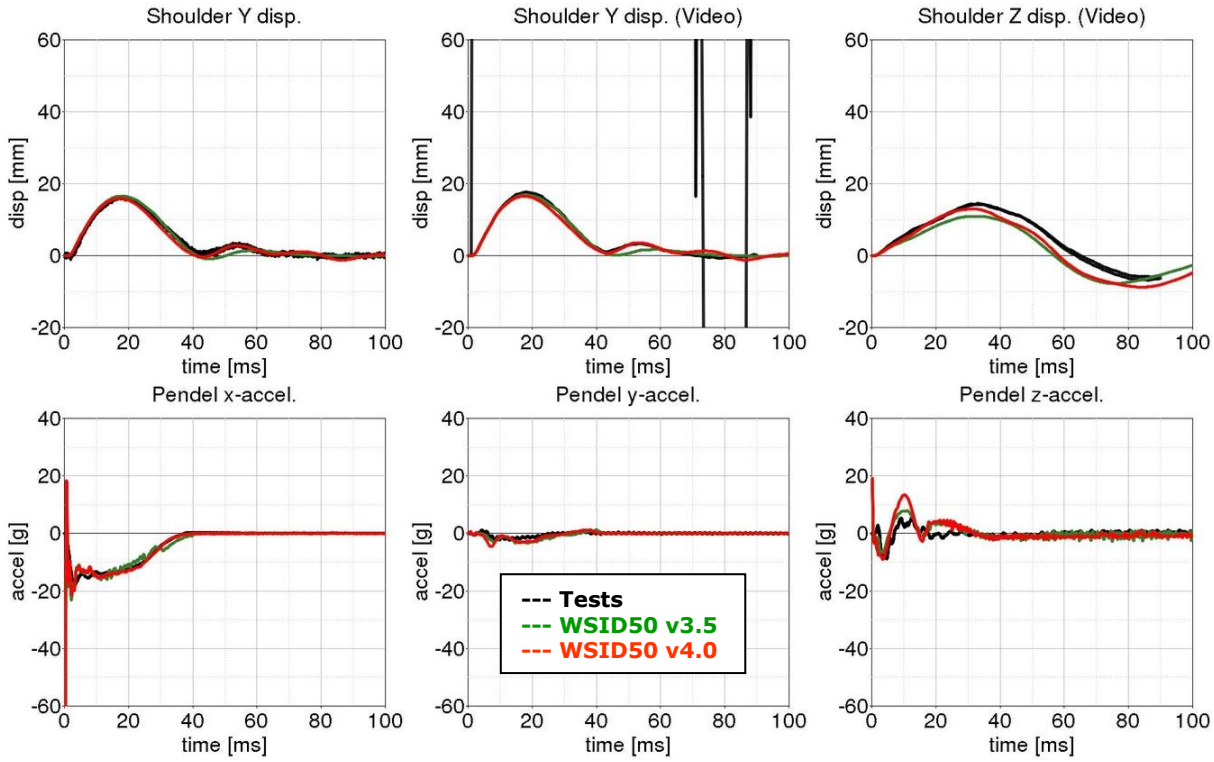


Figure 100: shoulder rib test oblique z-direction – low velocity

Shoulder rib test oblique z-direction with arm - medium velocity

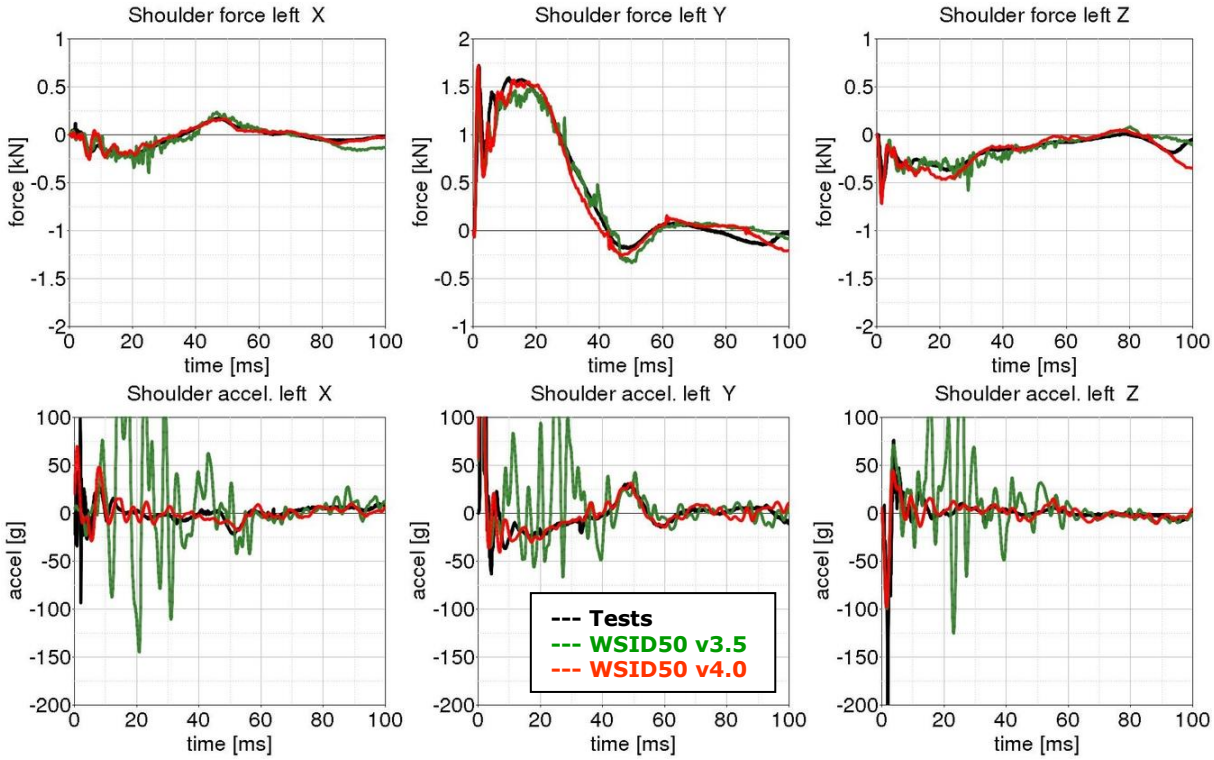


Figure 101: shoulder rib test oblique z-direction with arm – medium velocity

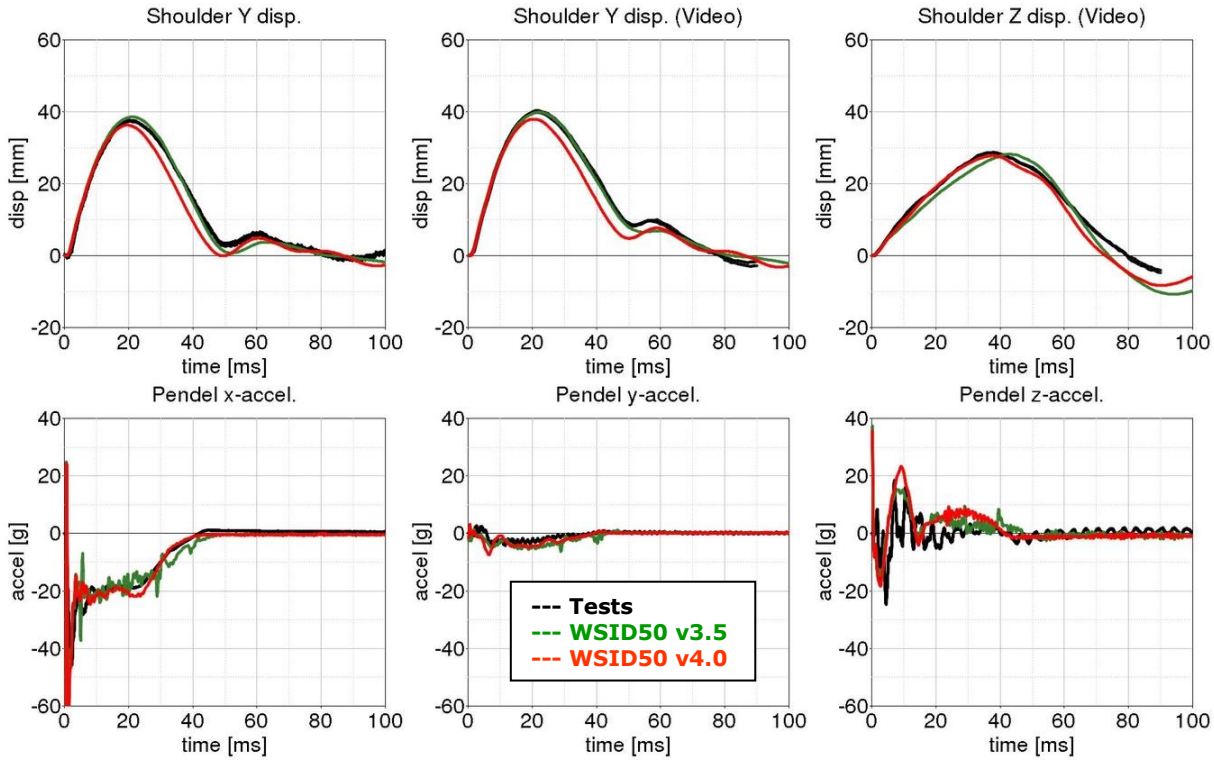


Figure 102: shoulder rib test oblique z-direction – medium velocity

Shoulder rib test oblique z-direction with arm - high velocity

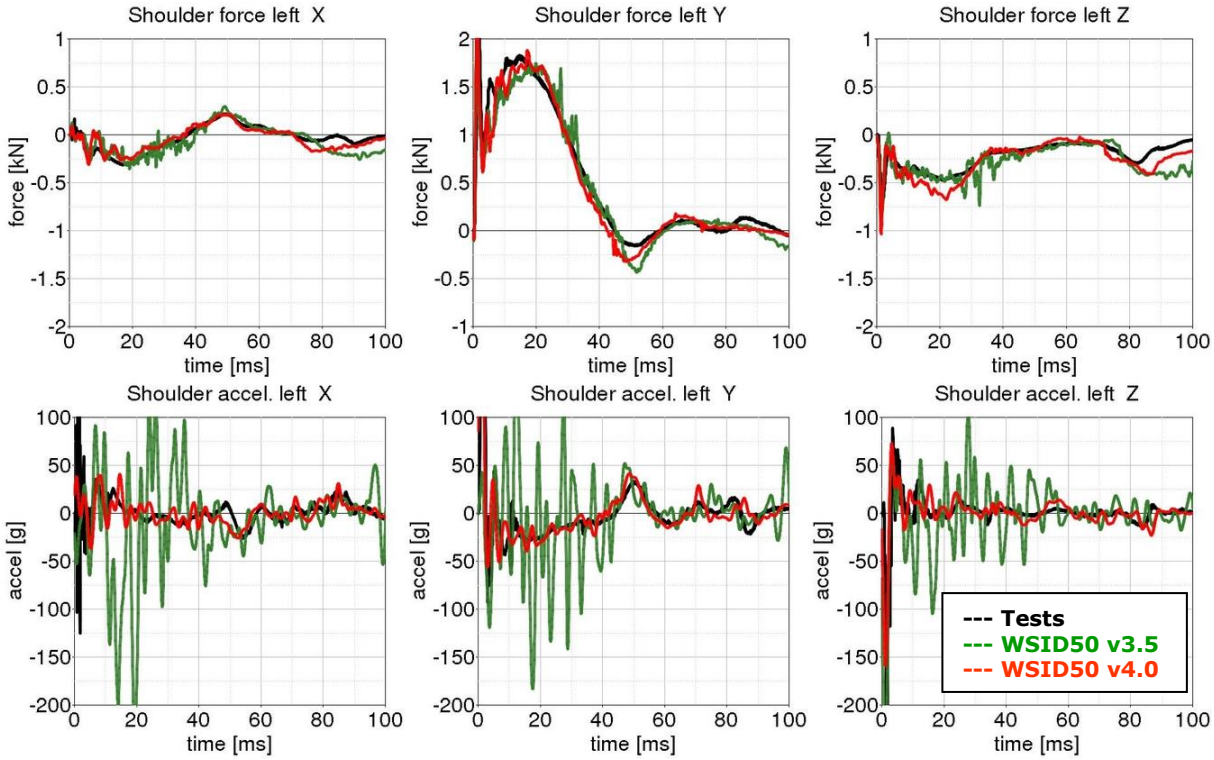


Figure 103: shoulder rib test oblique z-direction with arm – high velocity

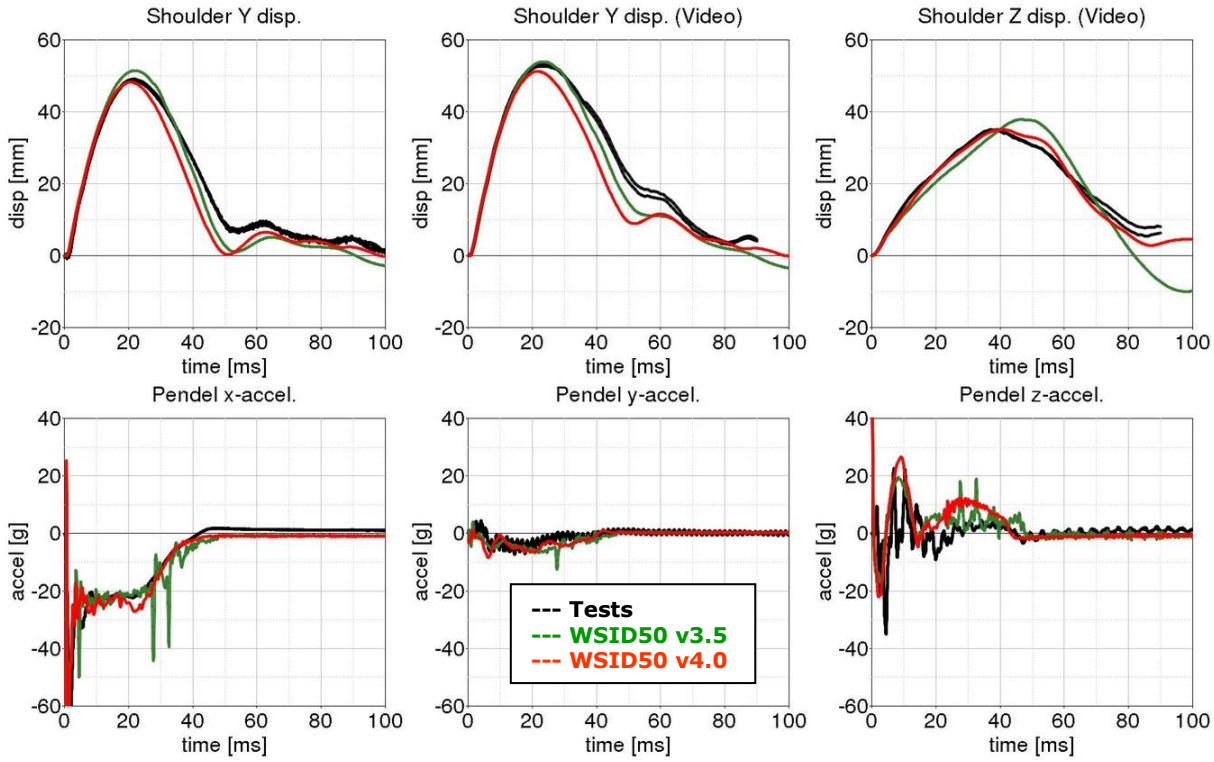


Figure 104: shoulder rib test oblique z-direction – high velocity

8.1.4 Lumbar spine test

The lumbar spine component has also been validated by the use of a component test. Here, the sacrum block with adapted lumbar load cell and the lumbar spine itself is mounted on a sled. On the lumbar spine, a mass body is mounted, which should represent the load on the lumbar spine from the torso of the WorldSID. The test setup is depicted in the following picture.

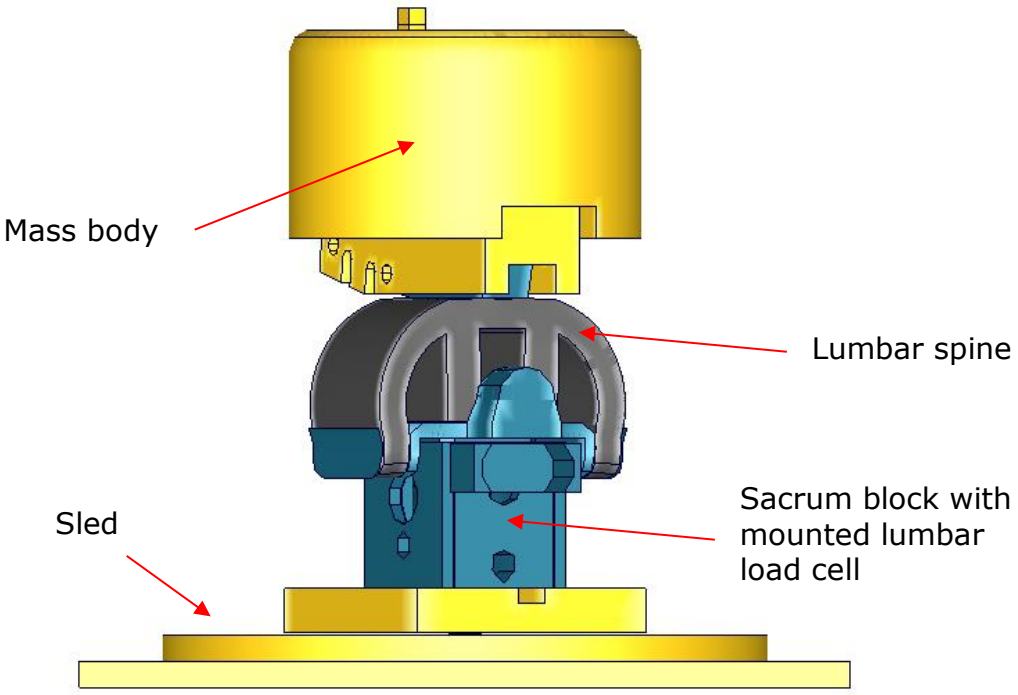


Figure 105: Lumbar spine component test setup

The sled is loaded by the use of two different pulses (20g triangular and 35g triangular) and the orientation of the lumbar spine is made for each pulse -- 90 and 60 degree. The test configurations are listed in the Table 33.

Test	Load angle	Pulse
1	90 degree	20 g triangular pulse
2	90 degree	35 g triangular pulse
3	60 degree	20 g triangular pulse
4	60 degree	35 g triangular pulse

Table 33: Test configurations for lumbar spine test

Results of 90 degree, 20g configuration:

Mass body accelerations

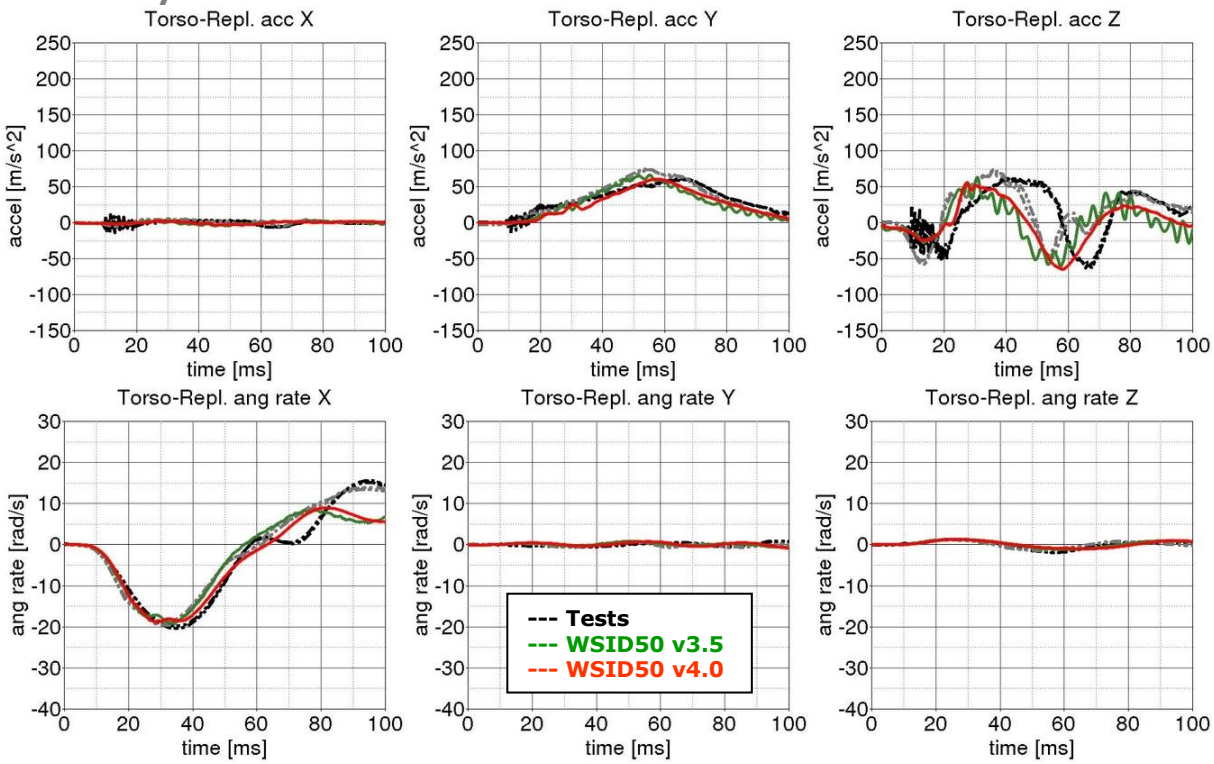


Figure 106: Result of lumbar spine test -- 20g, 90 degree (Mass body accelerations)

Lumbar load cell forces and moments

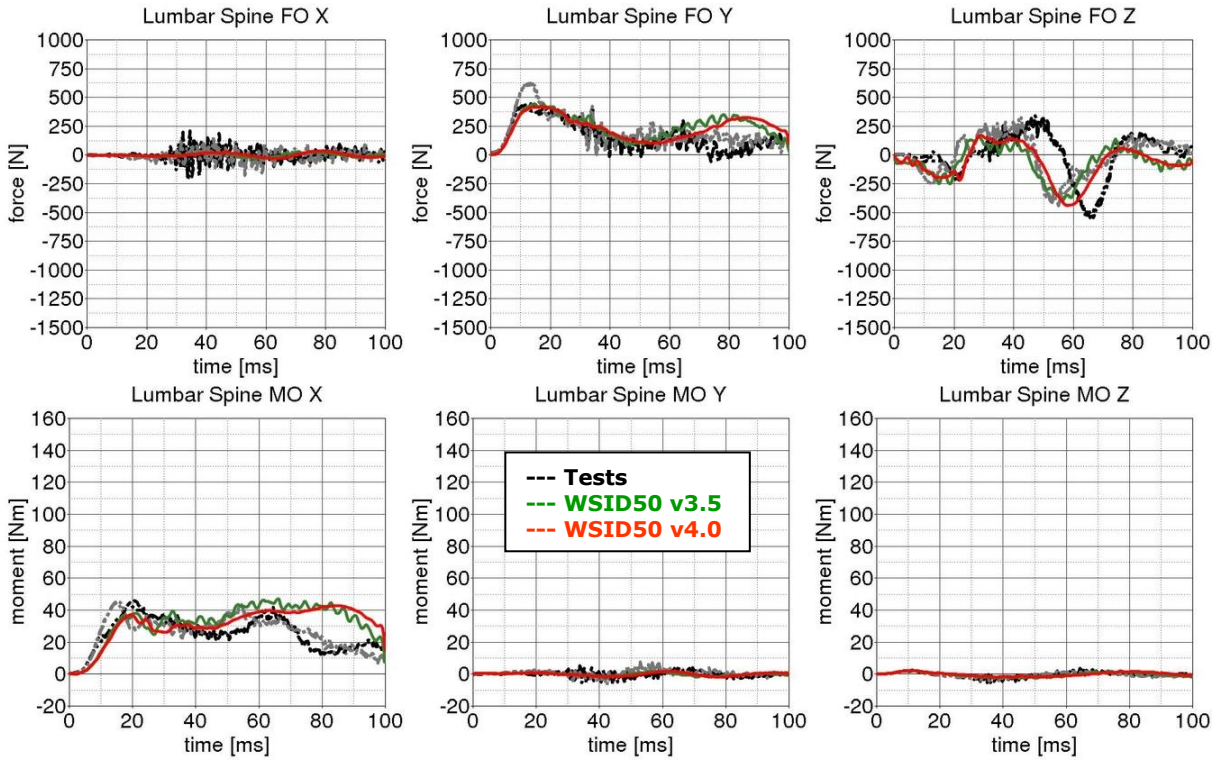


Figure 107: Result of lumbar spine test -- 20g, 90 degree (Lumbar load cell forces and moments)

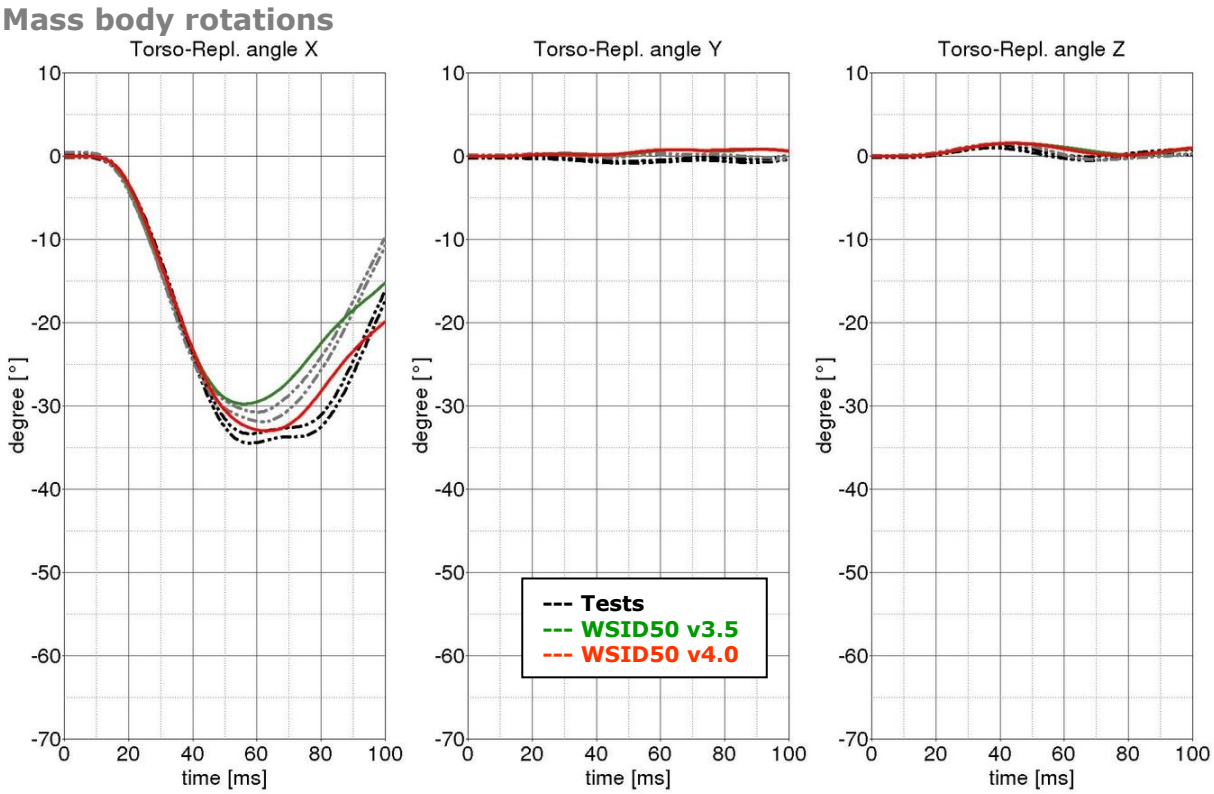


Figure 108: Result of lumbar spine test -- 20g, 90 degree (Mass body rotations)

Results of 90 degree, 35g configuration:

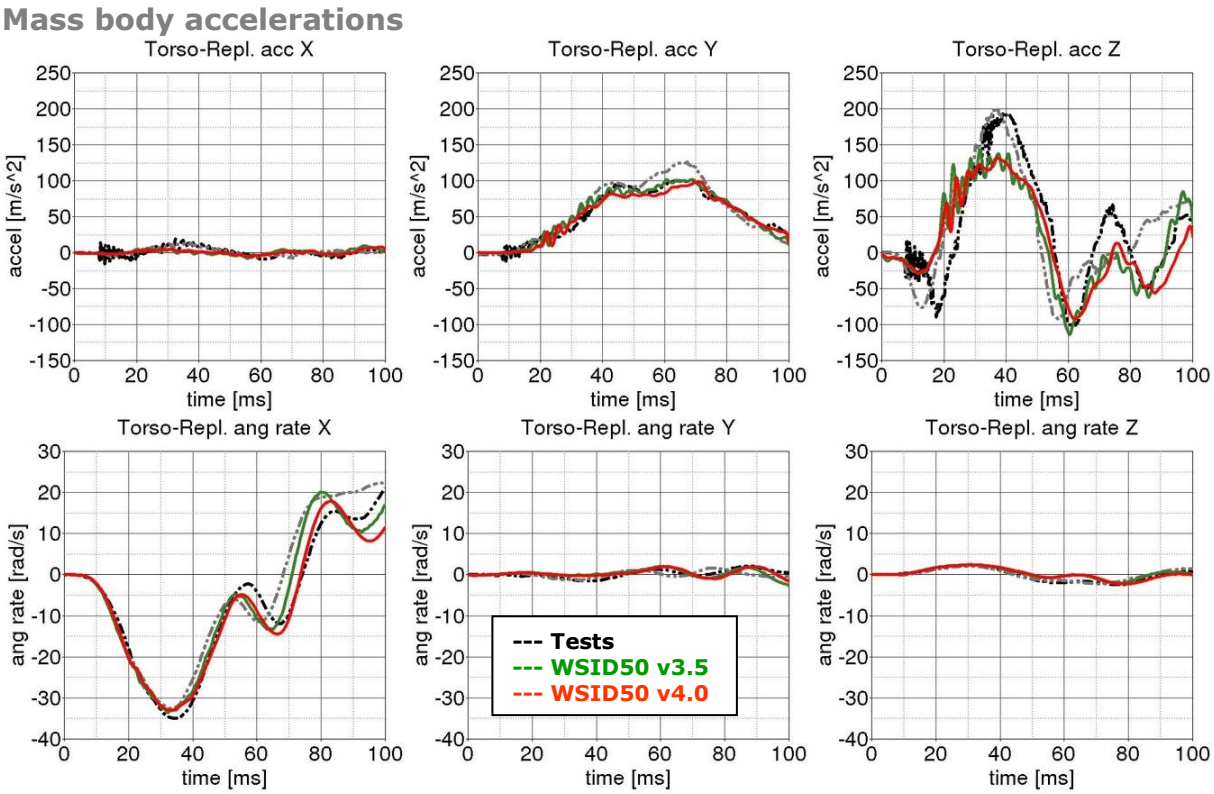


Figure 109: Result of lumbar spine test -- 35g, 90 degree (Mass body accelerations)

Lumbar load cell forces and moments

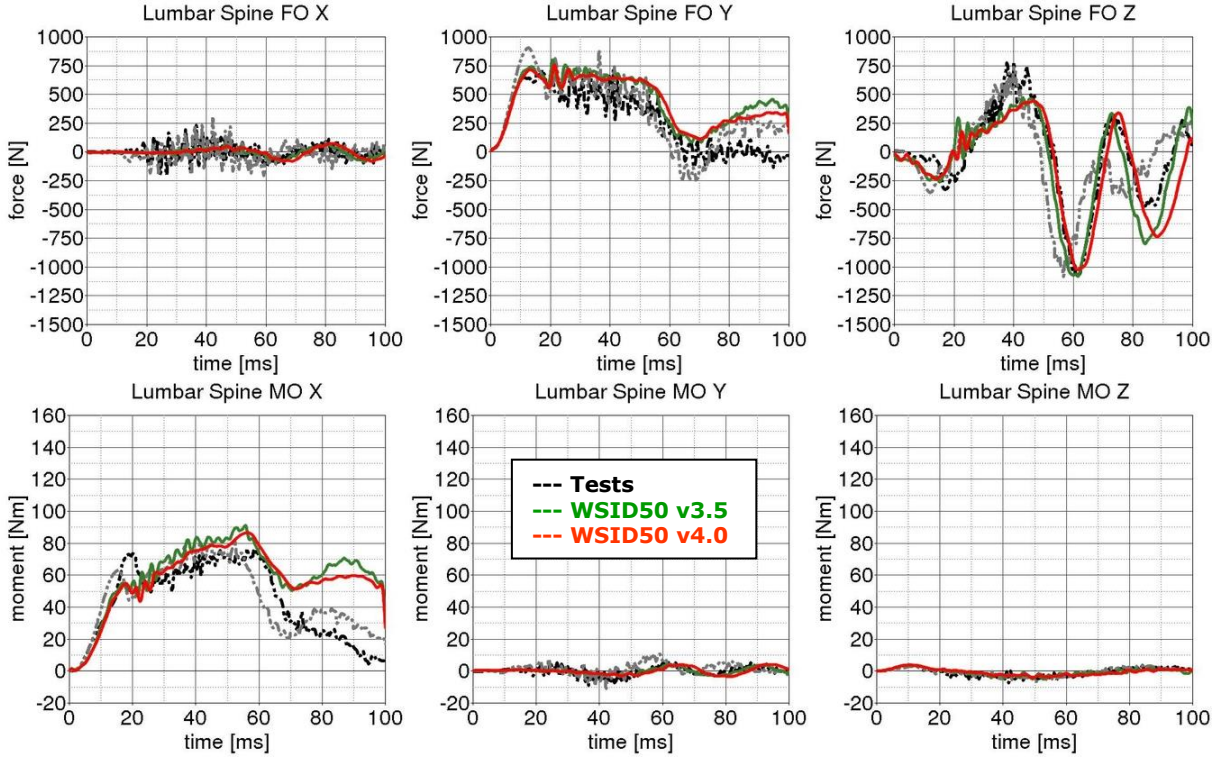


Figure 110: Result of lumbar spine test -- 35g, 90 degree (Lumbar load cell forces and moments)

Mass body rotations

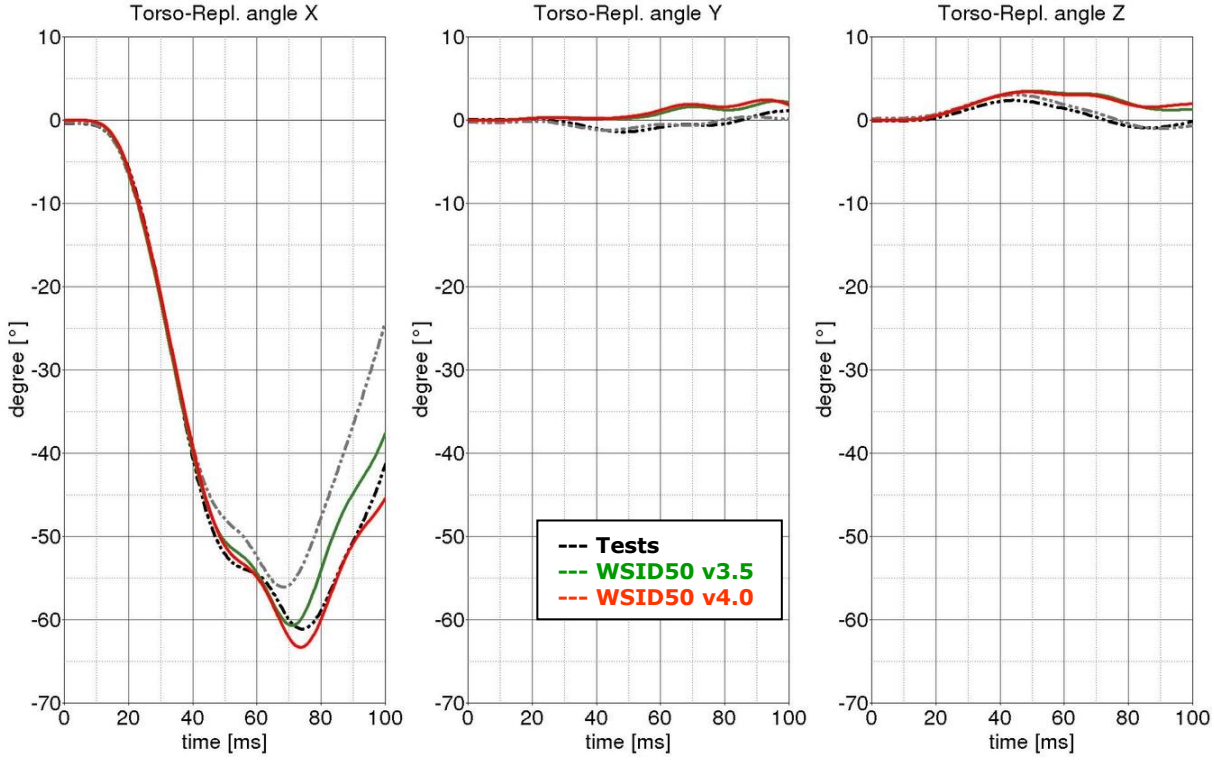


Figure 111: Result of lumbar spine test -- 35g, 90 degree (Mass body rotations)

Results of 60 degree, 20g configuration:

Mass body accelerations

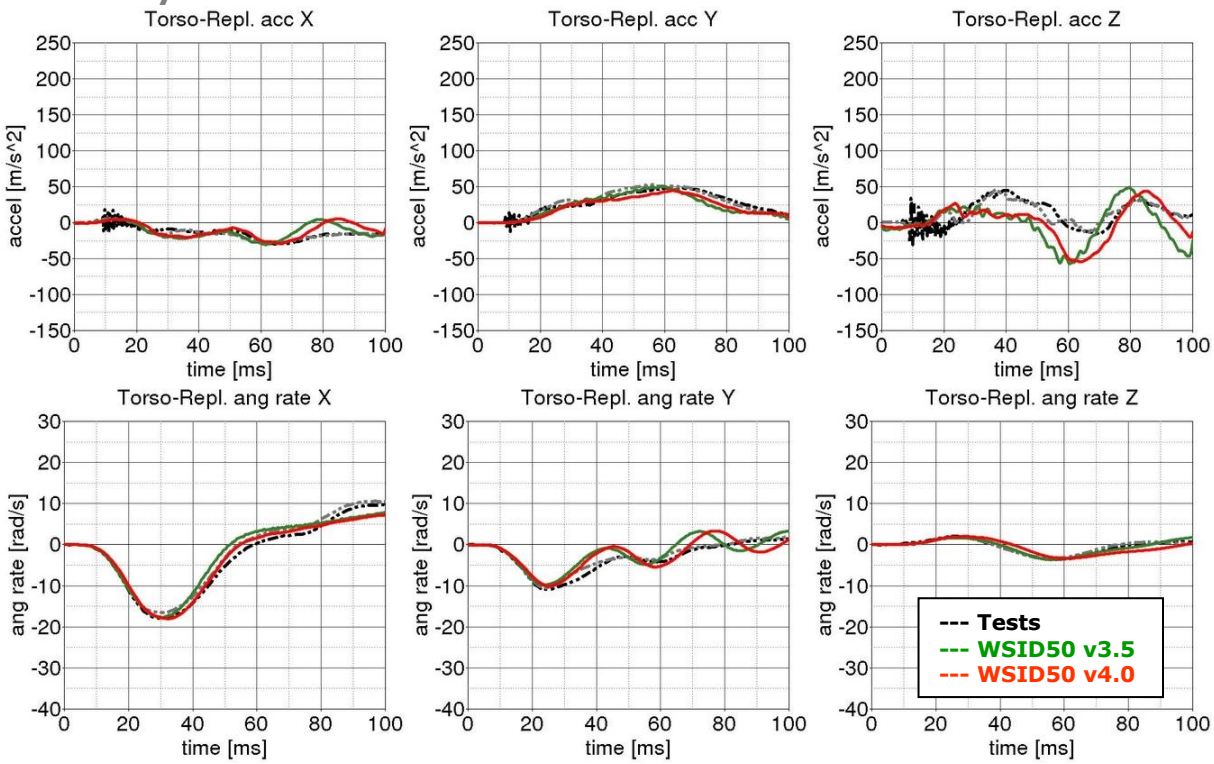


Figure 112: Result of lumbar spine test -- 20g, 60 degree (Mass body accelerations)

Lumbar load cell forces and moments

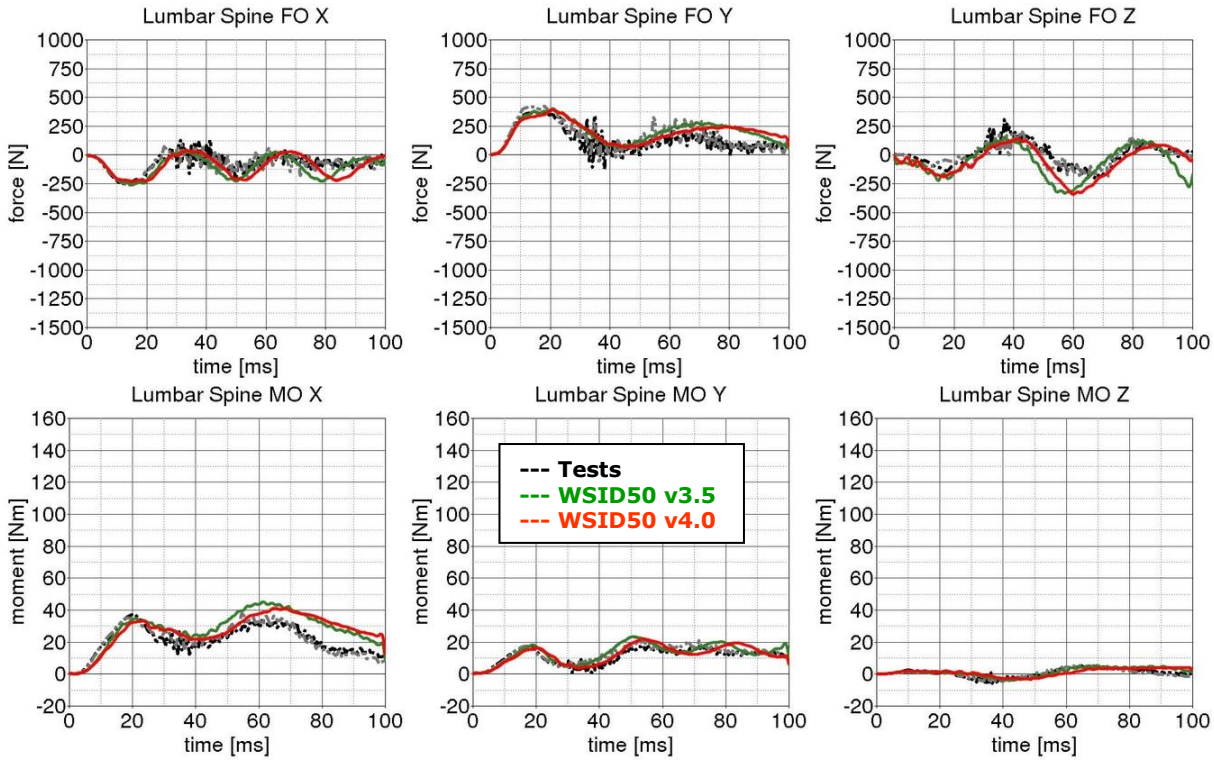


Figure 113: Result of lumbar spine test -- 20g, 60 degree (Lumbar load cell forces and moments)

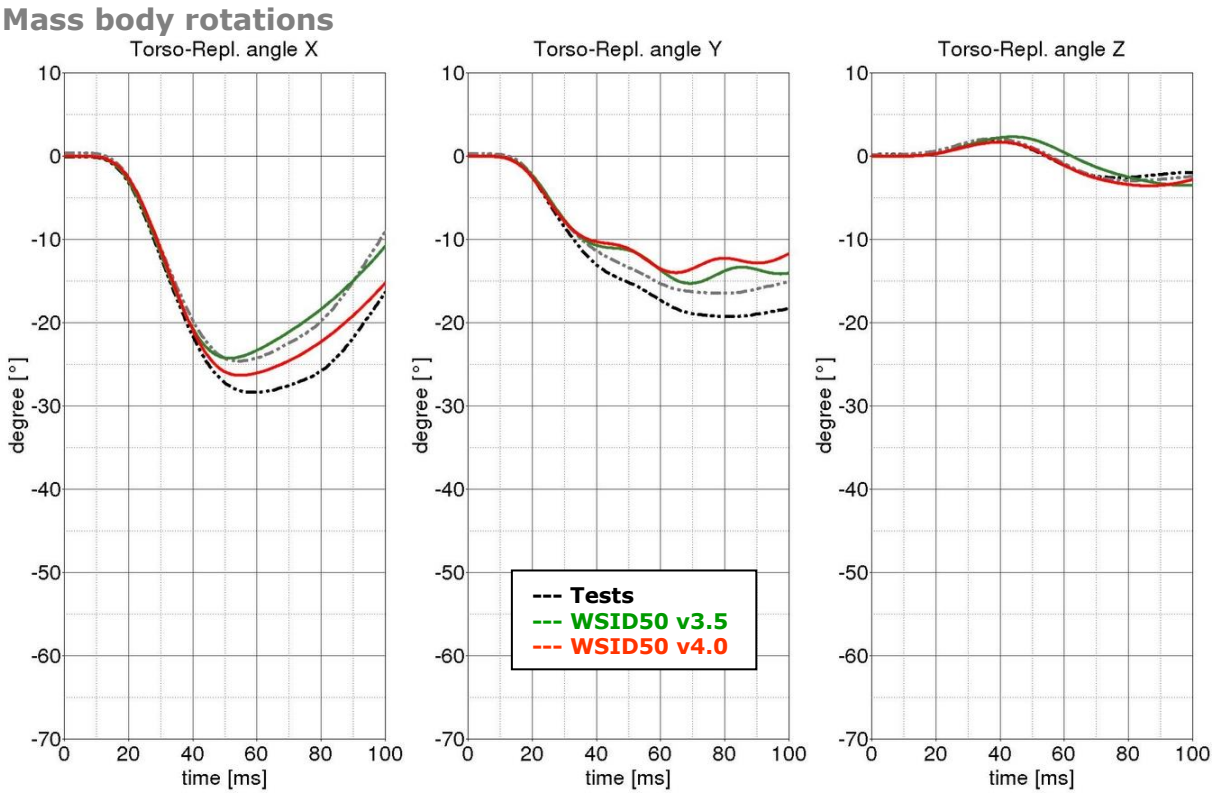


Figure 114: Result of lumbar spine test -- 20g, 60 degree (Mass body rotations)

Results of 60 degree, 35g configuration:

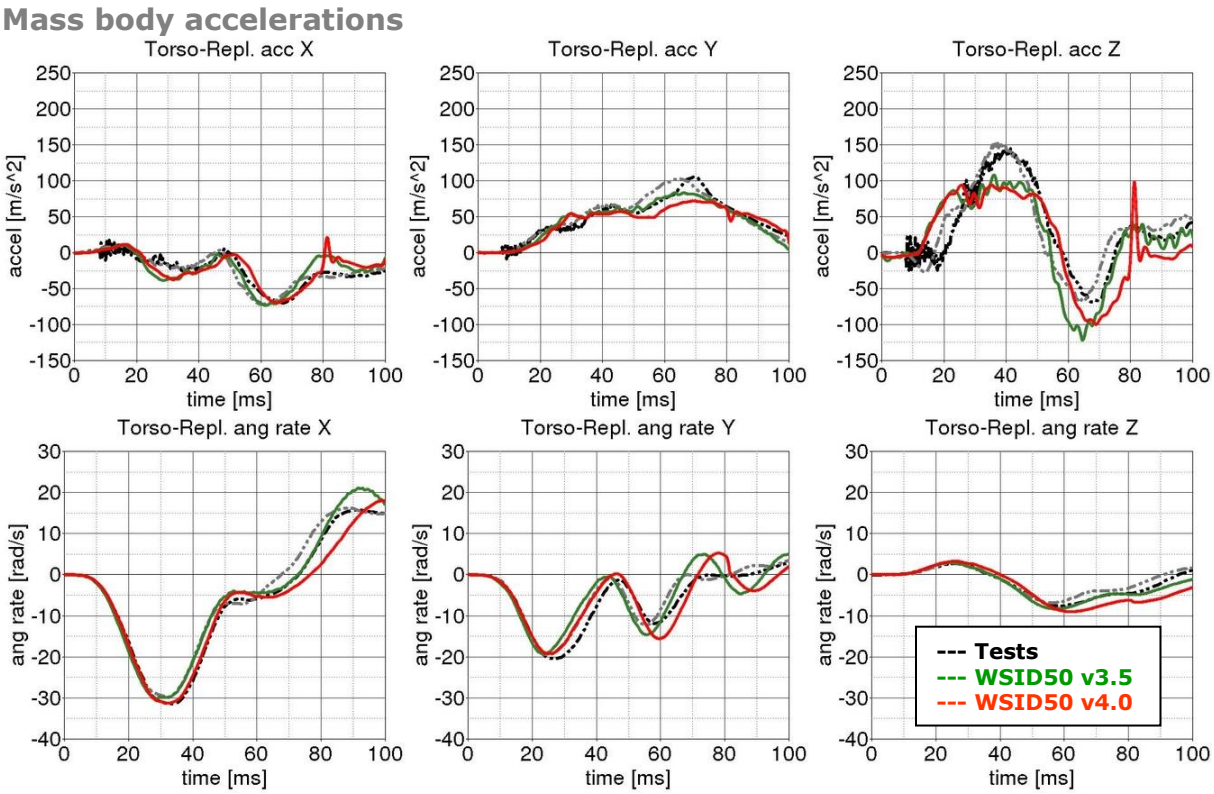


Figure 115: Result of lumbar spine test -- 35g, 60 degree (Mass body accelerations)

Lumbar load cell forces and moments

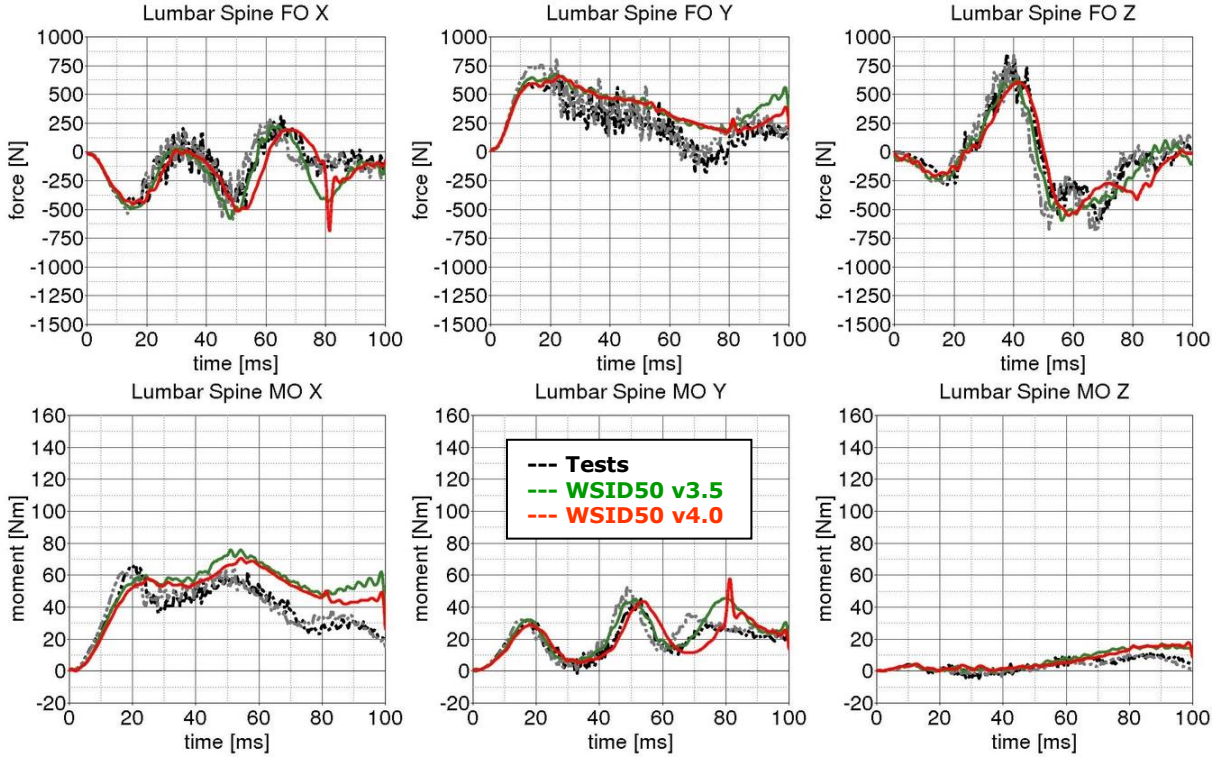


Figure 116: Result of lumbar spine test -- 35g, 60 degree (Lumbar load cell forces and moments)

Mass body rotations

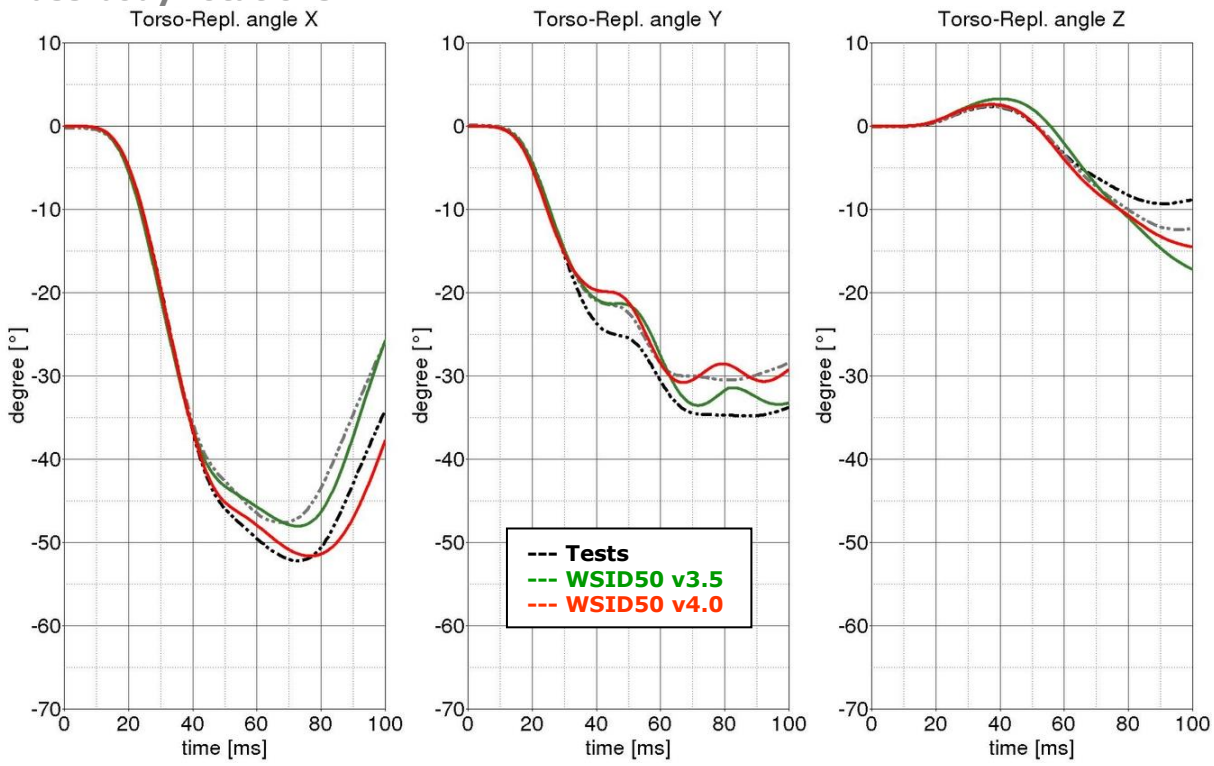


Figure 117: Result of lumbar spine test -- 35g, 60 degree (Mass body rotations)

8.1.5 Iliac wing test

The iliac wings are tested in three different configurations with the use of two different velocities. Here, the sacrum block with mounted iliac wings and pubic load cell is fixed on a table. The first two configurations use only one iliac wing and the half pubic construction. The third configuration is a load on the complete assembled pelvis area without the pelvis foam. The different configurations are depicted in the following figures.

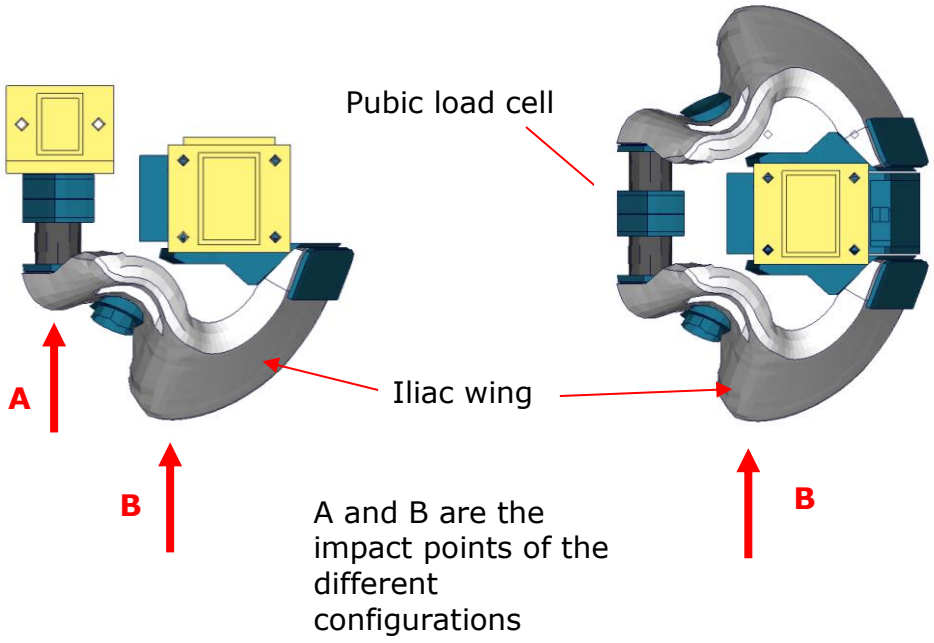


Figure 118: Iliac wing component test configurations

Test	Target point	Test setup	Velocities
1	A	half pelvis	low and high velocity
2	B	half pelvis	low and high velocity
3	B	full pelvis	low and high velocity

Table 34: Test configurations for iliac wing test

Results of target point A, low velocity, half pelvis:

Pendulum accelerations

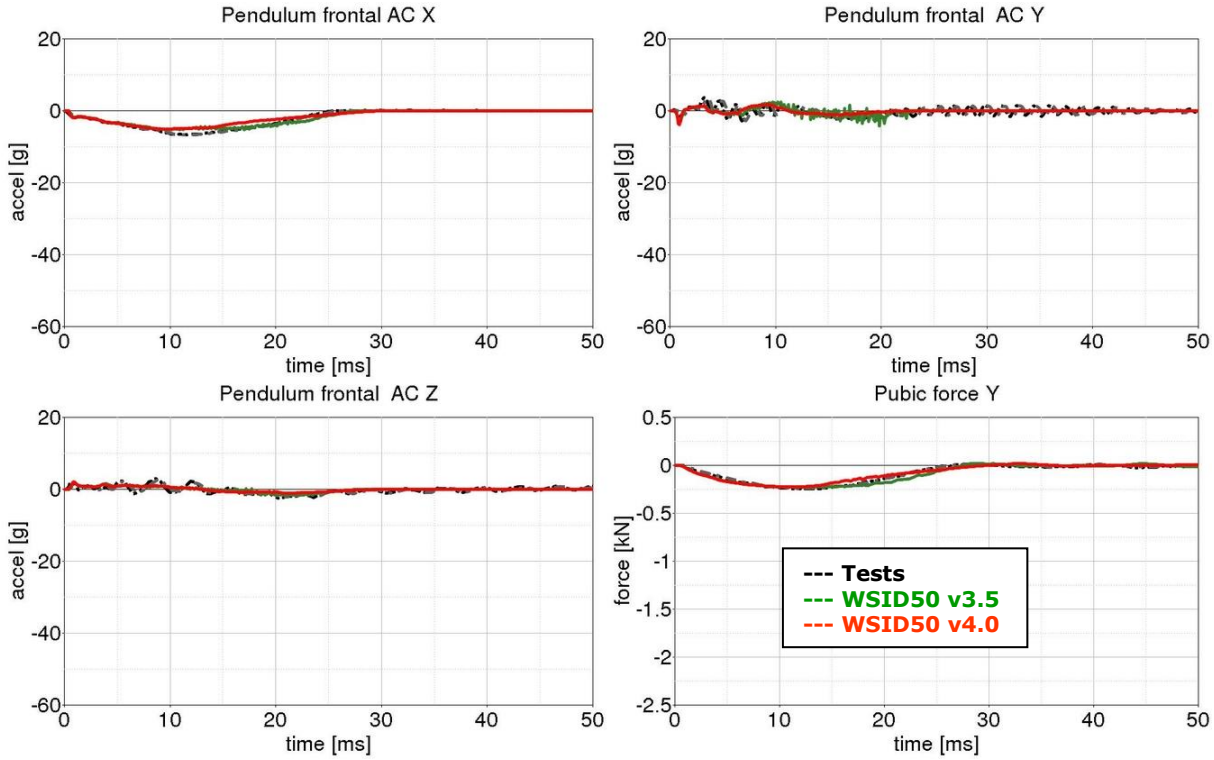


Figure 119: Result of iliac wing test -- Target point A, low velocity, half pelvis (Pendulum accelerations)

Sacro-iliac load cell

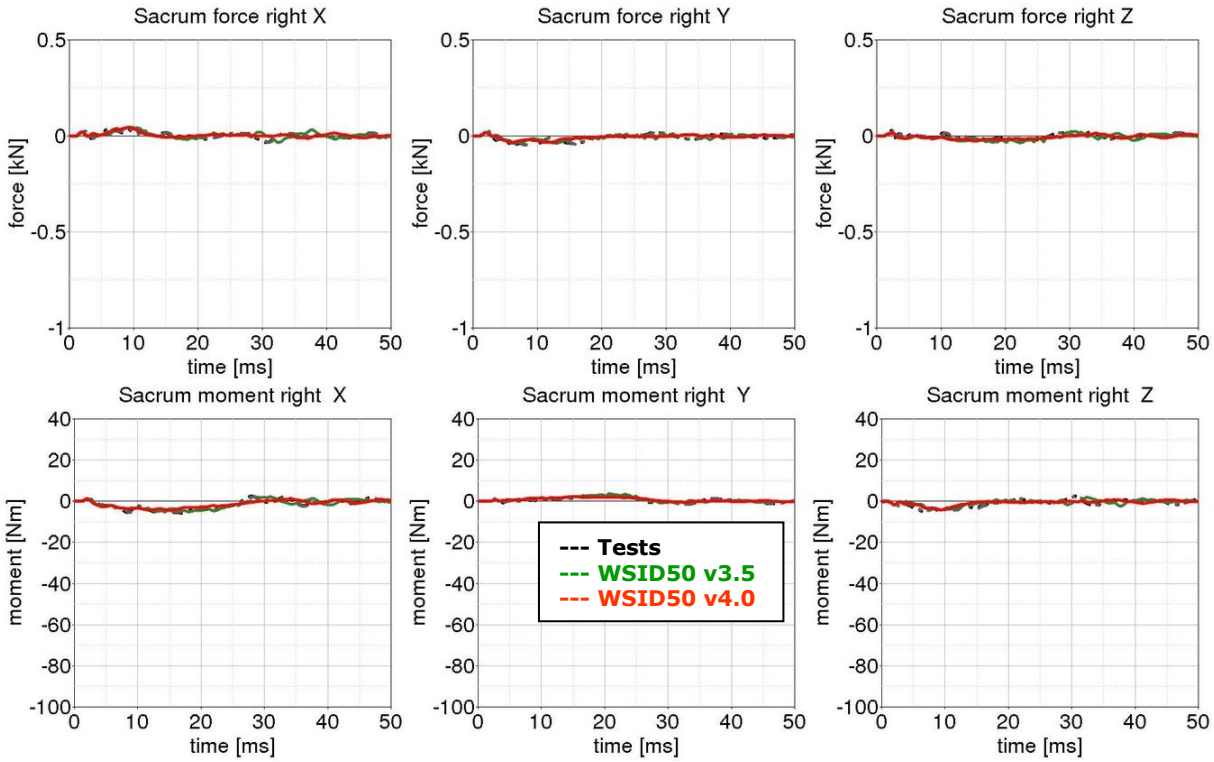


Figure 120: Result of iliac wing test -- Target point A, low velocity, half pelvis (Sacro-iliac load cell)

Results of target point A, high velocity, half pelvis:

Pendulum accelerations

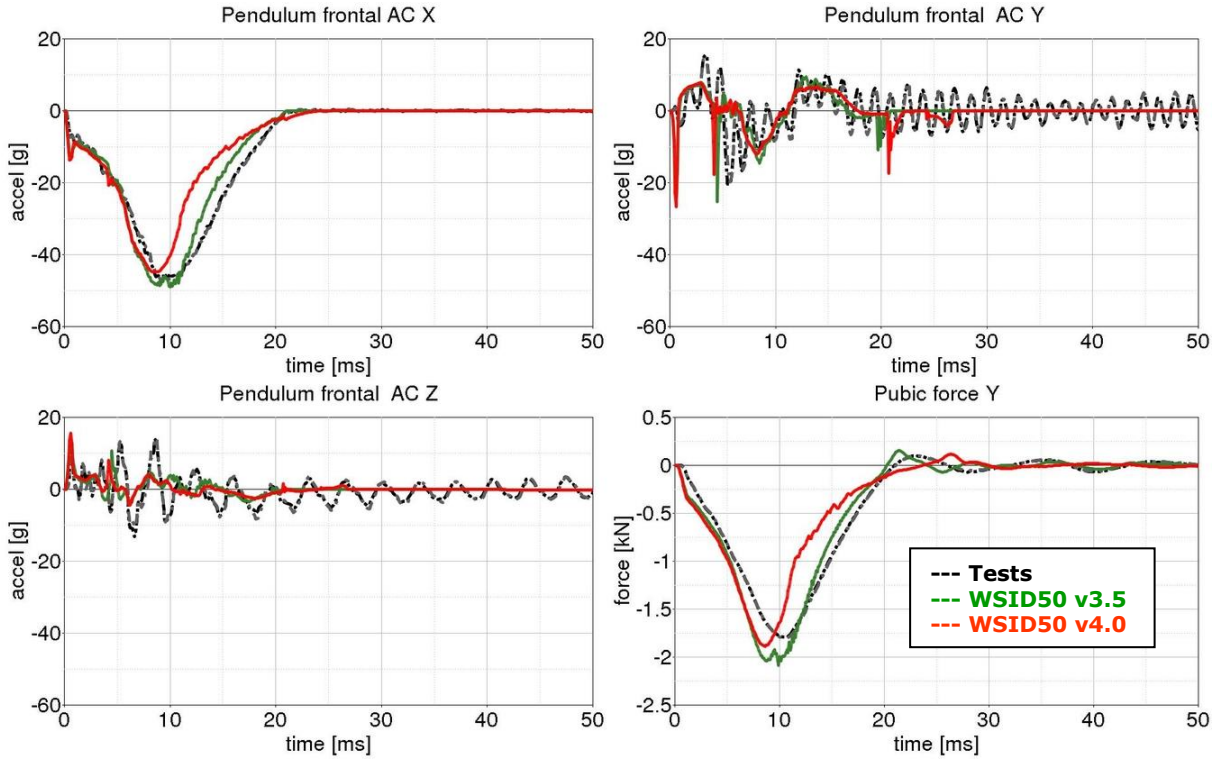


Figure 121: Result of iliac wing test -- Target point A, high velocity, half pelvis (Pendulum accelerations)

Sacro-iliac load cell

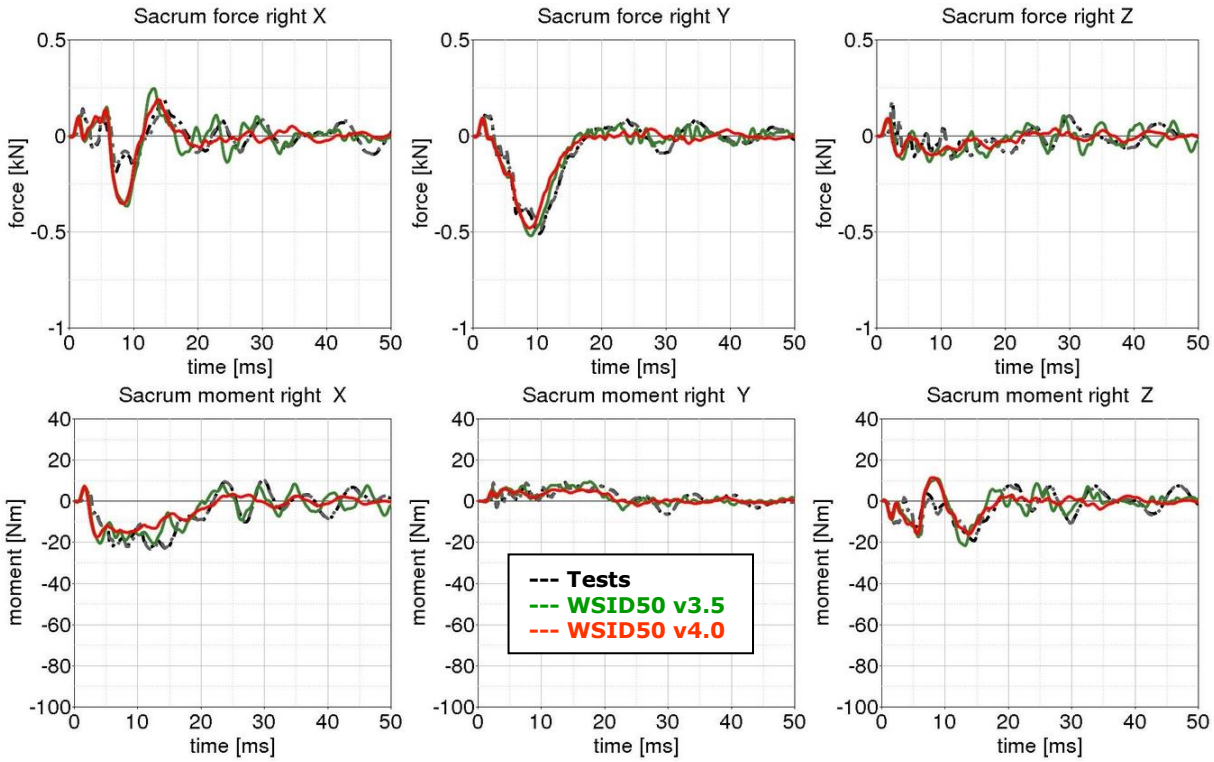


Figure 122: Result of iliac wing test -- Target point A, high velocity, half pelvis (Sacro-iliac load cell)

Results of target point B, low velocity, half pelvis:

Pendulum accelerations

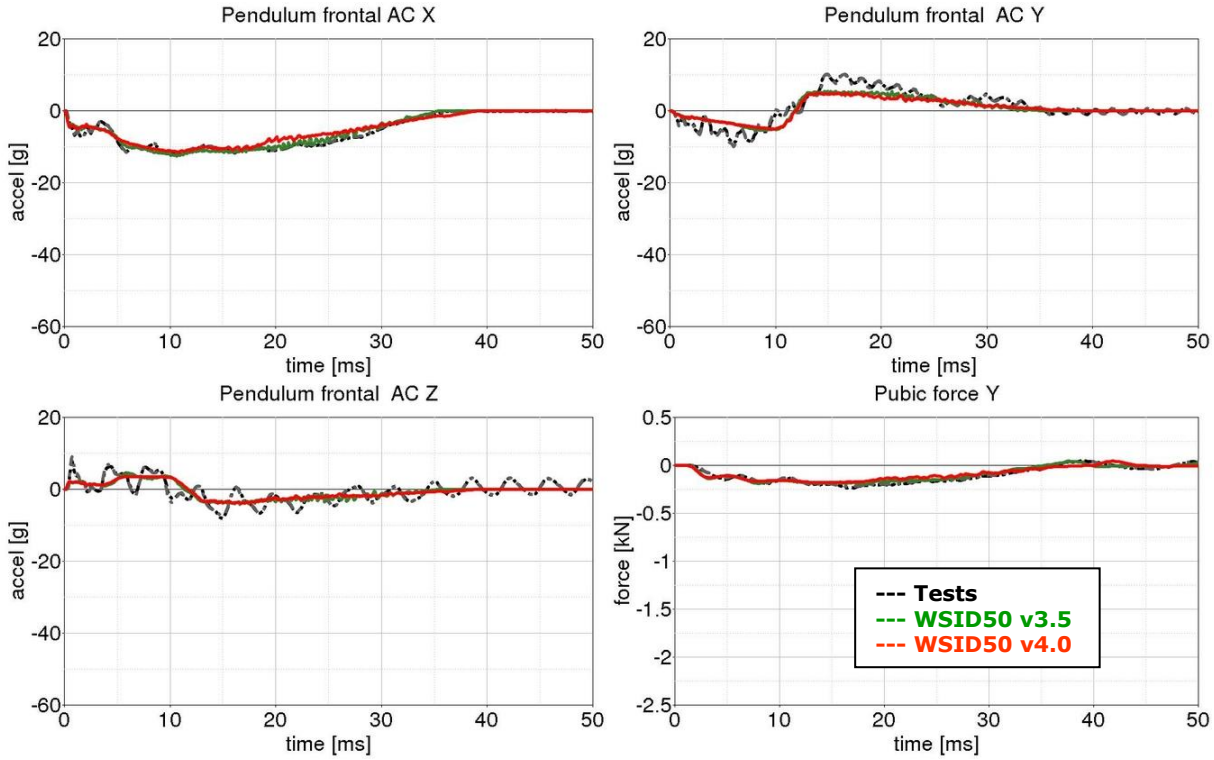


Figure 123: Result of iliac wing test -- Target point B, low velocity, half pelvis (Pendulum accelerations)

Sacro-iliac load cell

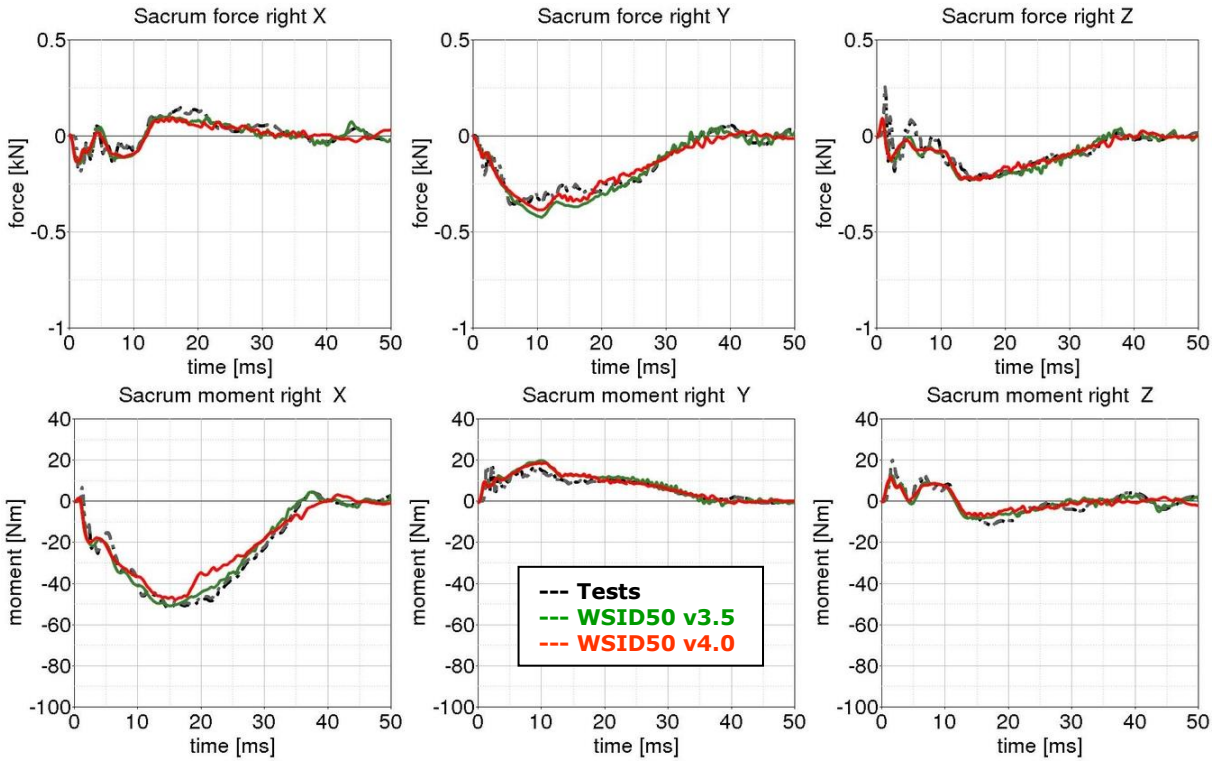


Figure 124: Result of iliac wing test -- Target point B, low velocity, half pelvis (Sacro-iliac load cell)

Results of target point B, high velocity, half pelvis:

Pendulum accelerations

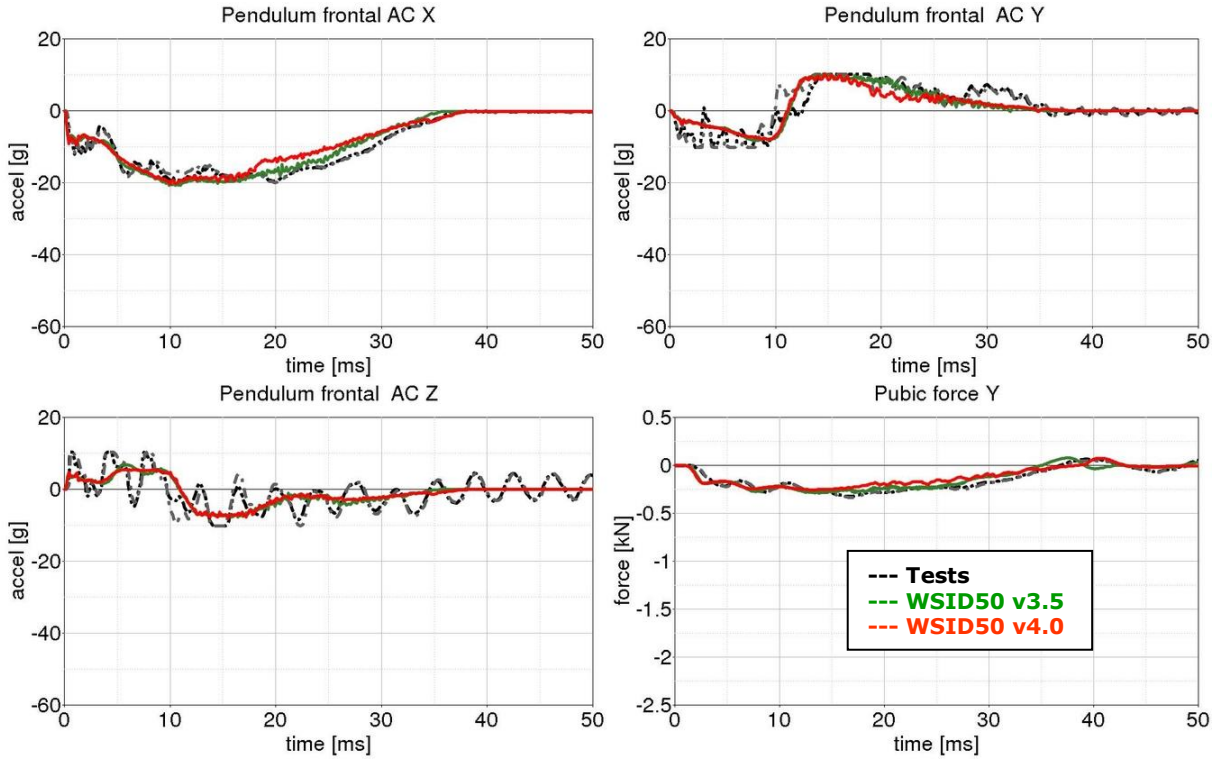


Figure 125: Result of iliac wing test -- Target point B, high velocity, half pelvis (Pendulum accelerations)

Sacro-iliac load cell

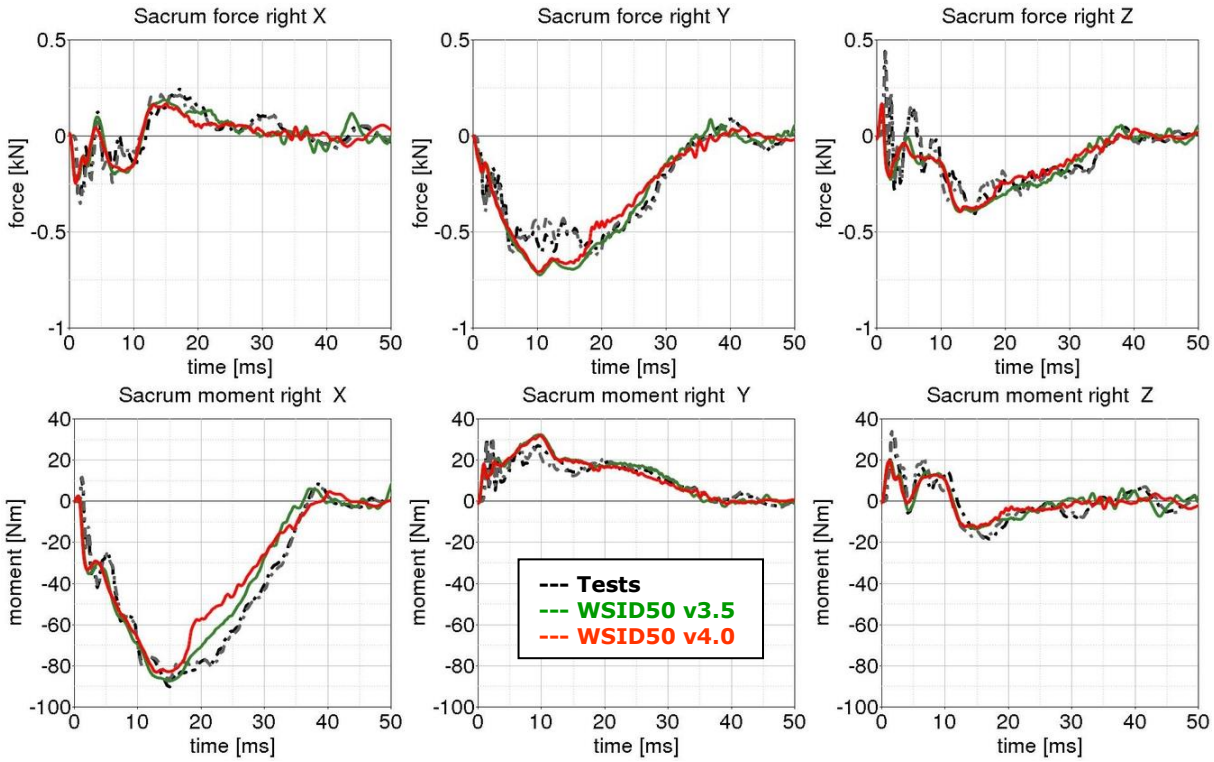


Figure 126: Result of iliac wing test -- Target point B, high velocity, half pelvis (Sacro-iliac load cell)

Results of target point B, low velocity, full pelvis:

Pendulum accelerations

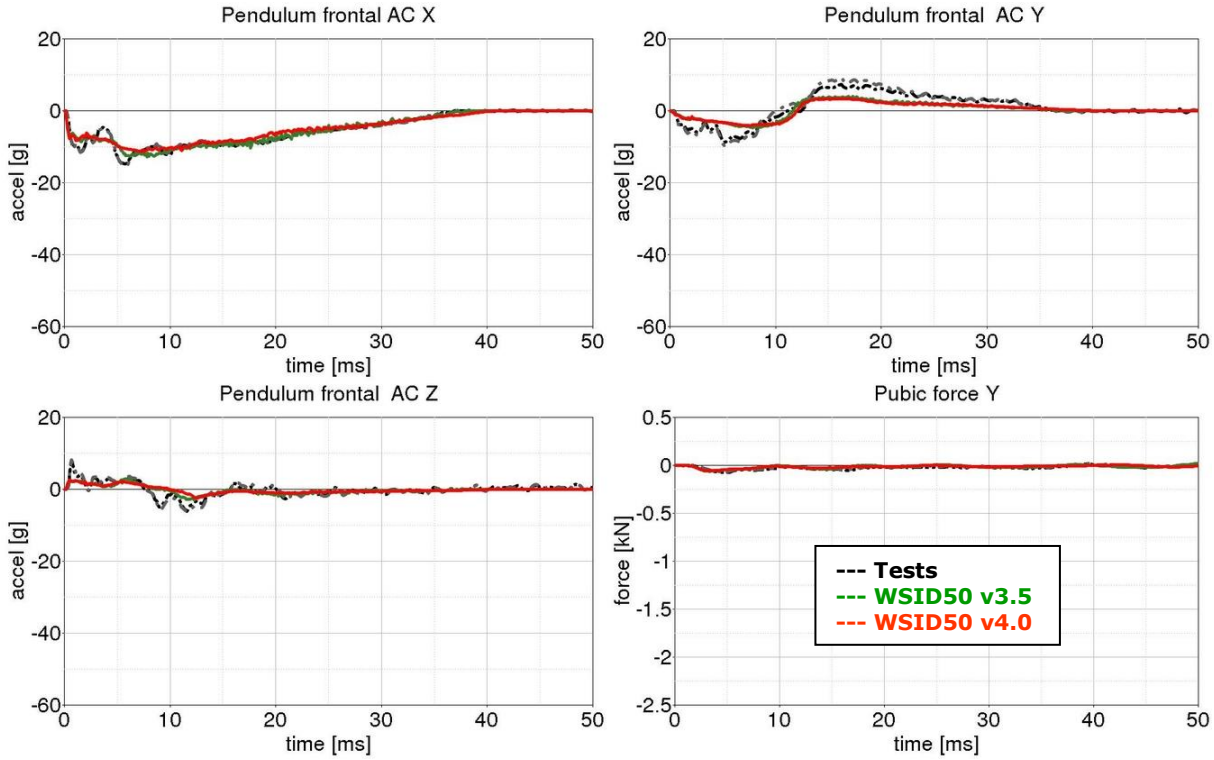


Figure 127: Result of iliac wing test -- Target point B, low velocity, full pelvis (Pendulum accelerations)

Sacro-iliac load cell

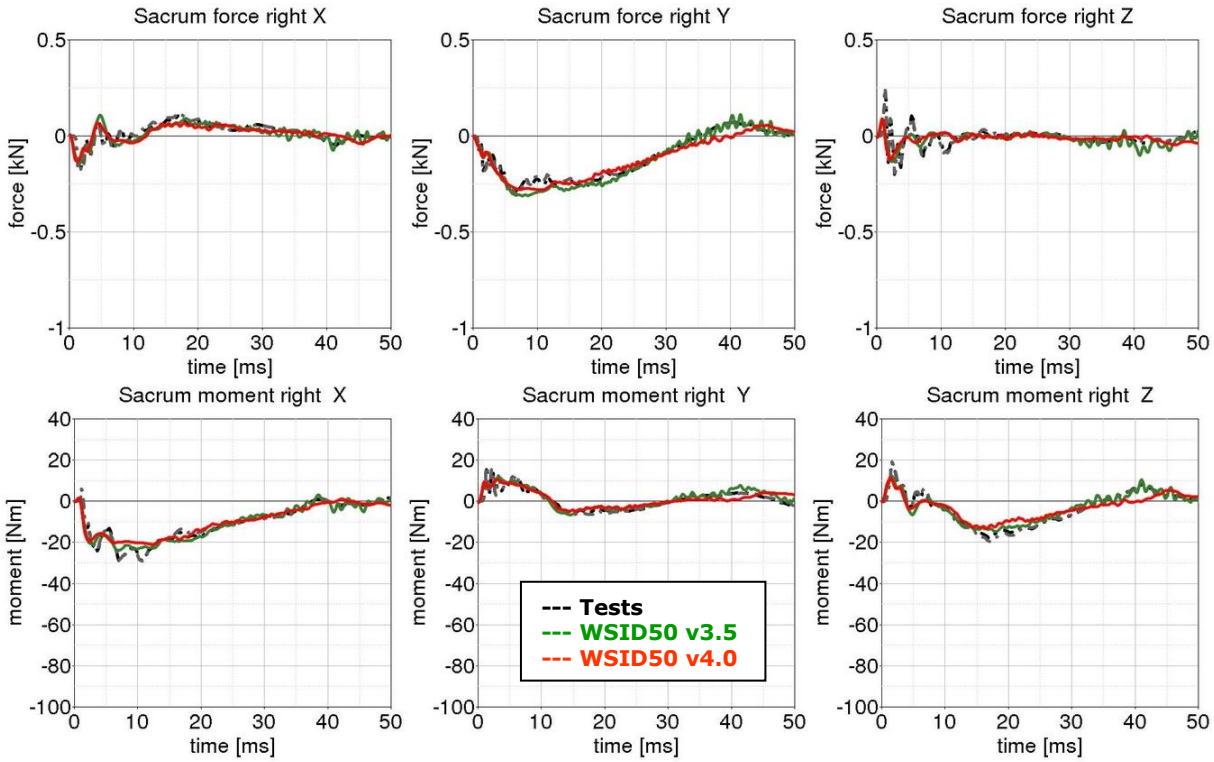


Figure 128: Result of iliac wing test -- Target point B, low velocity, full pelvis (Sacro-iliac load cell)

Results of target point B, high velocity, full pelvis:

Pendulum accelerations

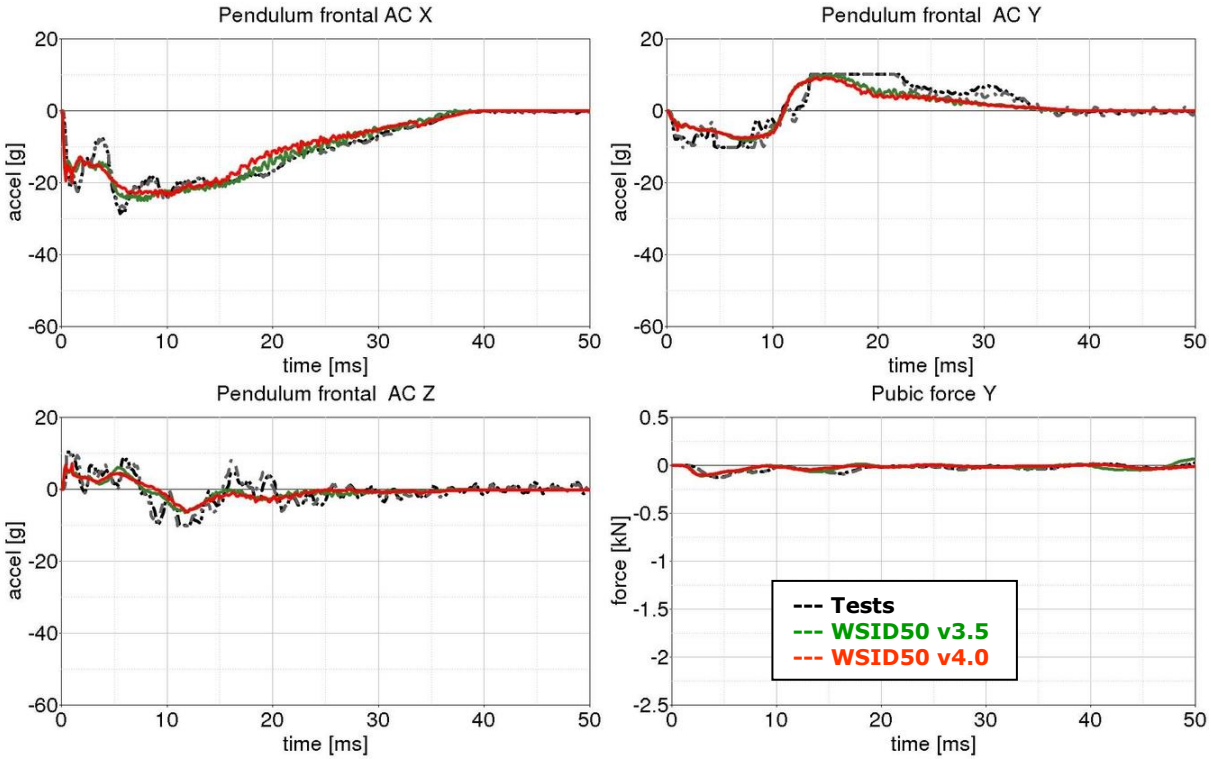


Figure 129: Result of iliac wing test -- Target point B, high velocity, full pelvis (Pendulum accelerations)

Sacro-iliac load cell

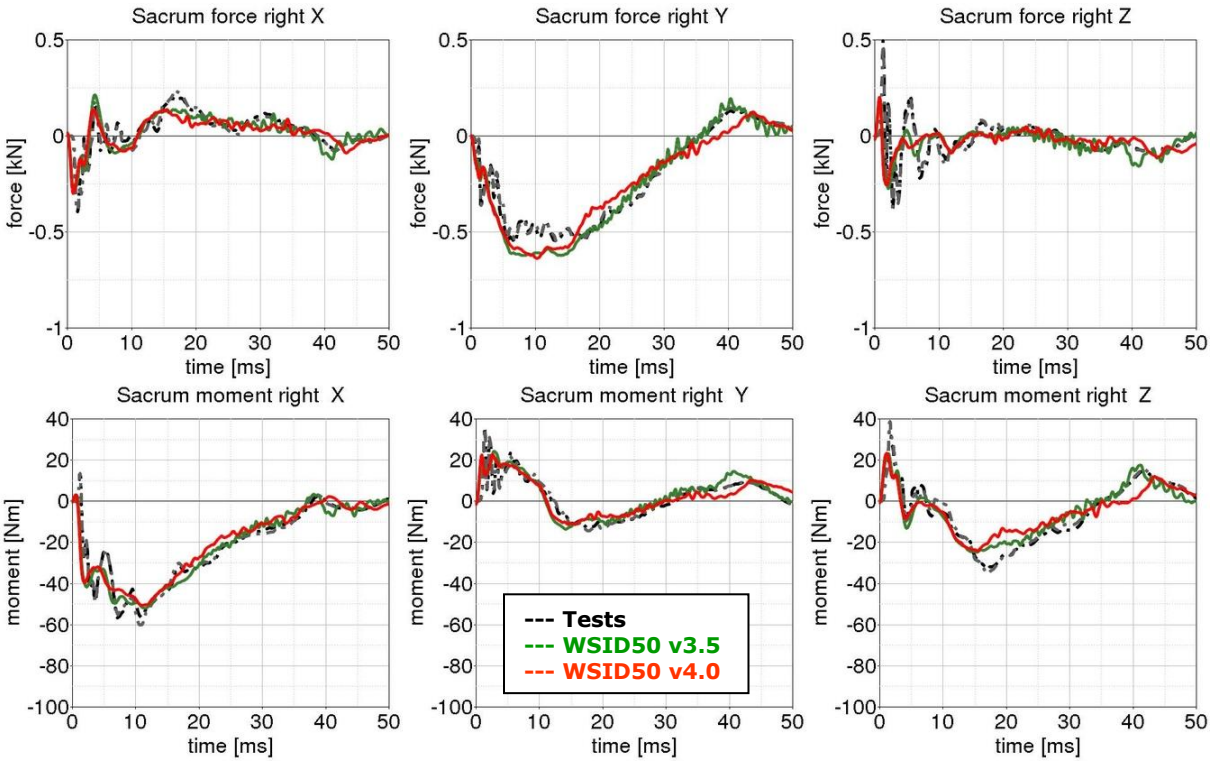


Figure 130: Result of iliac wing test -- Target point B, high velocity, full pelvis (Sacro-iliac load cell)

8.2 Calibration tests

The calibration tests are also used to validate the WorldSID model. The tests are used as described in the WorldSID manual of the physical dummy (Road vehicles — Design and performance specifications for the WorldSID 50th percentile male side-impact dummy, Part 1-4, ISO 15830-1 to 15830-4).
For each test, a short description of the test configuration is given in each single section. For more detailed information of the test setup please use the hardware manual of the WorldSID.

8.2.1 Head drop test

The disconnected head drops on a rigid plate. Then the head accelerations are measured.

Two configurations are used: frontal and lateral drop test. The configurations are depicted in the following figure.

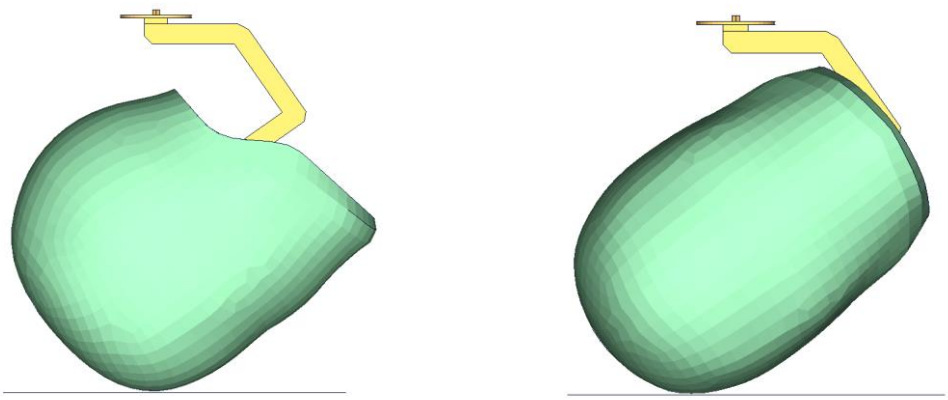


Figure 131: Head drop test, Left: Frontal test, Right: Lateral test

The results and the corridors are shown in the following 2 plots:

Results of frontal head drop test

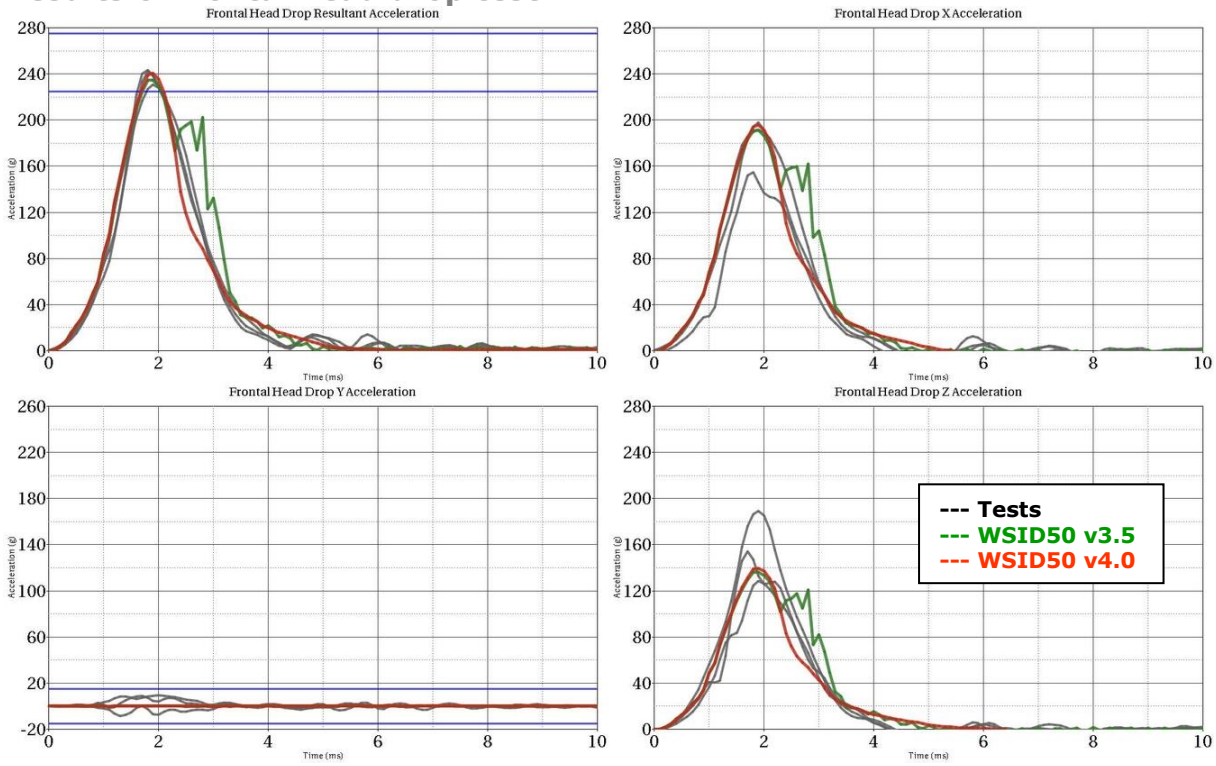


Figure 132: Results of frontal head drop test

Results of lateral head drop test

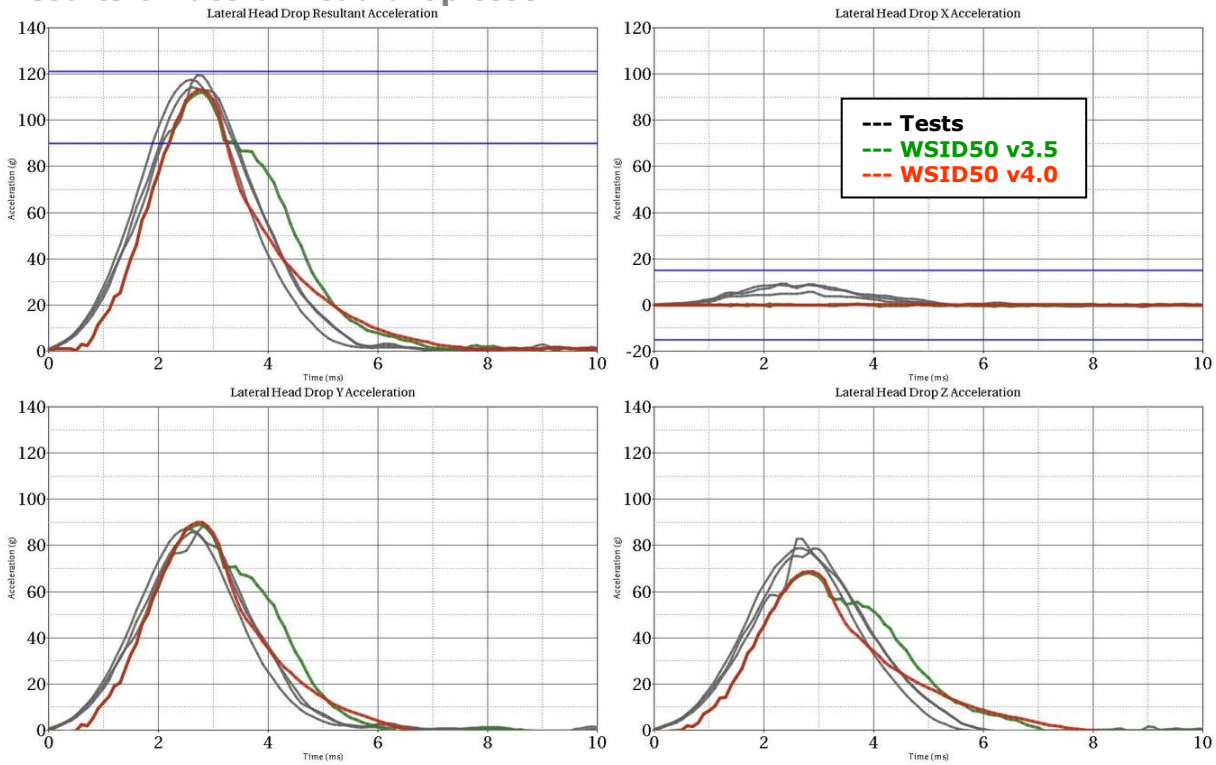


Figure 133: Results of lateral head drop test

8.2.2 Neck pendulum test

The neck calibration test is simulated as described in the WorldSID manual ISO-15830 part 2. The test setup is depicted in the figure below. The neck is adapted to a long pendulum. The pendulum runs into a part of honeycomb to get decelerated, thereby causing the neck to bend against the load direction. As mass replacement, the head form is used instead of the original head.

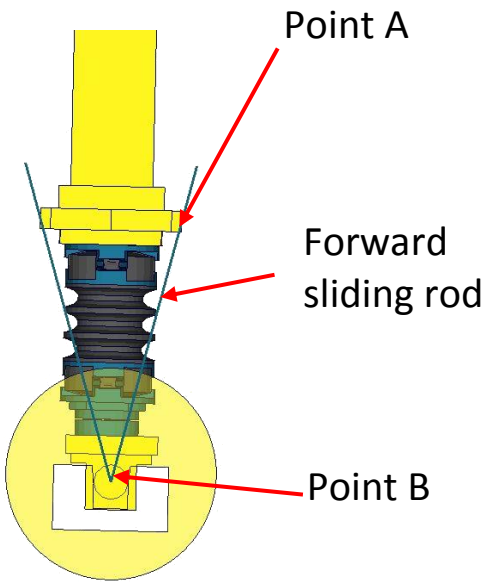


Figure 134: Neck pendulum calibration test setup

In the test, the load cell forces and moments are measured and the rotations of the points A and B are used to describe the kinematics of the neck.

The results and the corresponding calibration corridors are shown in the following figures.

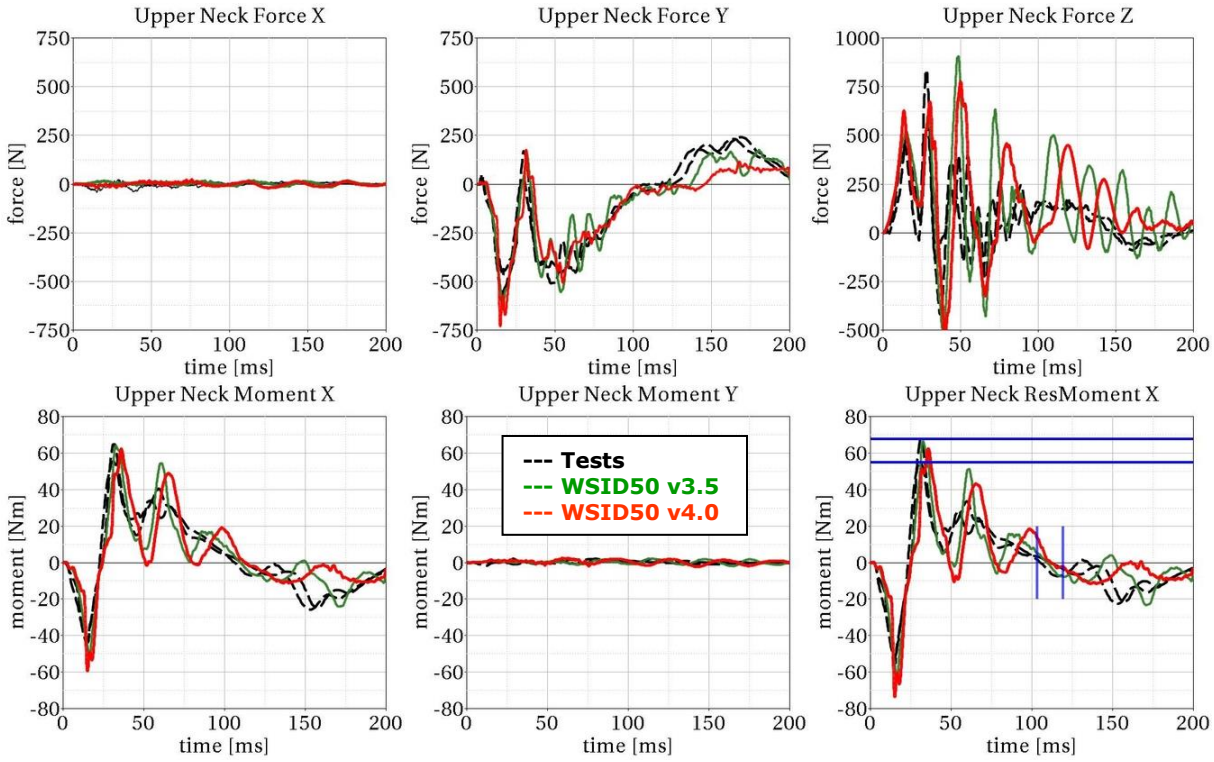


Figure 135: Result of neck calibration test upper neck load cell

Head form rotation results

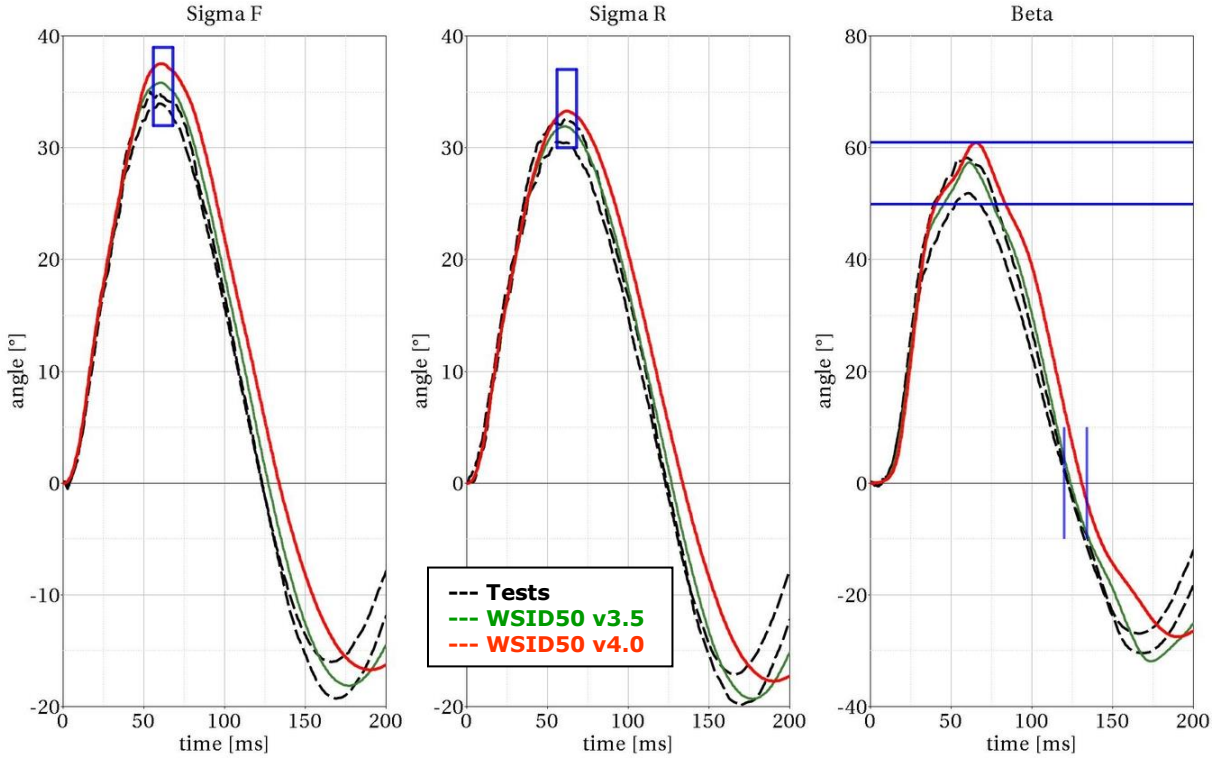


Figure 136: Result of neck calibration test head form rotations

8.2.3 Shoulder pendulum test

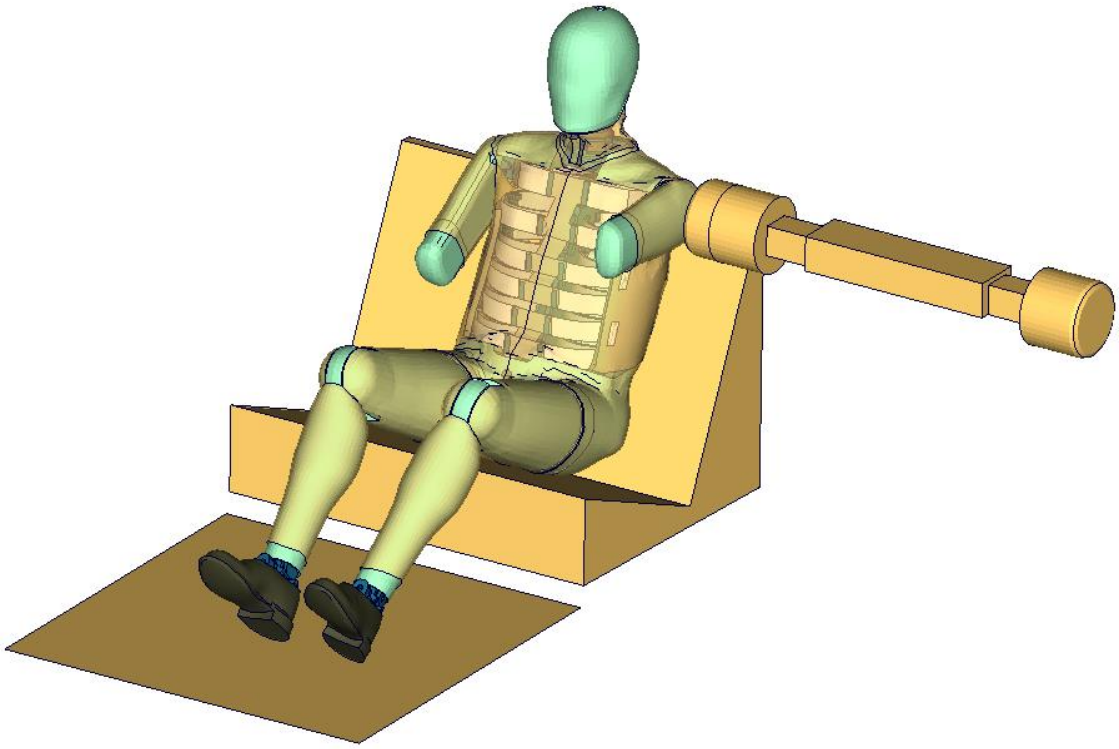


Figure 137: Shoulder calibration test setup

Results of shoulder calibration test with arm (Page 1)

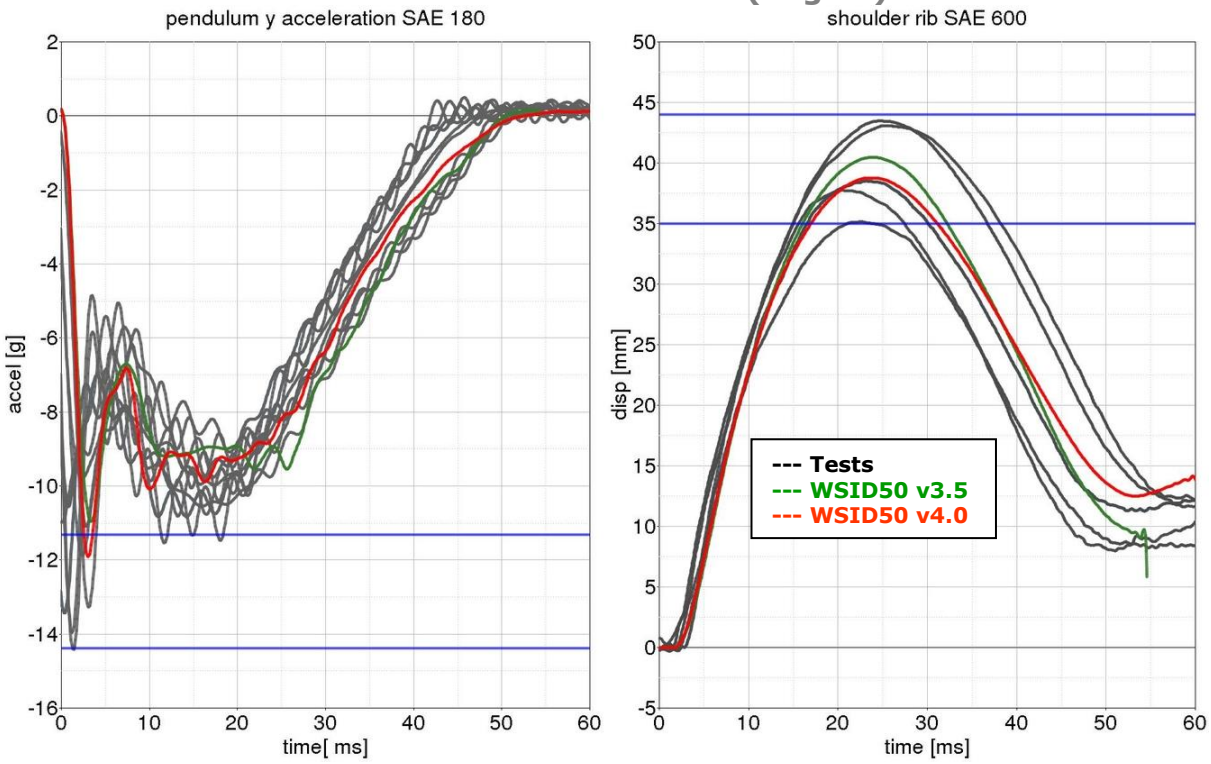


Figure 138: Shoulder calibration test results with arm (Page 1)

8.2.4 Thorax pendulum test without arm

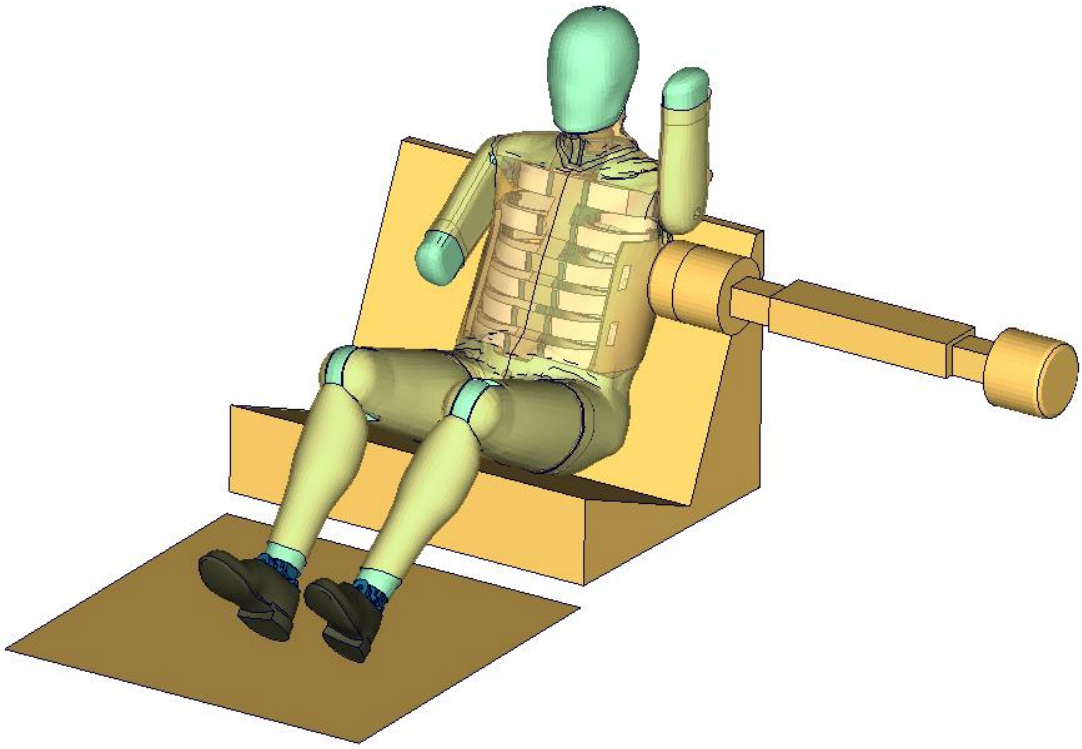


Figure 139: Thorax calibration test setup without arm

Results of thorax calibration test without arm (Page 1)

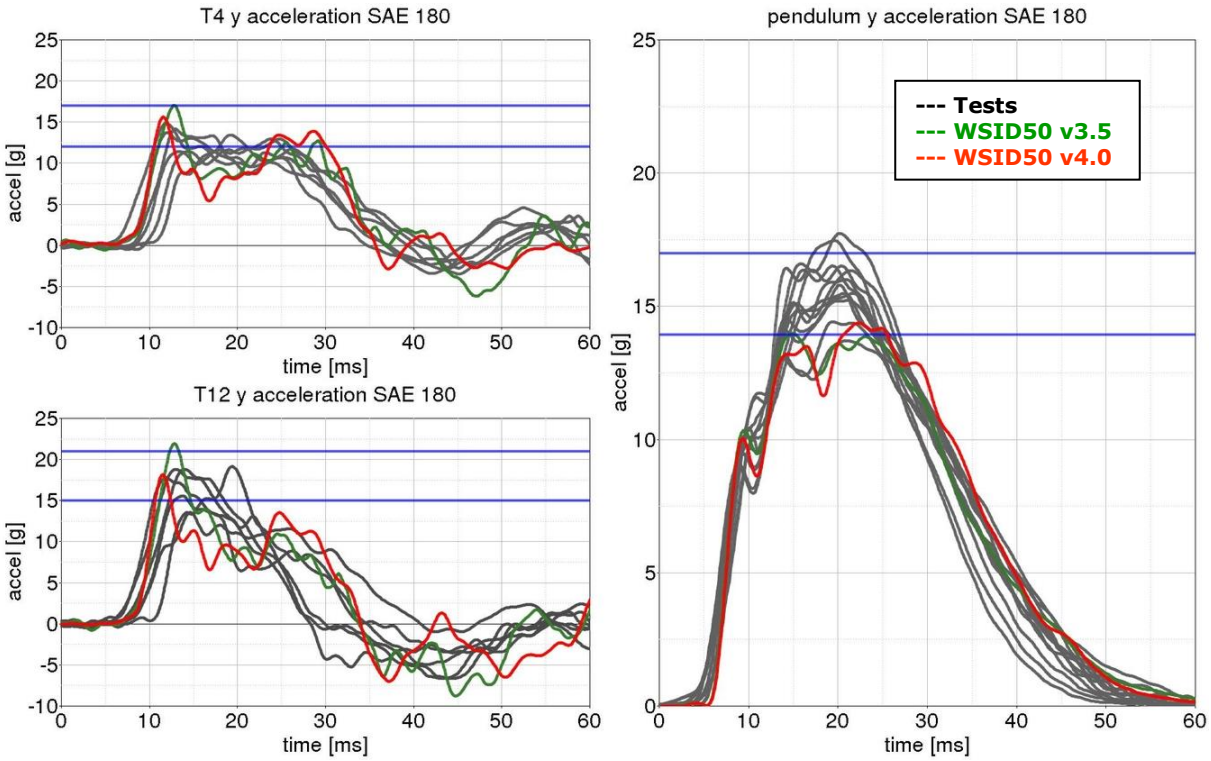


Figure 140: Thorax calibration test results without arm (Page 1)

Results of thorax calibration test without arm (Page 2)

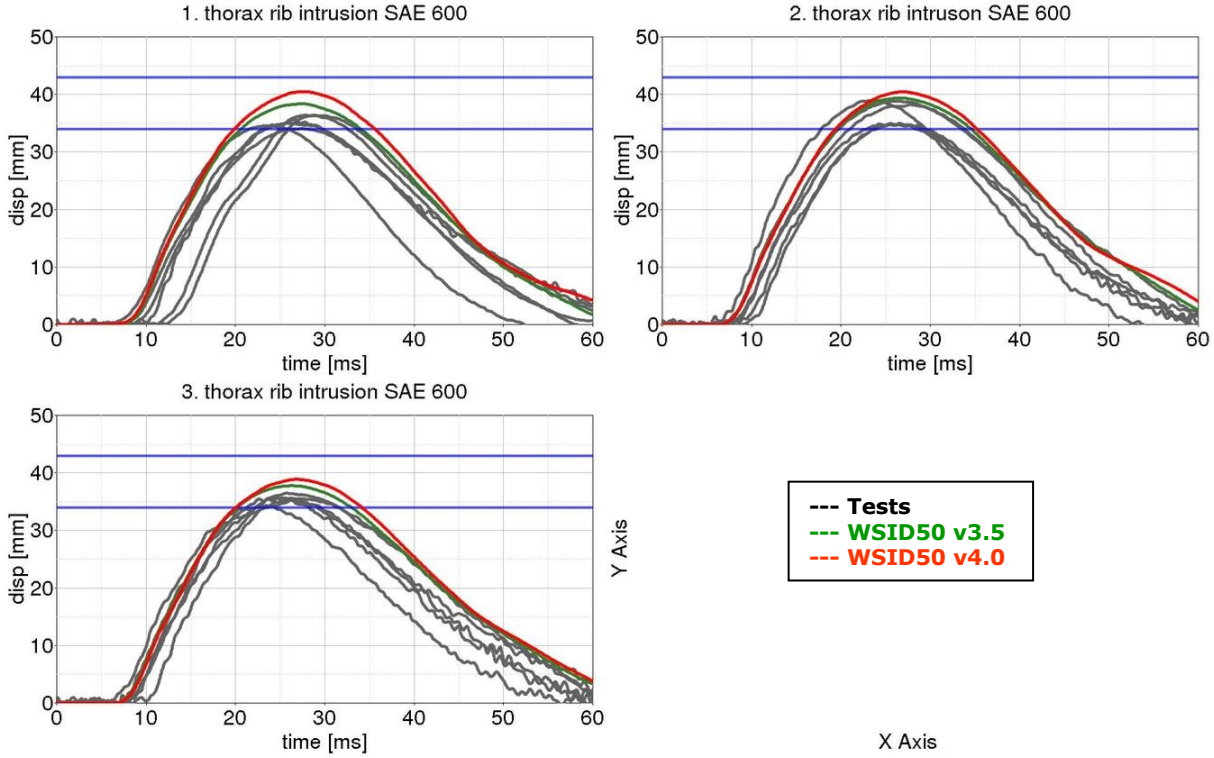


Figure 141: Thorax calibration test results without arm (Page 2)

8.2.5 Thorax pendulum test with arm

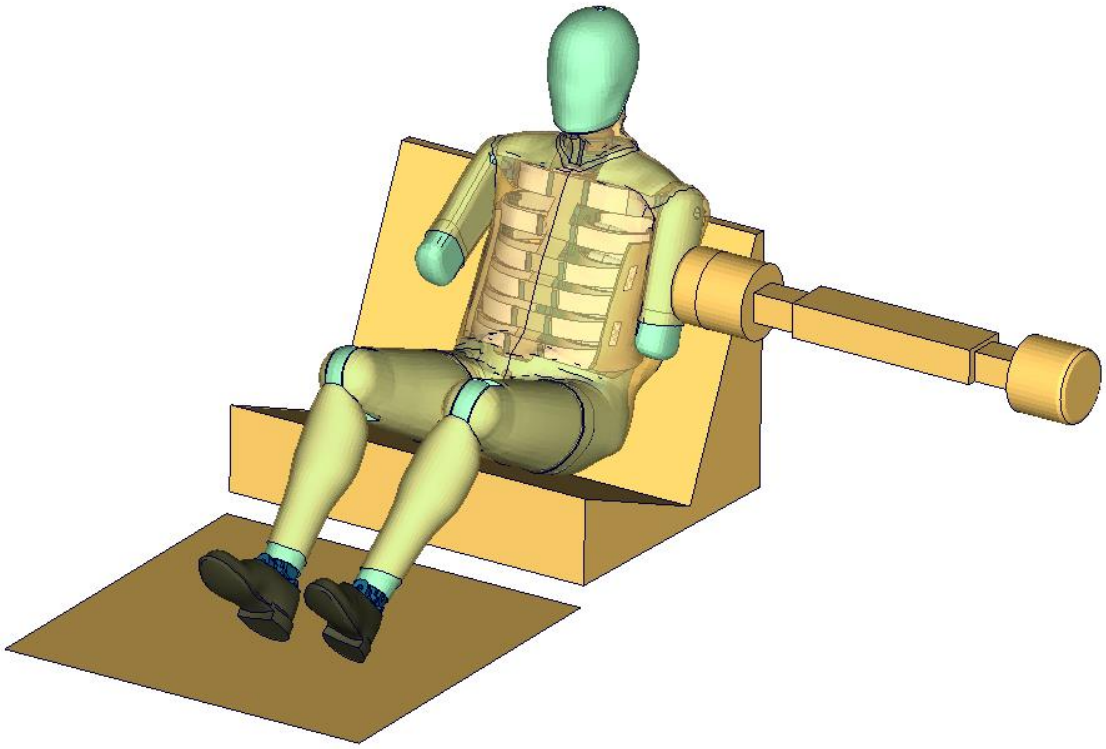


Figure 142: Thorax calibration test setup with arm

Results of thorax calibration test with arm (Page 1)

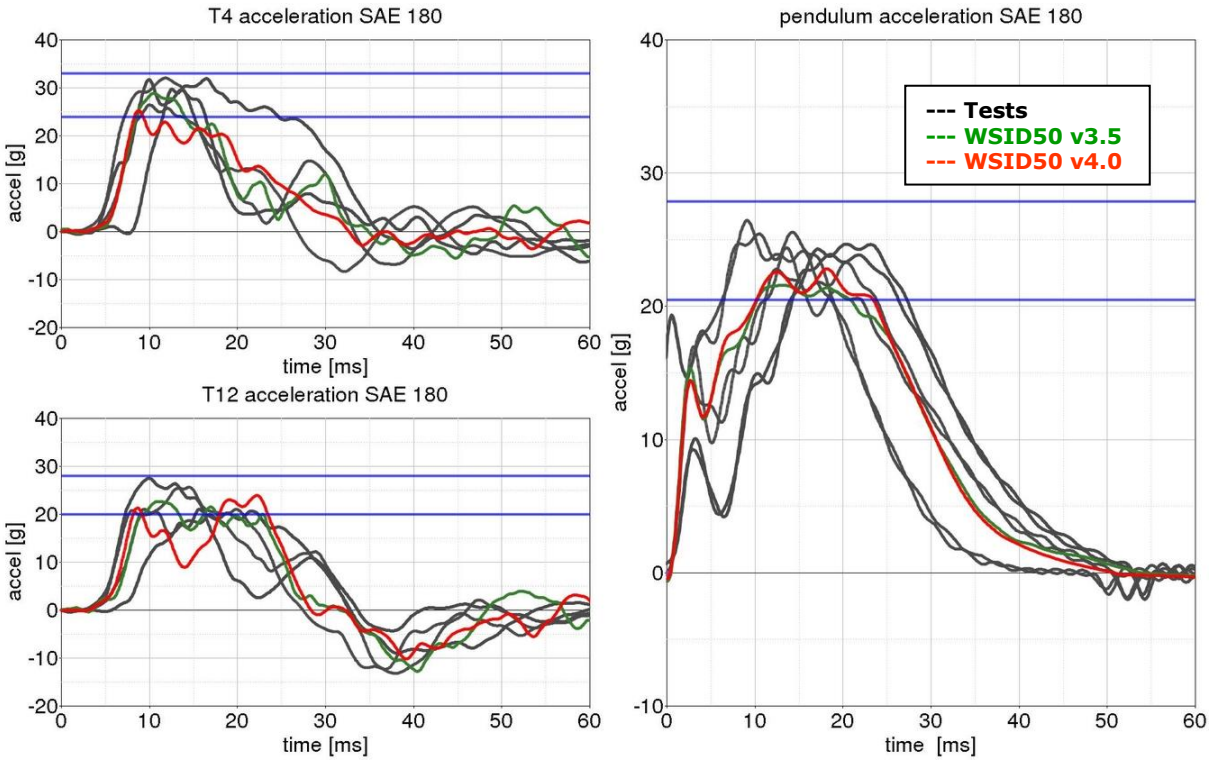


Figure 143: Thorax calibration test results with arm (Page 1)

Results of thorax calibration test with arm (Page 2)

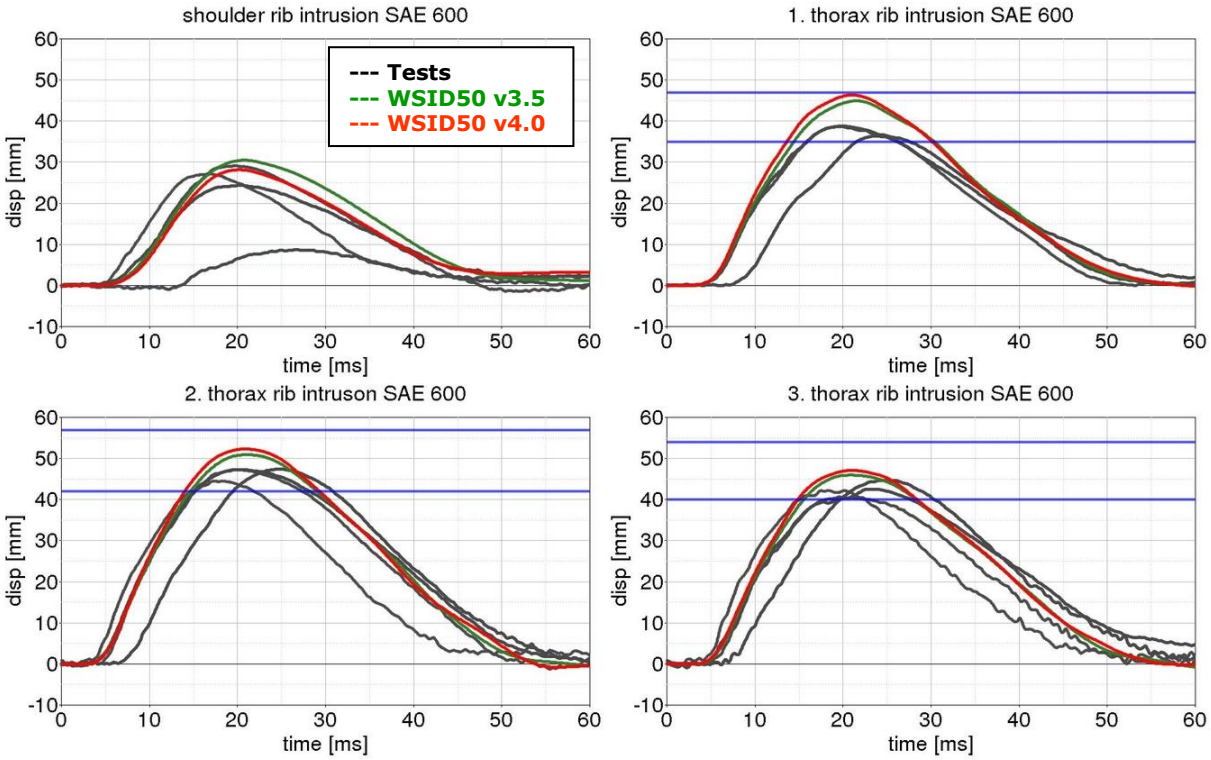


Figure 144: Thorax calibration test results with arm (Page 2)

8.2.6 Abdomen pendulum test

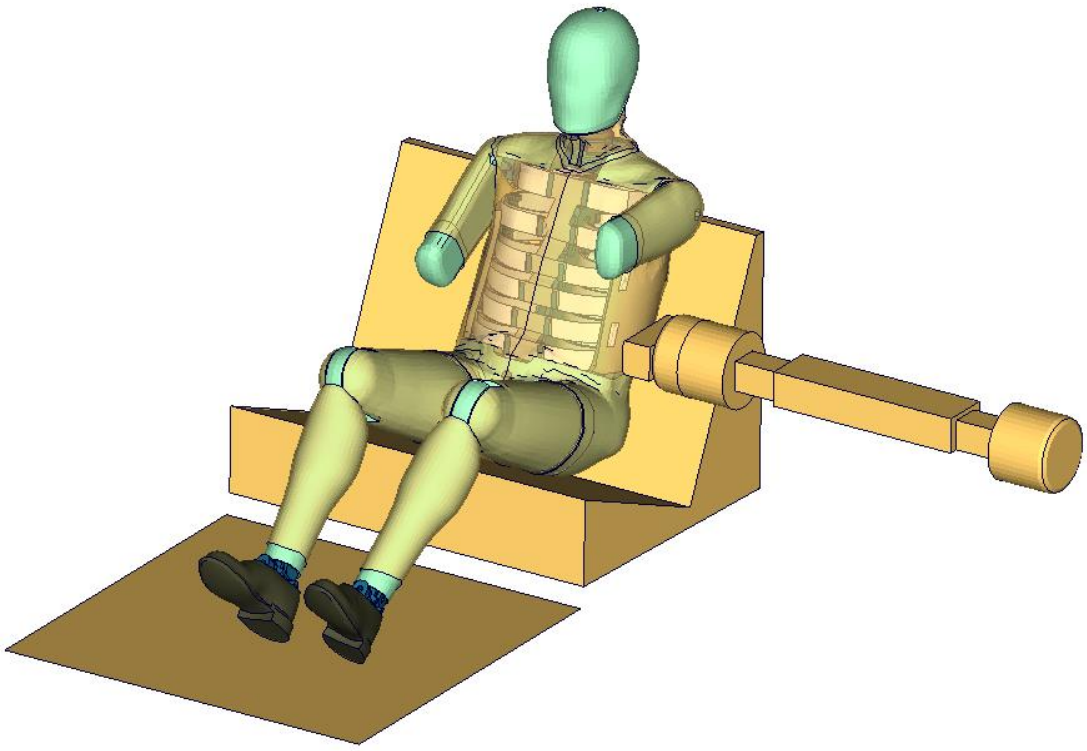


Figure 145: Abdomen calibration test setup

Results of abdomen calibration test with arm (Page 1)

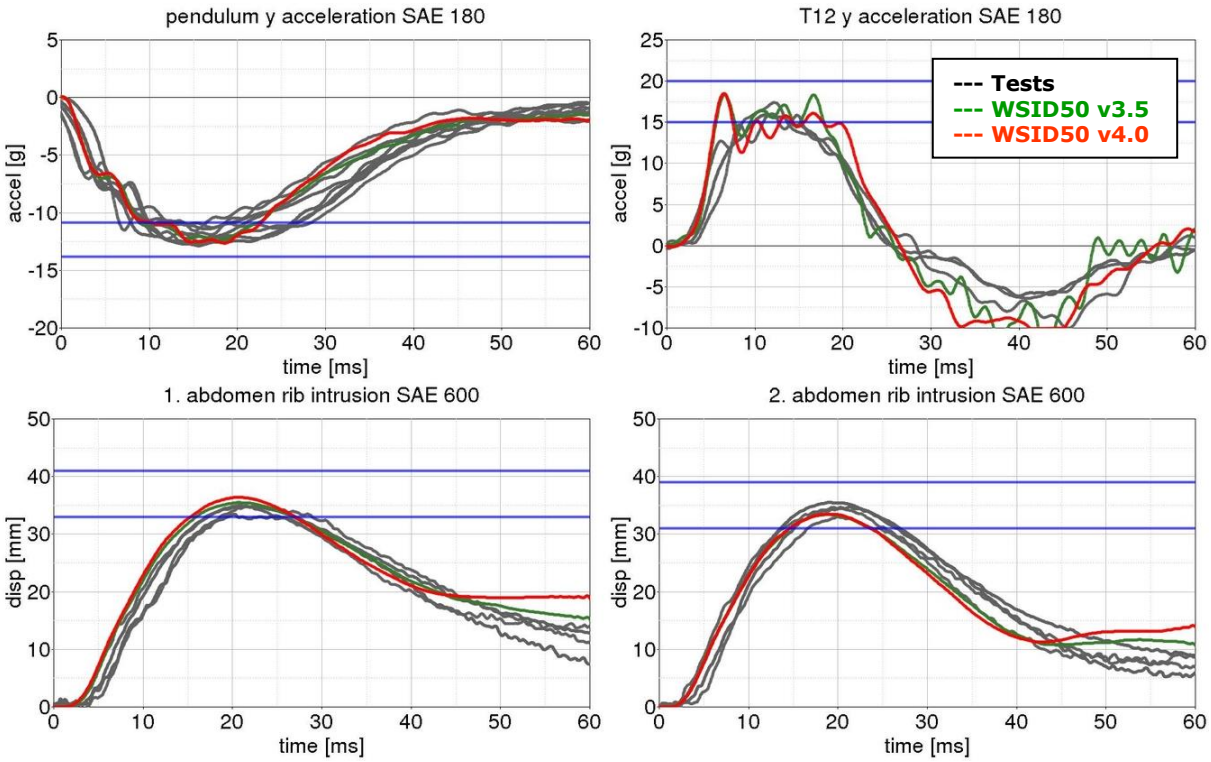


Figure 146: Abdomen calibration test results with arm (Page 1)

8.2.7 Pelvis pendulum test

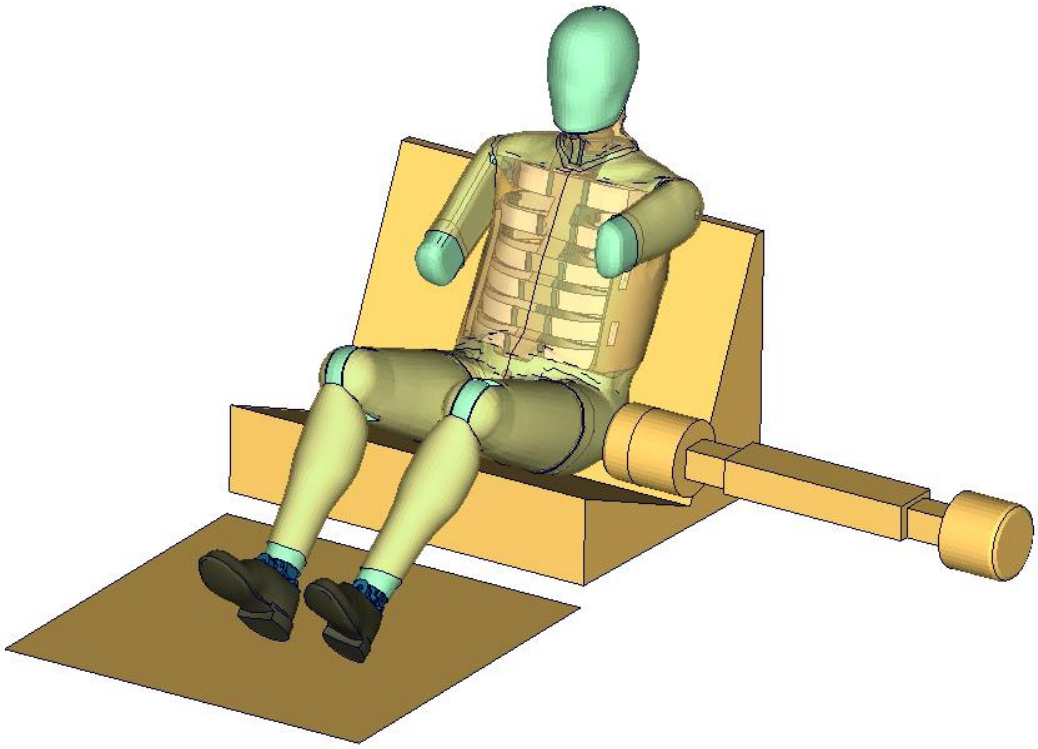


Figure 147: Pelvis calibration test setup

Results of pelvis calibration test with arm (Page 1)

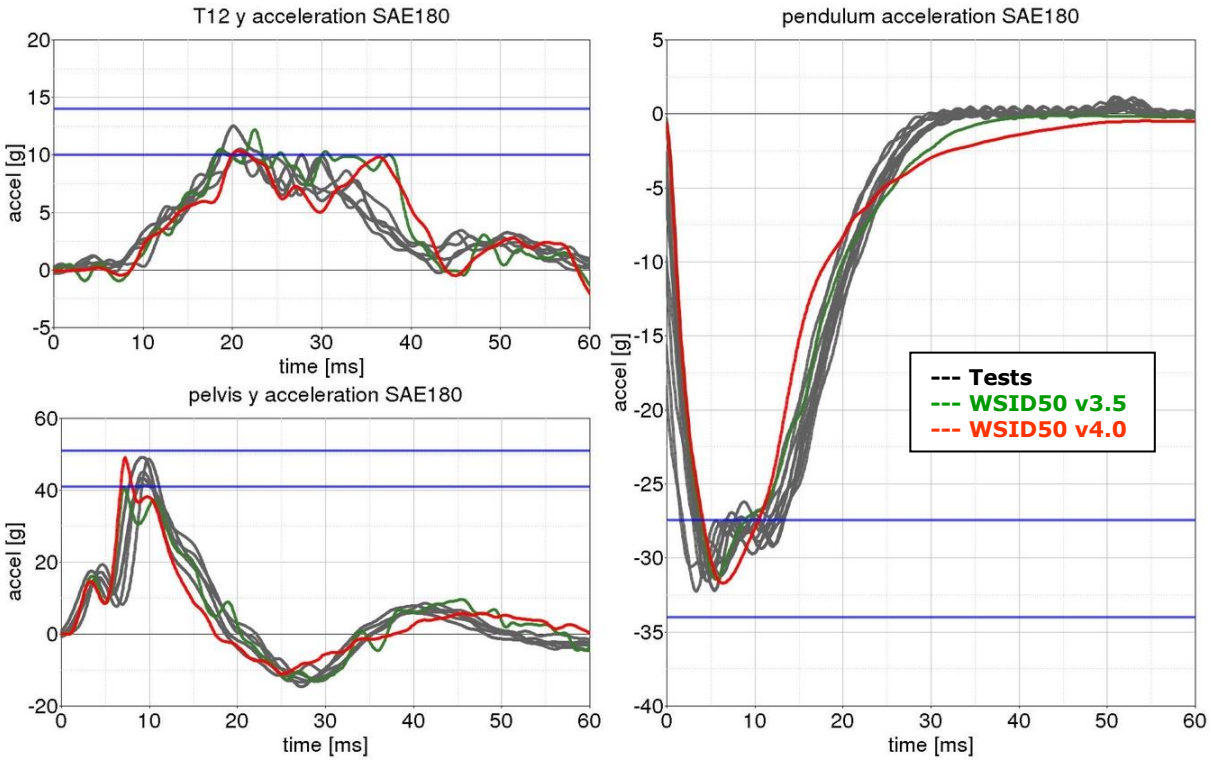


Figure 148: Pelvis calibration test results with arm (Page 1)

8.3 Sled Tests

The following sled tests are used for validation. There are two different sled shapes and for each shape two different arm positions. In addition one test is done without the jacket and one without the Arm.

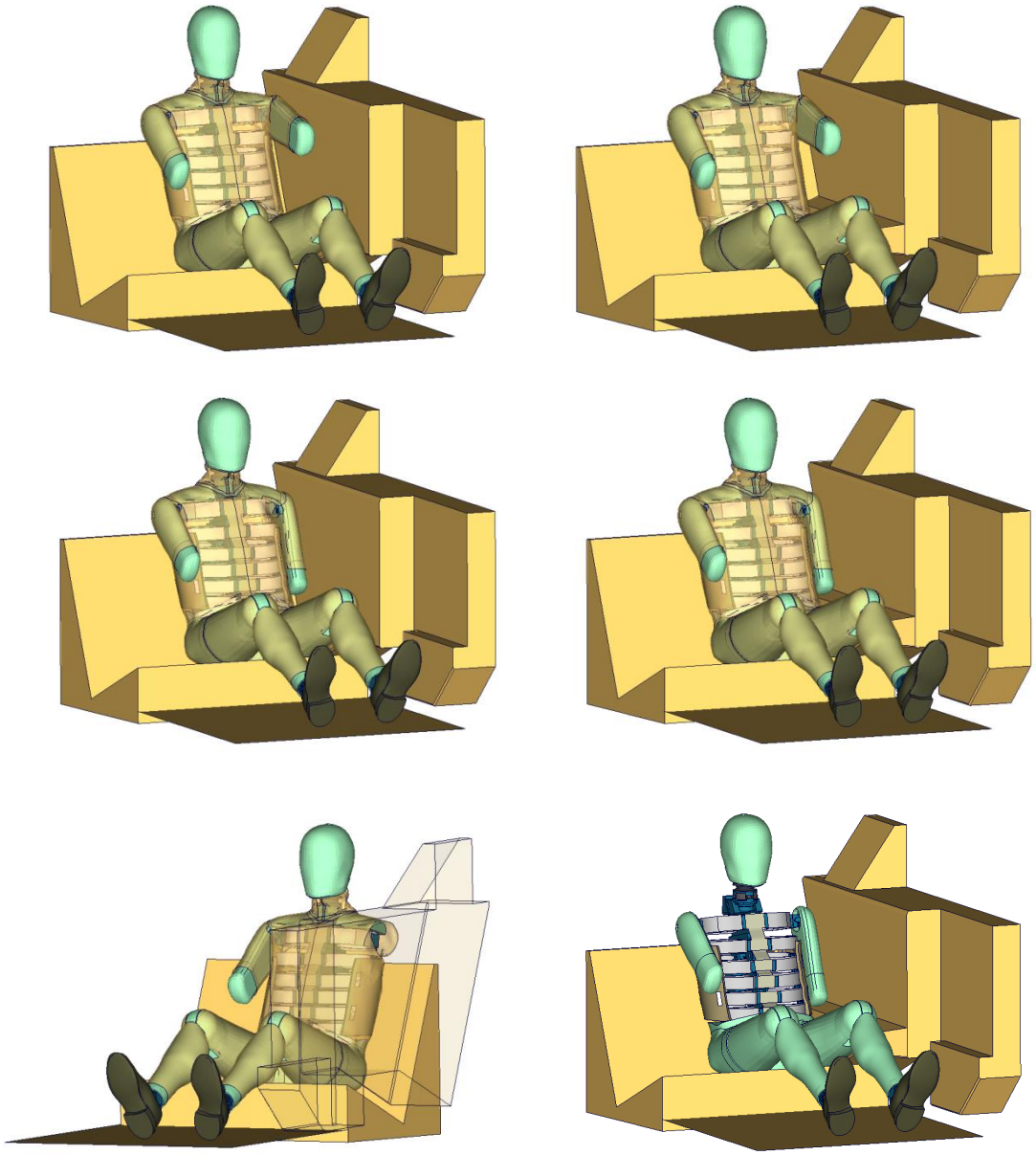


Figure 149: Sled tests for next WorldSID release. Left hand side: Plane sled. Right hand side: Plane sled with pelvis pusher

8.3.1 Flat barrier

8.3.1.1 Arm position second notch

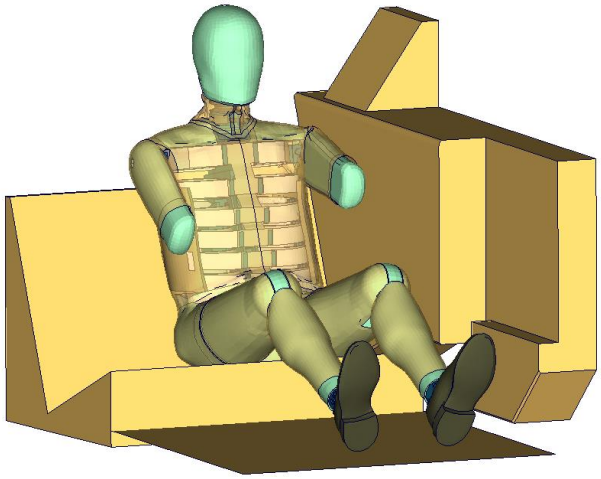
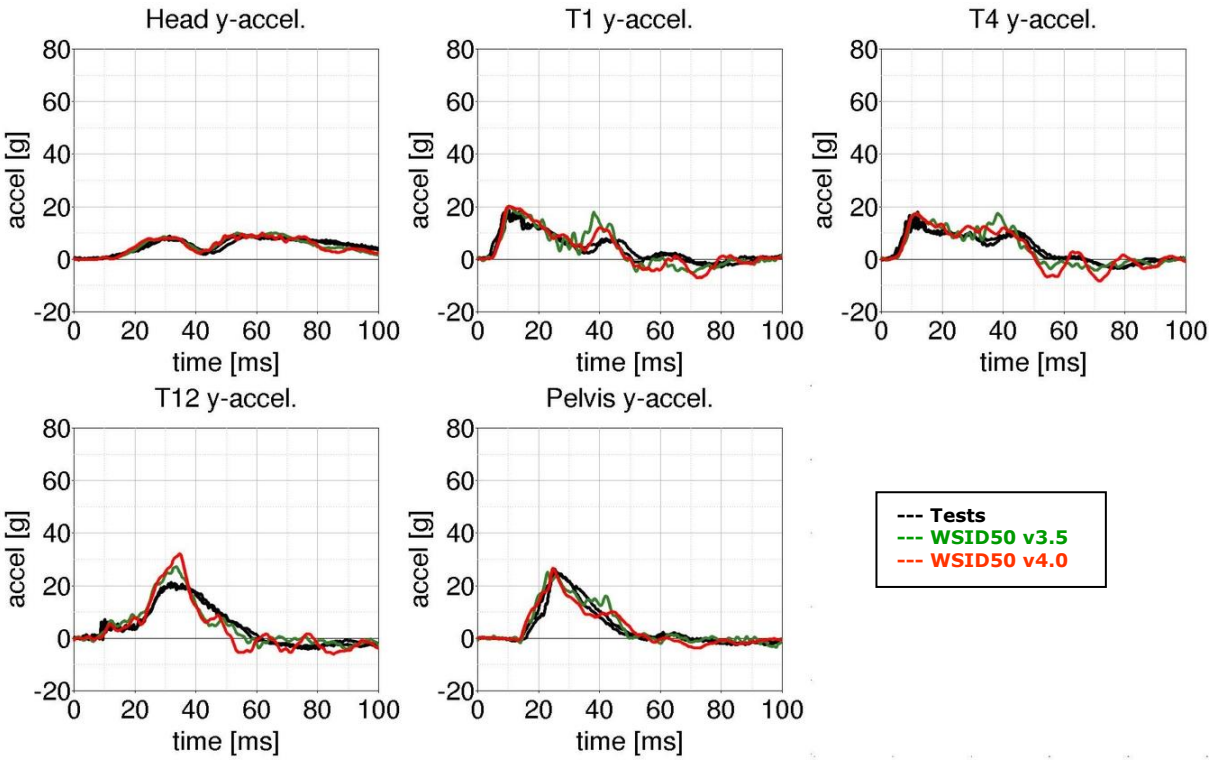
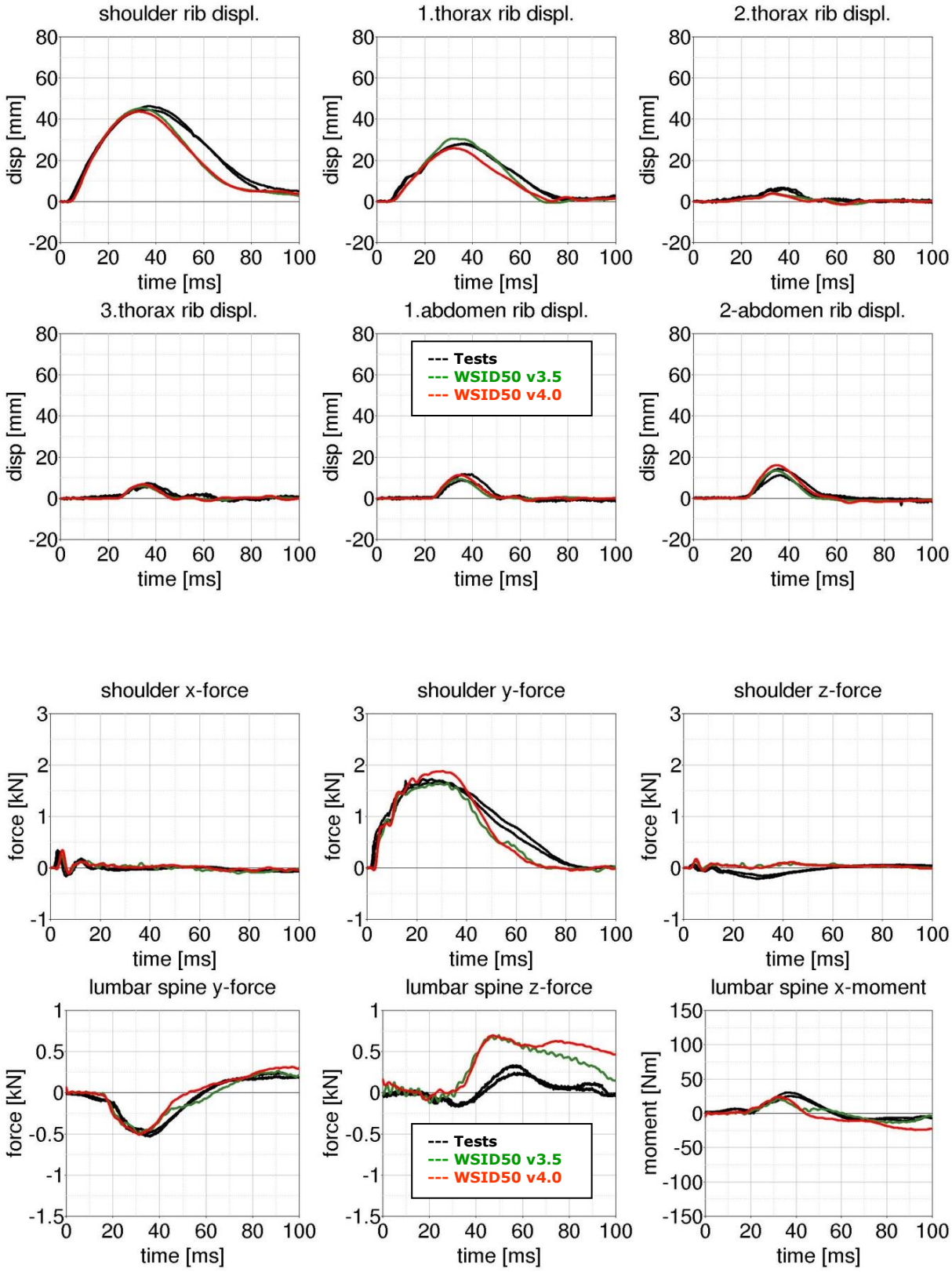
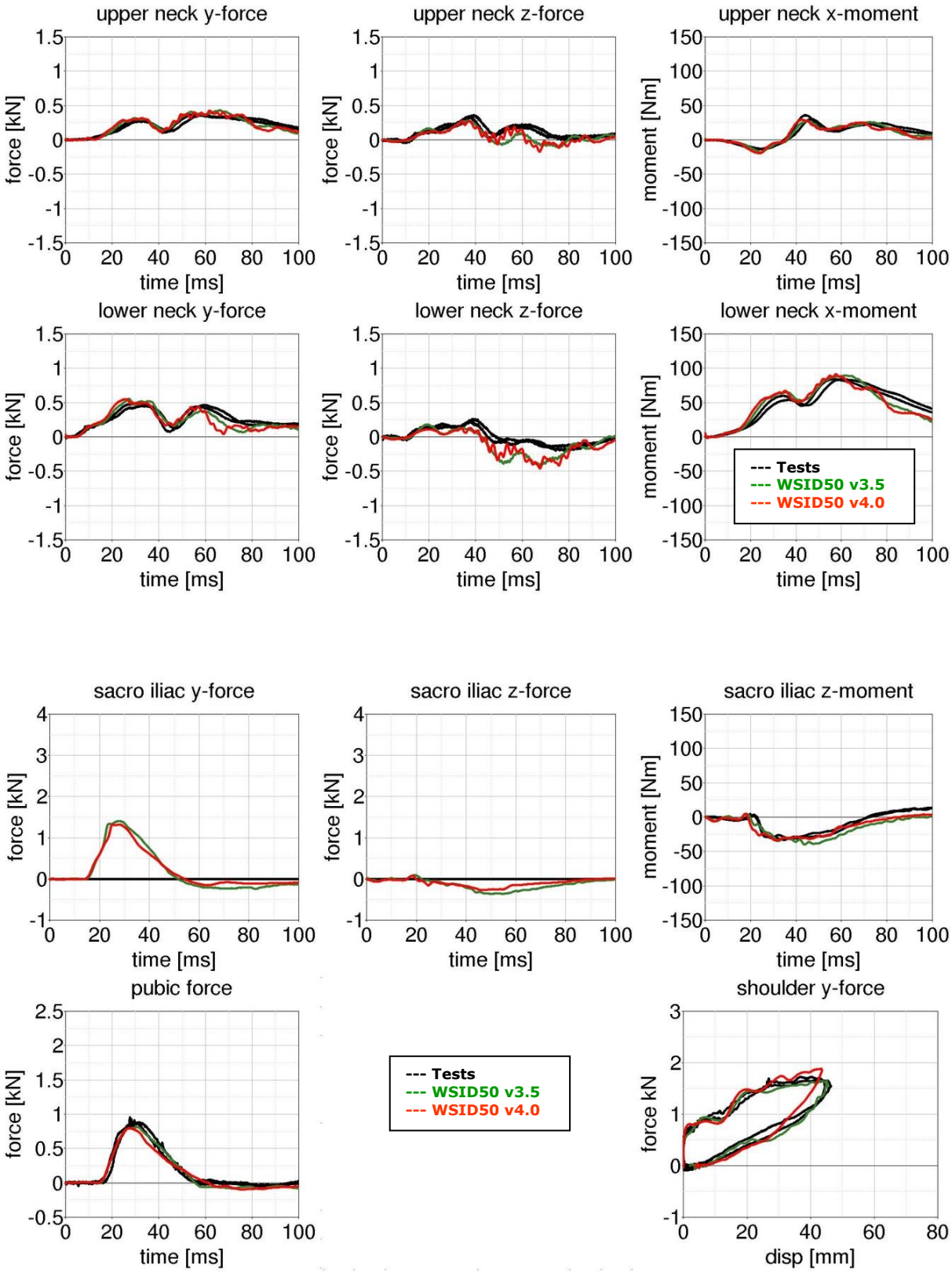


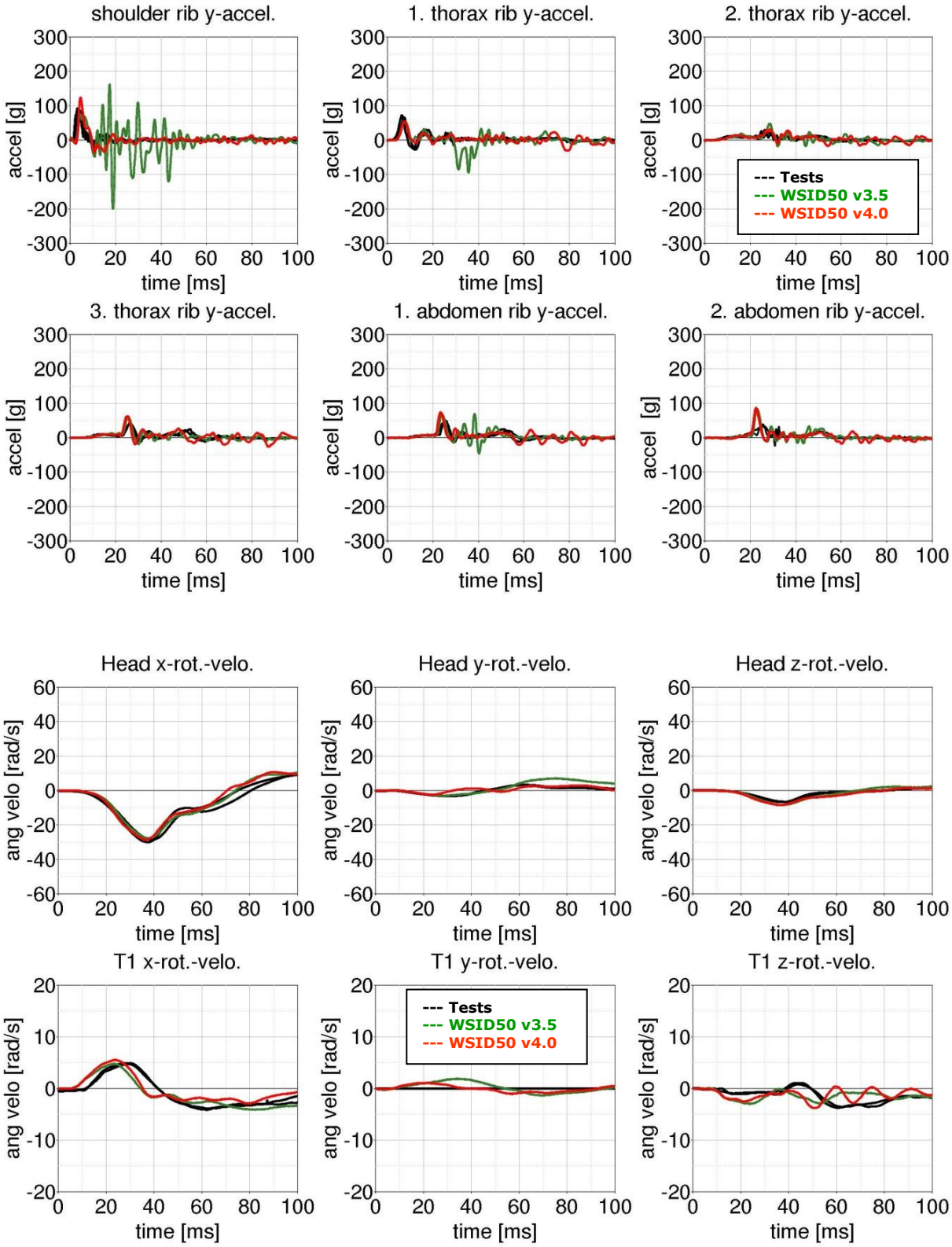
Figure 150: Flat barrier and arm second notch.

Low velocity:

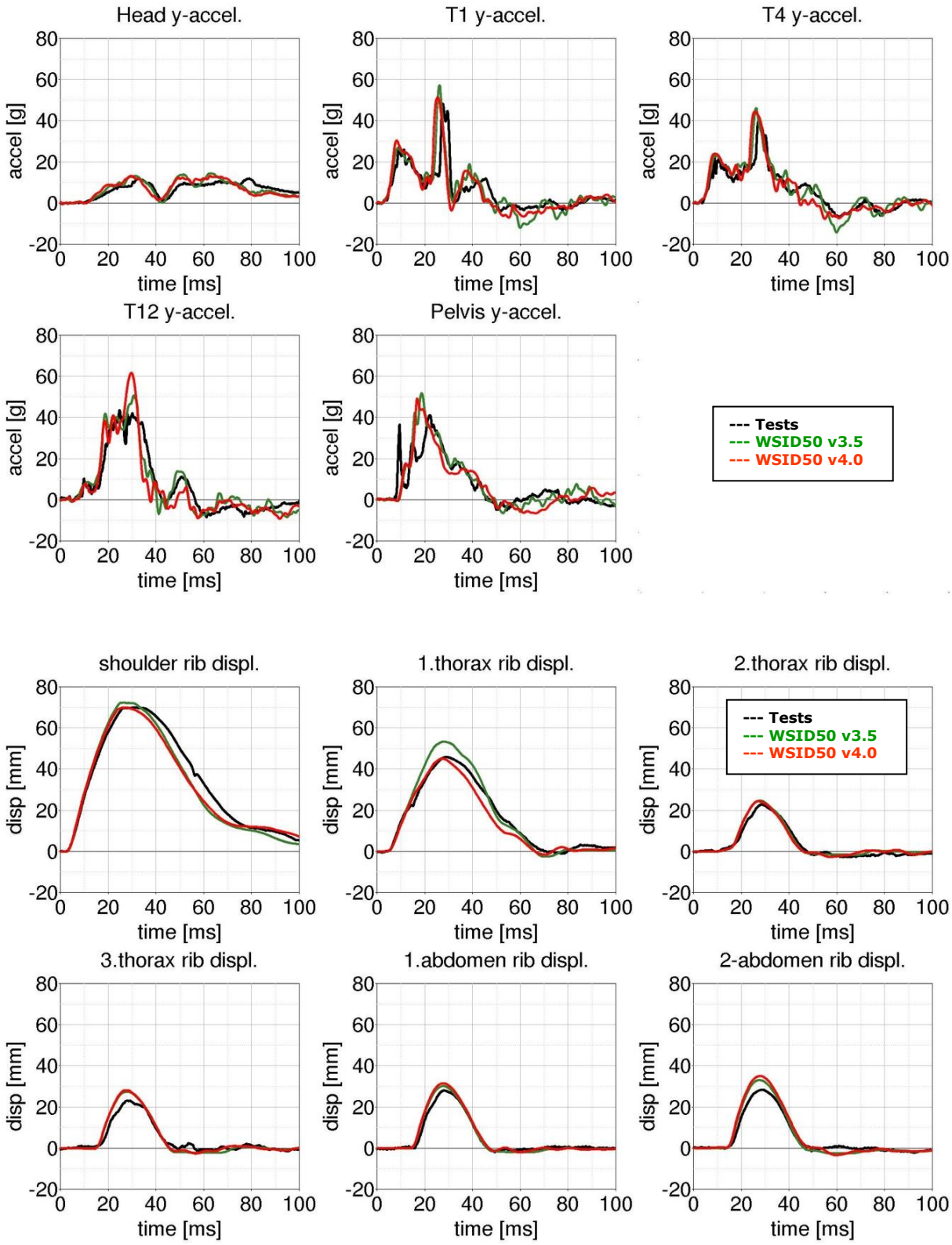


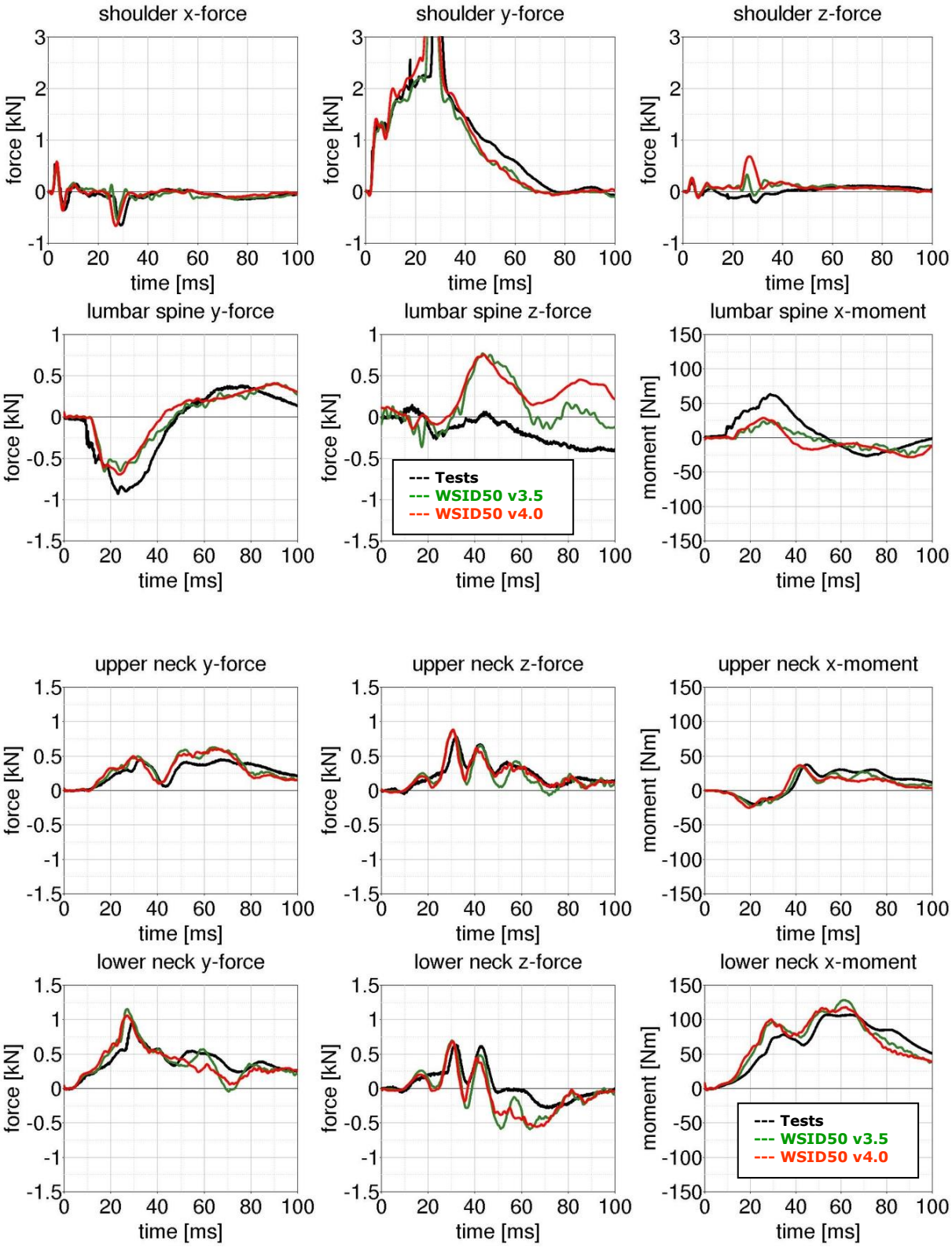

shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
disp [mm]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder x-force
shoulder y-force
shoulder z-force
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
force [kN]
moment [Nm]

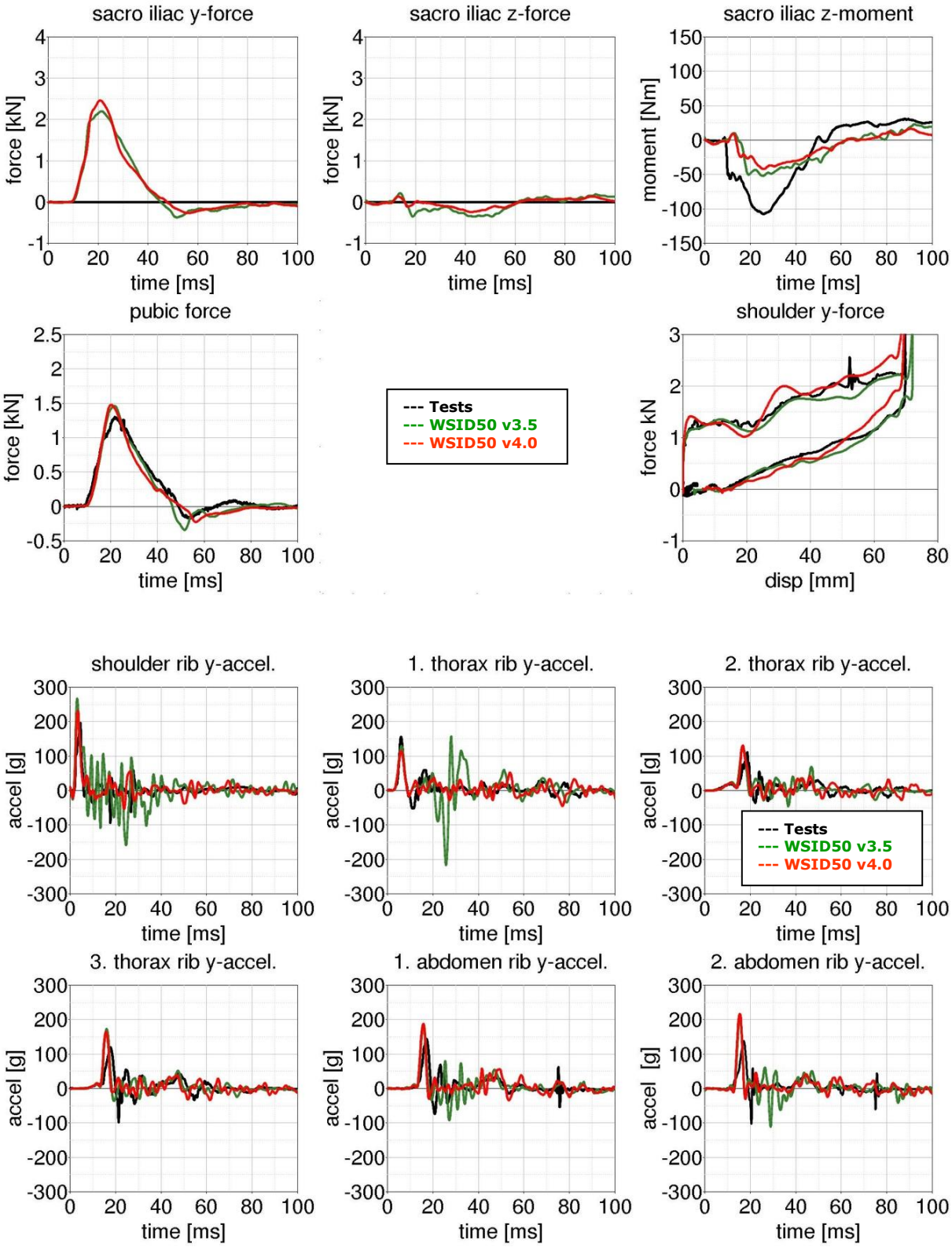

upper neck y-force
force [kN]
time [ms]
upper neck z-force
force [kN]
time [ms]
upper neck x-moment
moment [Nm]
time [ms]
lower neck y-force
force [kN]
time [ms]
lower neck z-force
force [kN]
time [ms]
lower neck x-moment
moment [Nm]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
sacro iliac y-force
force [kN]
time [ms]
sacro iliac z-force
force [kN]
time [ms]
sacro iliac z-moment
moment [Nm]
time [ms]
pubic force
force [kN]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder y-force
force kN
disp [mm]

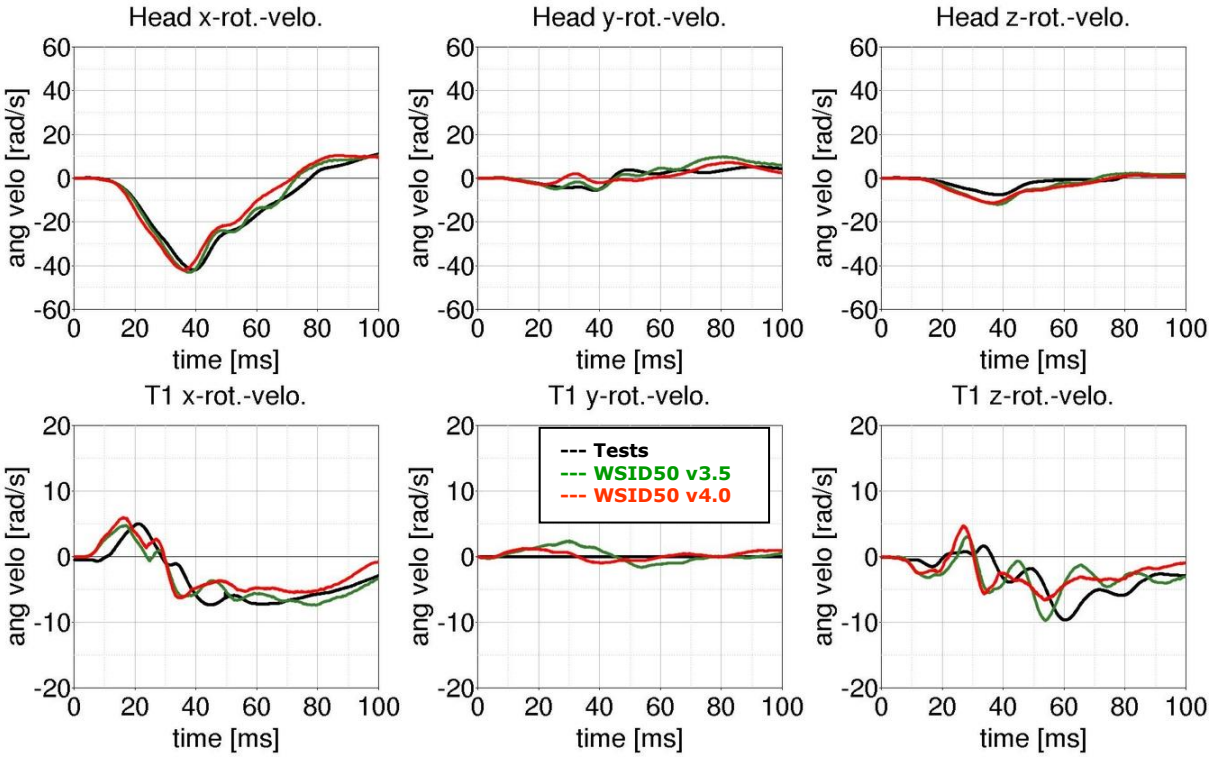

shoulder rib y-accel.
1. thorax rib y-accel.
2. thorax rib y-accel.
3. thorax rib y-accel.
1. abdomen rib y-accel.
2. abdomen rib y-accel.
accel [g]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
Head x-rot.-velo.
Head y-rot.-velo.
Head z-rot.-velo.
T1 x-rot.-velo.
T1 y-rot.-velo.
T1 z-rot.-velo.
ang velo [rad/s]

High velocity:




shoulder x-force
shoulder y-force
shoulder z-force
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
upper neck y-force
upper neck z-force
upper neck x-moment
lower neck y-force
lower neck z-force
lower neck x-moment
force [kN]
moment [Nm]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0


sacro iliac y-force
force [kN]
time [ms]
sacro iliac z-force
force [kN]
time [ms]
sacro iliac z-moment
moment [Nm]
time [ms]
pubic force
force [kN]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder y-force
force kN
disp [mm]
shoulder rib y-accel.
accel [g]
time [ms]
1. thorax rib y-accel.
accel [g]
time [ms]
2. thorax rib y-accel.
accel [g]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
3. thorax rib y-accel.
accel [g]
time [ms]
1. abdomen rib y-accel.
accel [g]
time [ms]
2. abdomen rib y-accel.
accel [g]
time [ms]


Head x-rot.-velo.
Head y-rot.-velo.
Head z-rot.-velo.
T1 x-rot.-velo.
T1 y-rot.-velo.
T1 z-rot.-velo.
ang velo [rad/s]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0

Arm position first notch

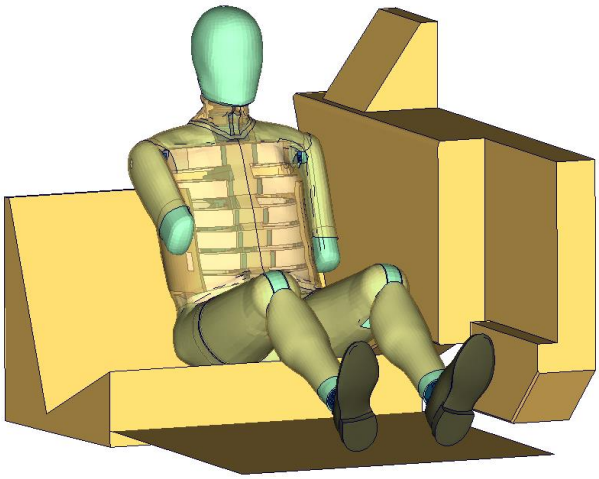
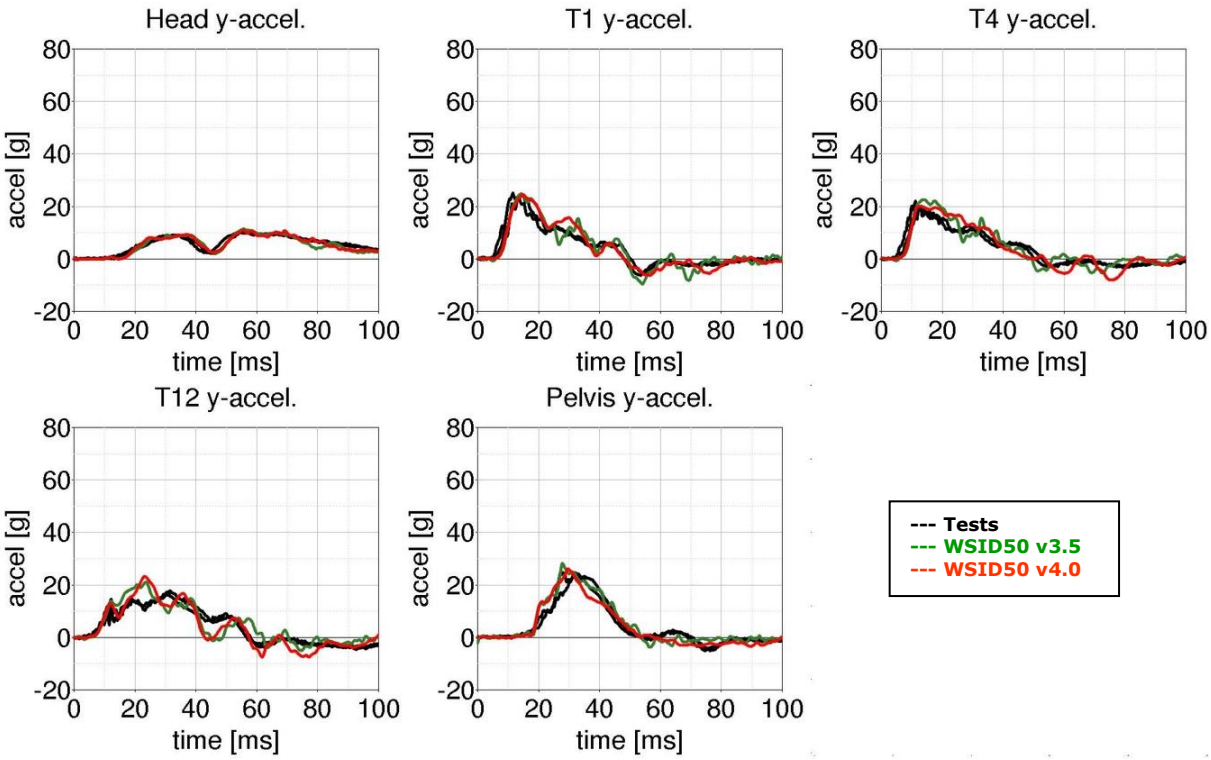
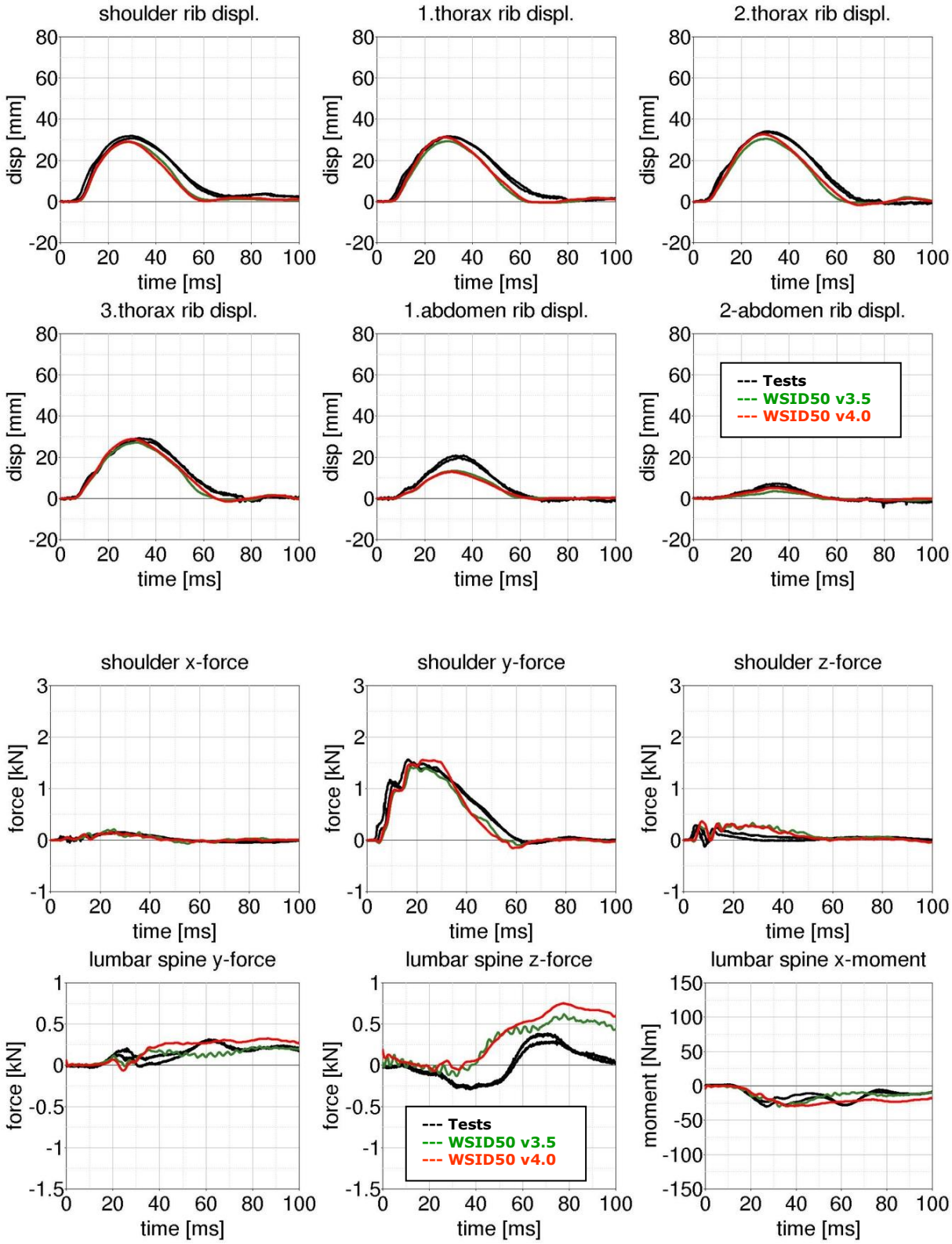
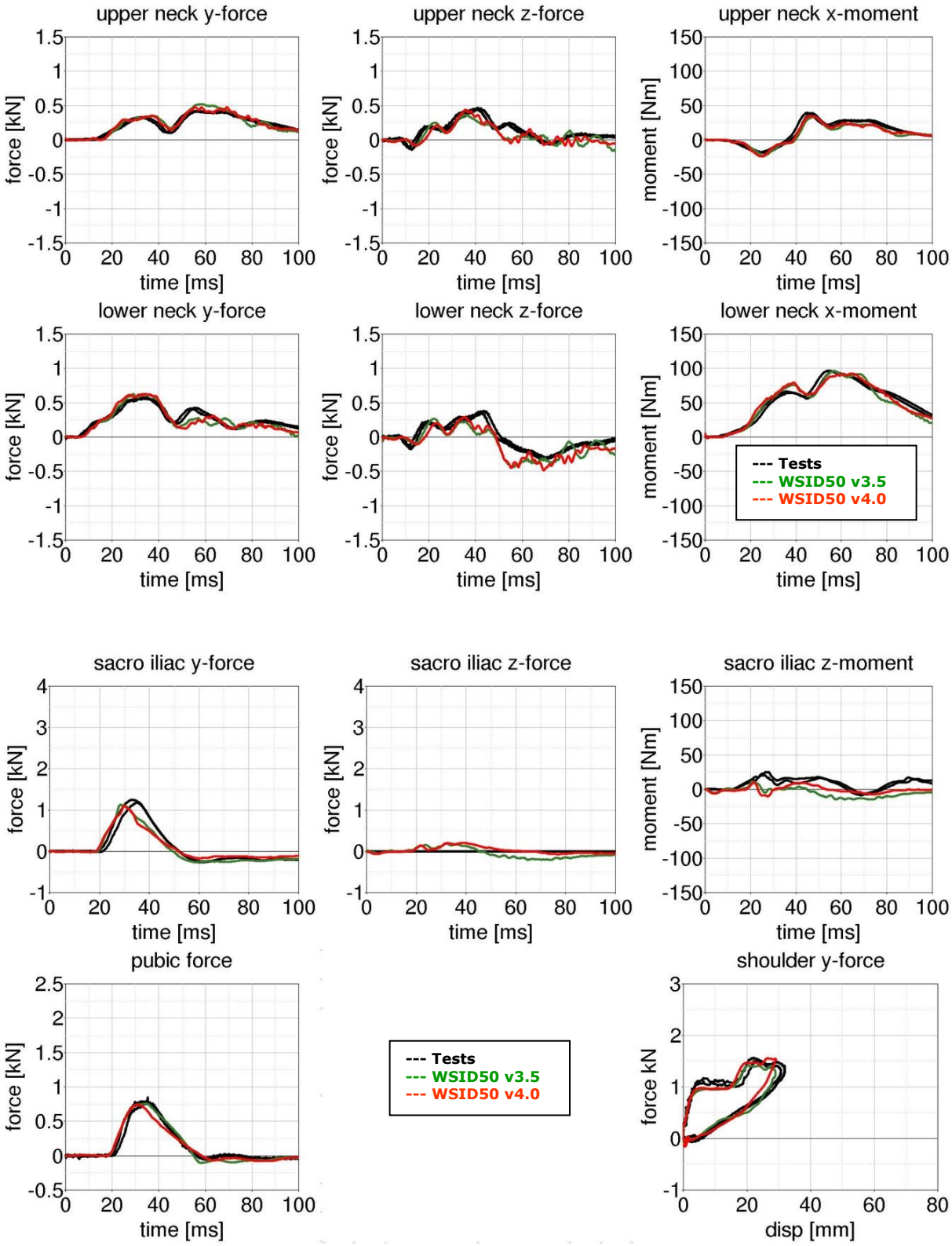


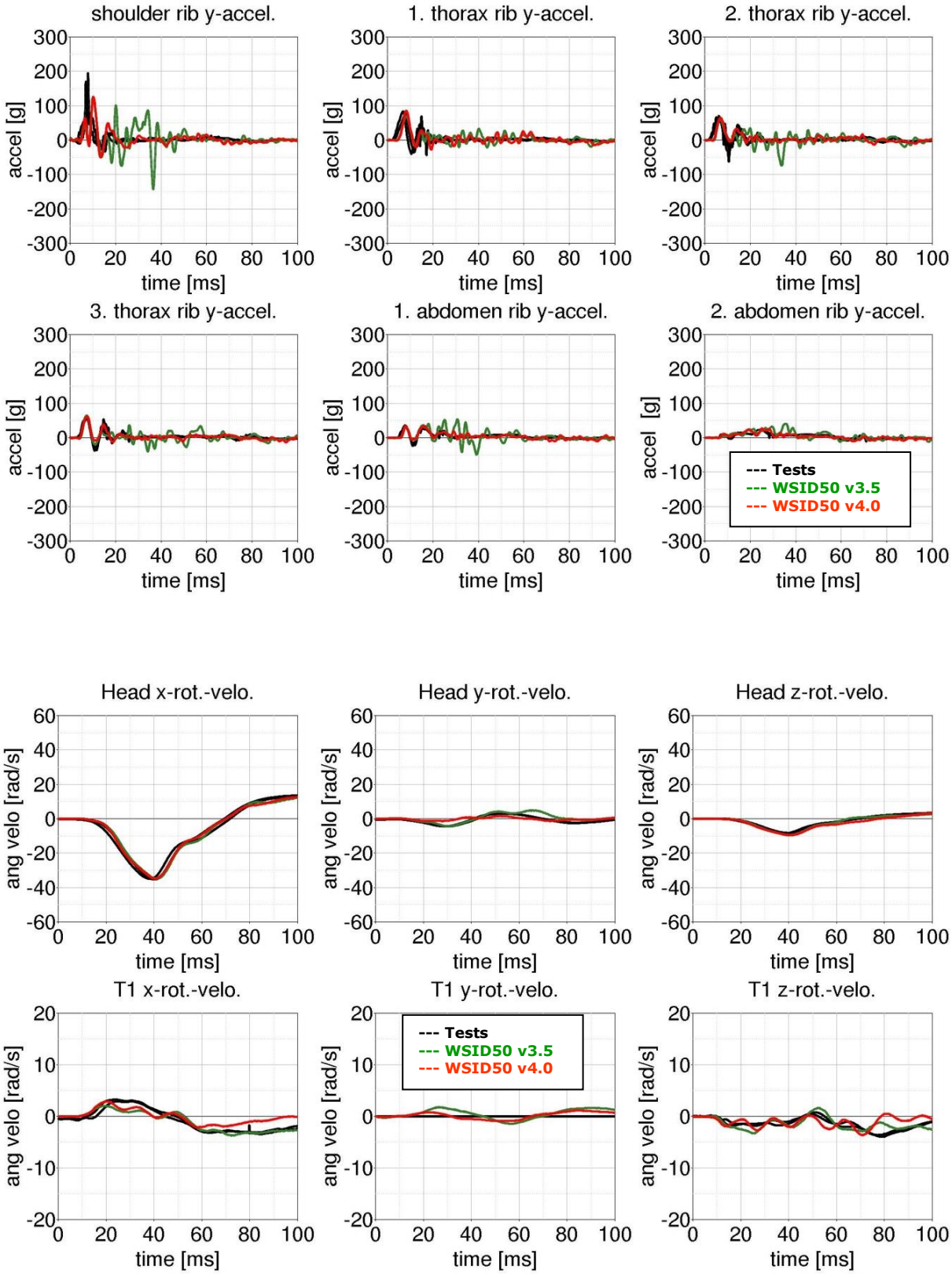
Figure 151: Flat barrier and arm first notch.

Low velocities:

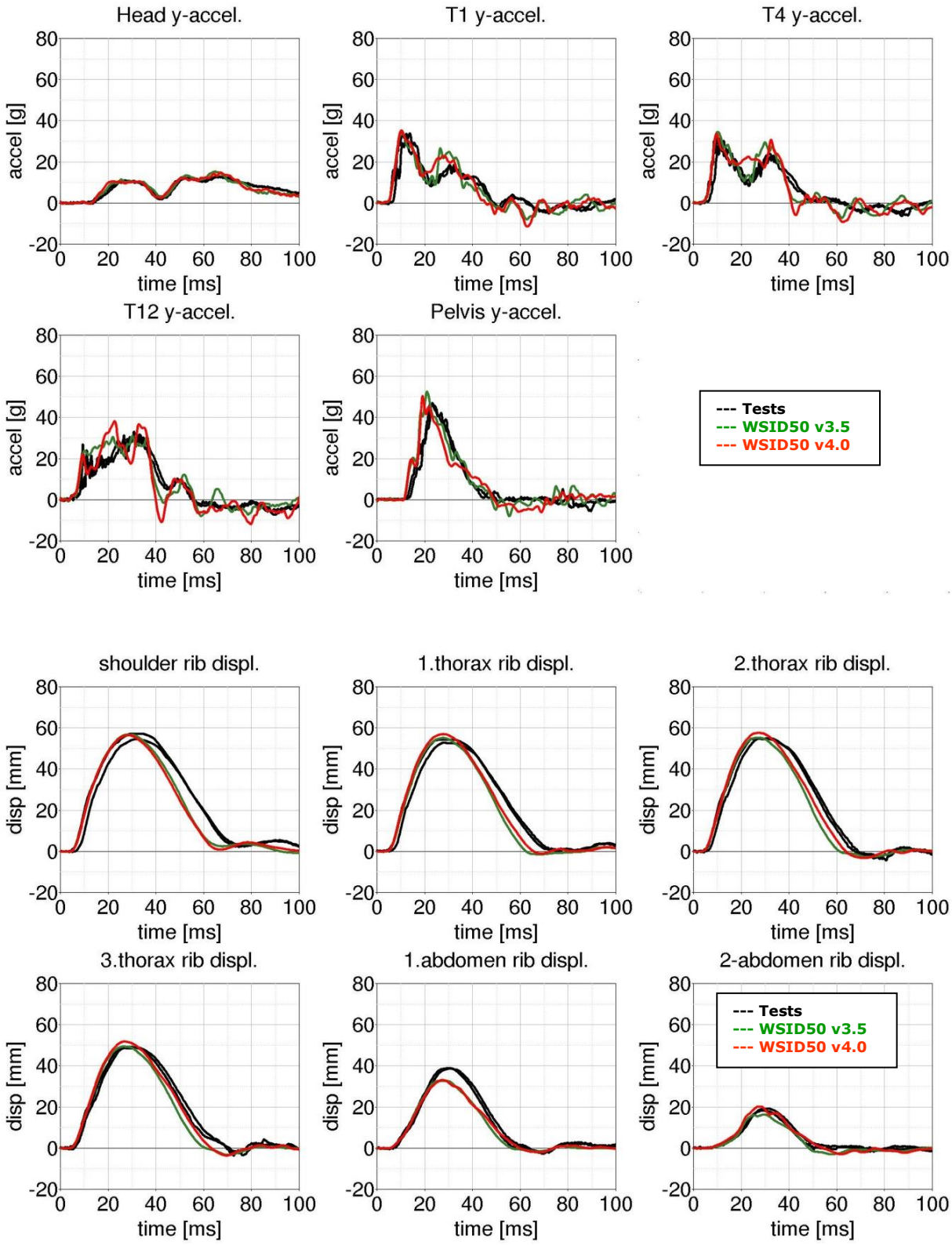


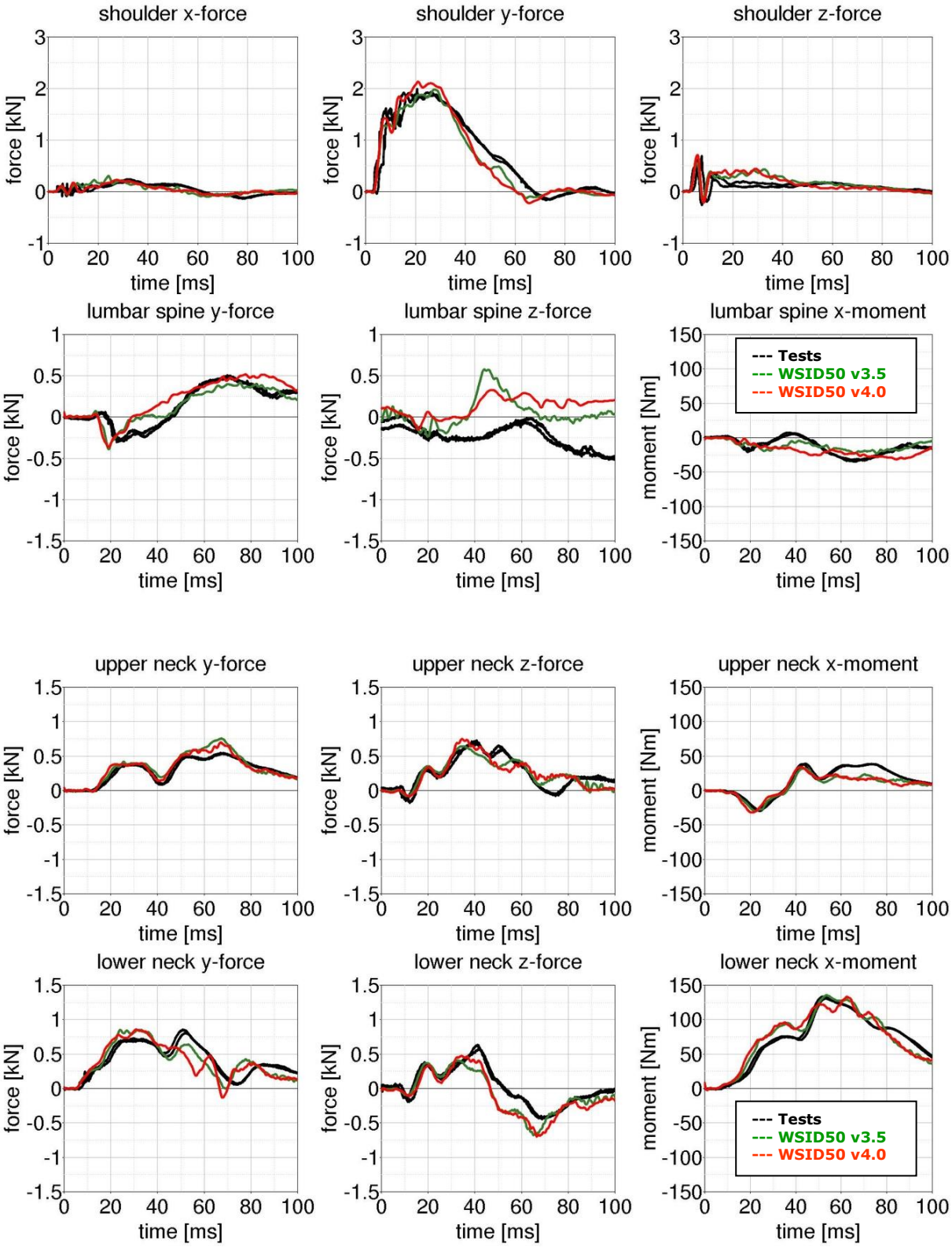

shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
disp [mm]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder x-force
shoulder y-force
shoulder z-force
force [kN]
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
moment [Nm]

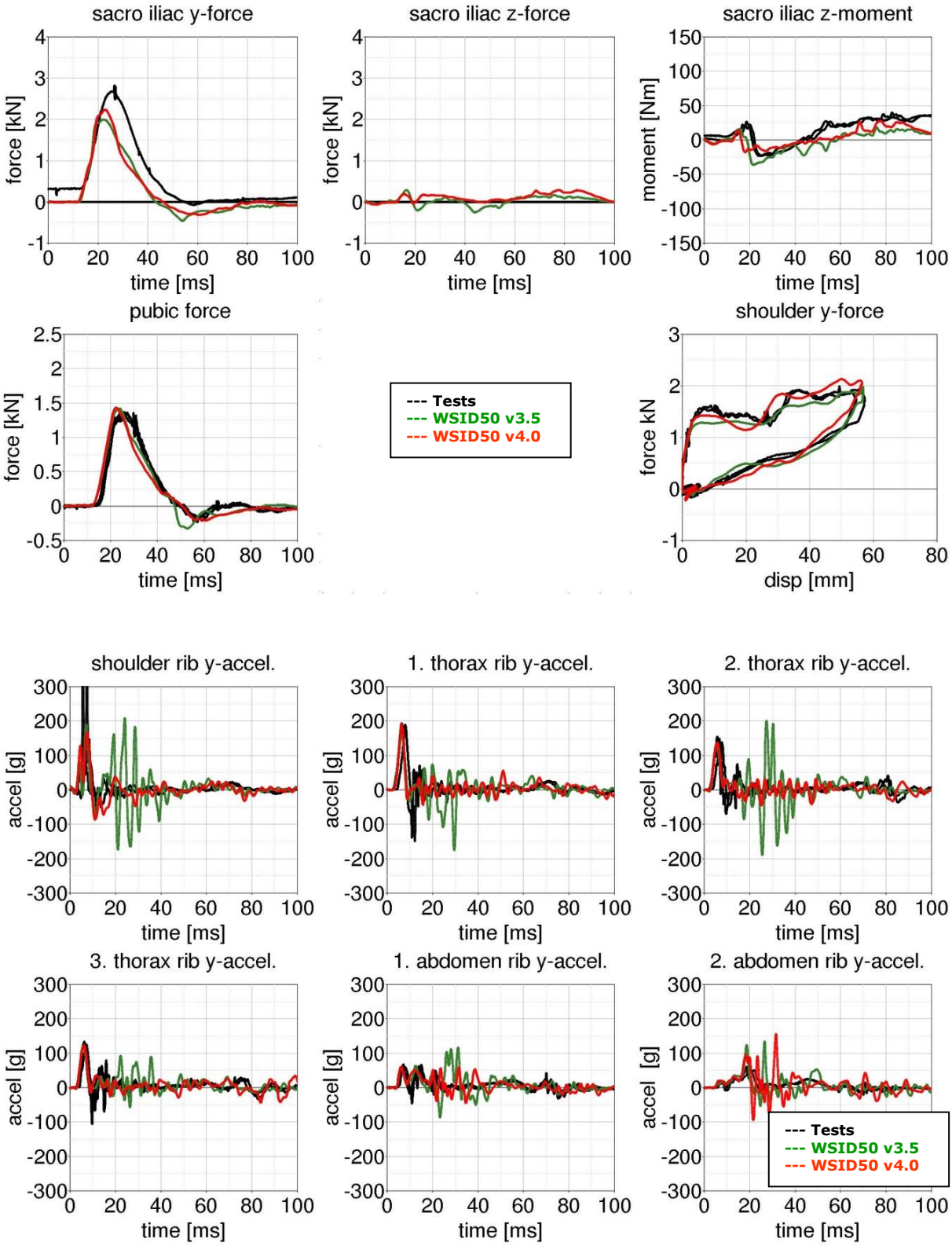

upper neck y-force
force [kN]
time [ms]
upper neck z-force
force [kN]
time [ms]
upper neck x-moment
moment [Nm]
time [ms]
lower neck y-force
force [kN]
time [ms]
lower neck z-force
force [kN]
time [ms]
lower neck x-moment
moment [Nm]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
sacro iliac y-force
force [kN]
time [ms]
sacro iliac z-force
force [kN]
time [ms]
sacro iliac z-moment
moment [Nm]
time [ms]
pubic force
force [kN]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder y-force
force kN
disp [mm]

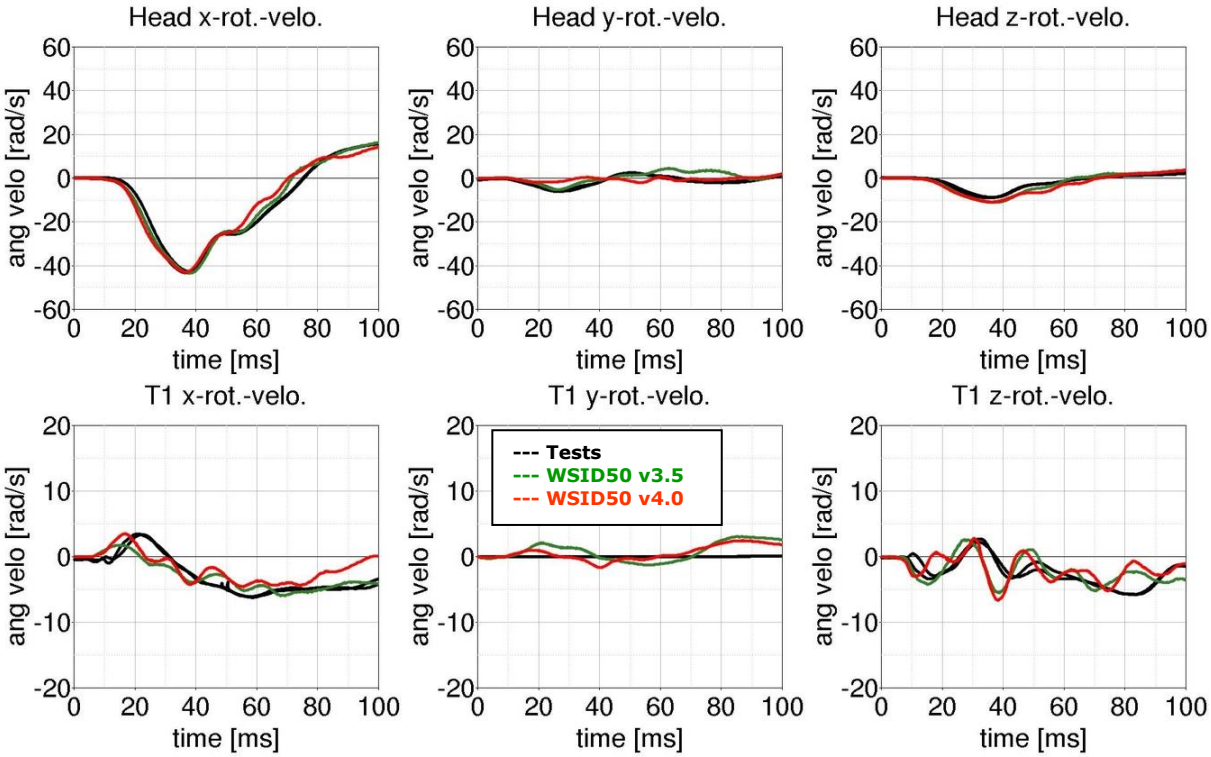

shoulder rib y-accel.
1. thorax rib y-accel.
2. thorax rib y-accel.
3. thorax rib y-accel.
1. abdomen rib y-accel.
2. abdomen rib y-accel.
accel [g]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
Head x-rot.-velo.
Head y-rot.-velo.
Head z-rot.-velo.
T1 x-rot.-velo.
T1 y-rot.-velo.
T1 z-rot.-velo.
ang velo [rad/s]

High velocity:




shoulder x-force
shoulder y-force
shoulder z-force
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
upper neck y-force
upper neck z-force
upper neck x-moment
lower neck y-force
lower neck z-force
lower neck x-moment
force [kN]
moment [Nm]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0


sacro iliac y-force
force [kN]
time [ms]
sacro iliac z-force
force [kN]
time [ms]
sacro iliac z-moment
moment [Nm]
time [ms]
pubic force
force [kN]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder y-force
force kN
disp [mm]
shoulder rib y-accel.
accel [g]
time [ms]
1. thorax rib y-accel.
accel [g]
time [ms]
2. thorax rib y-accel.
accel [g]
time [ms]
3. thorax rib y-accel.
accel [g]
time [ms]
1. abdomen rib y-accel.
accel [g]
time [ms]
2. abdomen rib y-accel.
accel [g]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0


Head x-rot.-velo.
Head y-rot.-velo.
Head z-rot.-velo.
T1 x-rot.-velo.
T1 y-rot.-velo.
T1 z-rot.-velo.
ang velo [rad/s]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0

Pelvis shape barrier

8.3.1.2 Arm position second notch

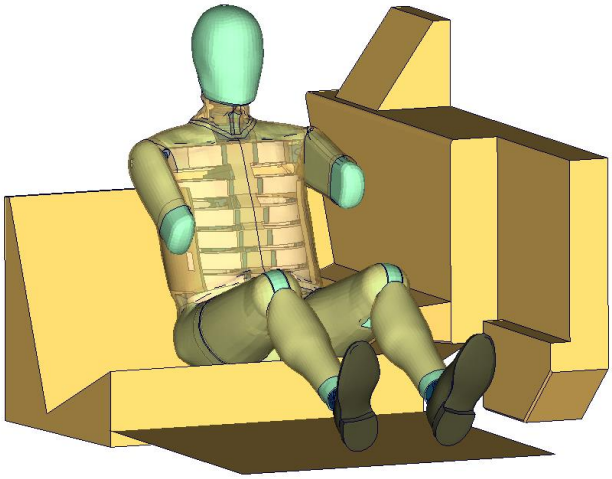
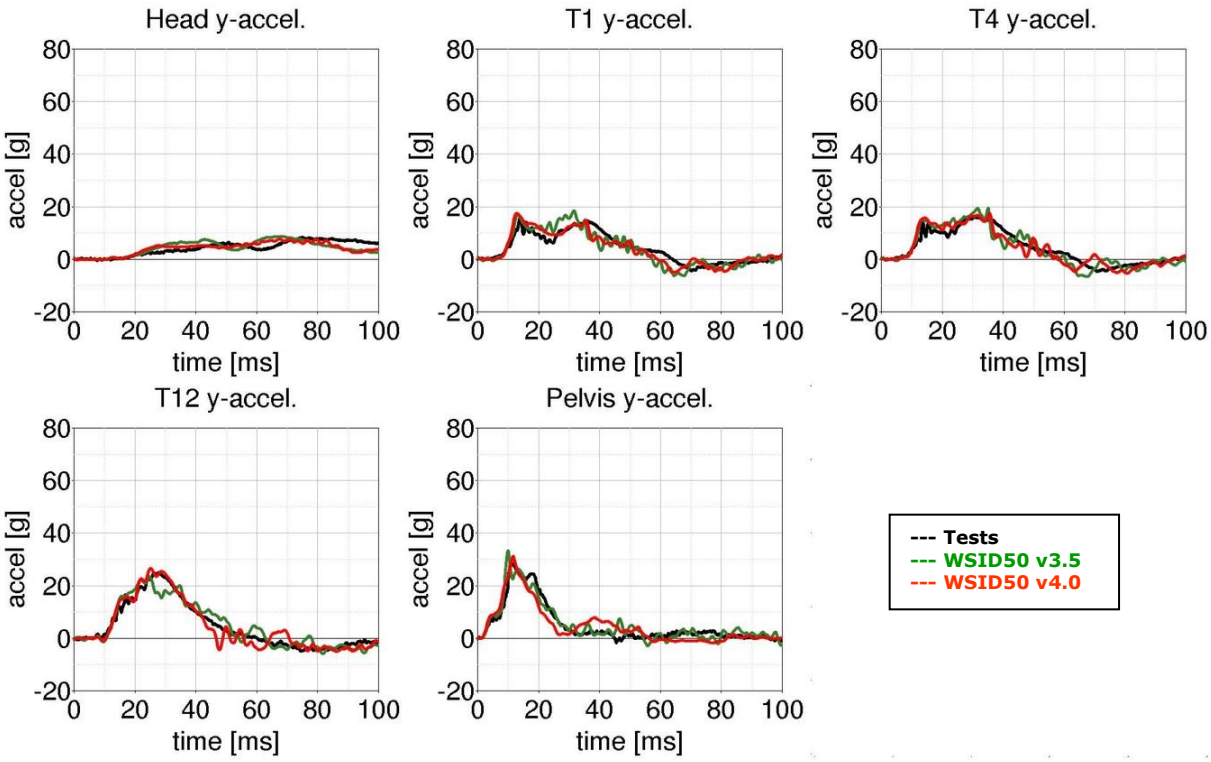
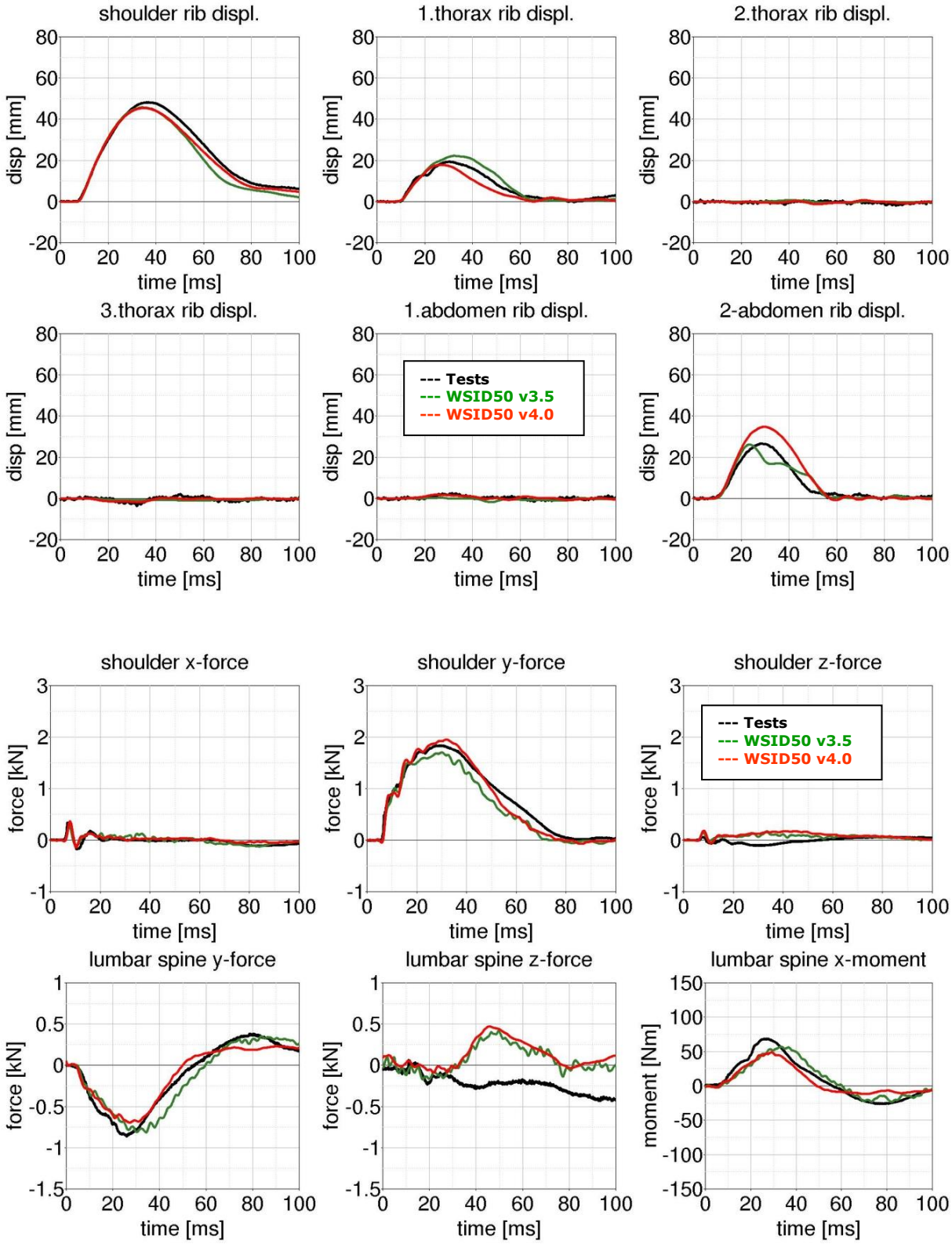
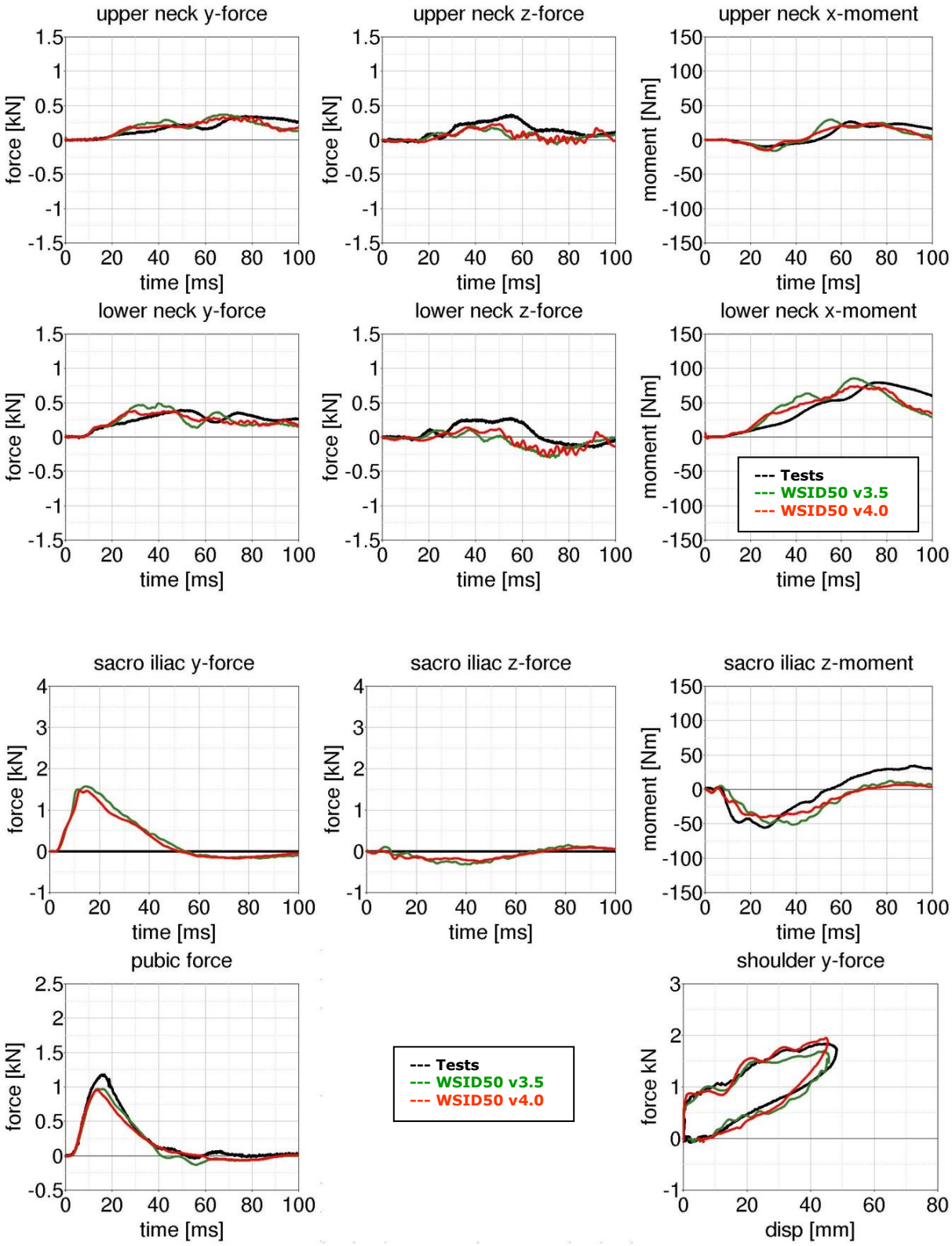


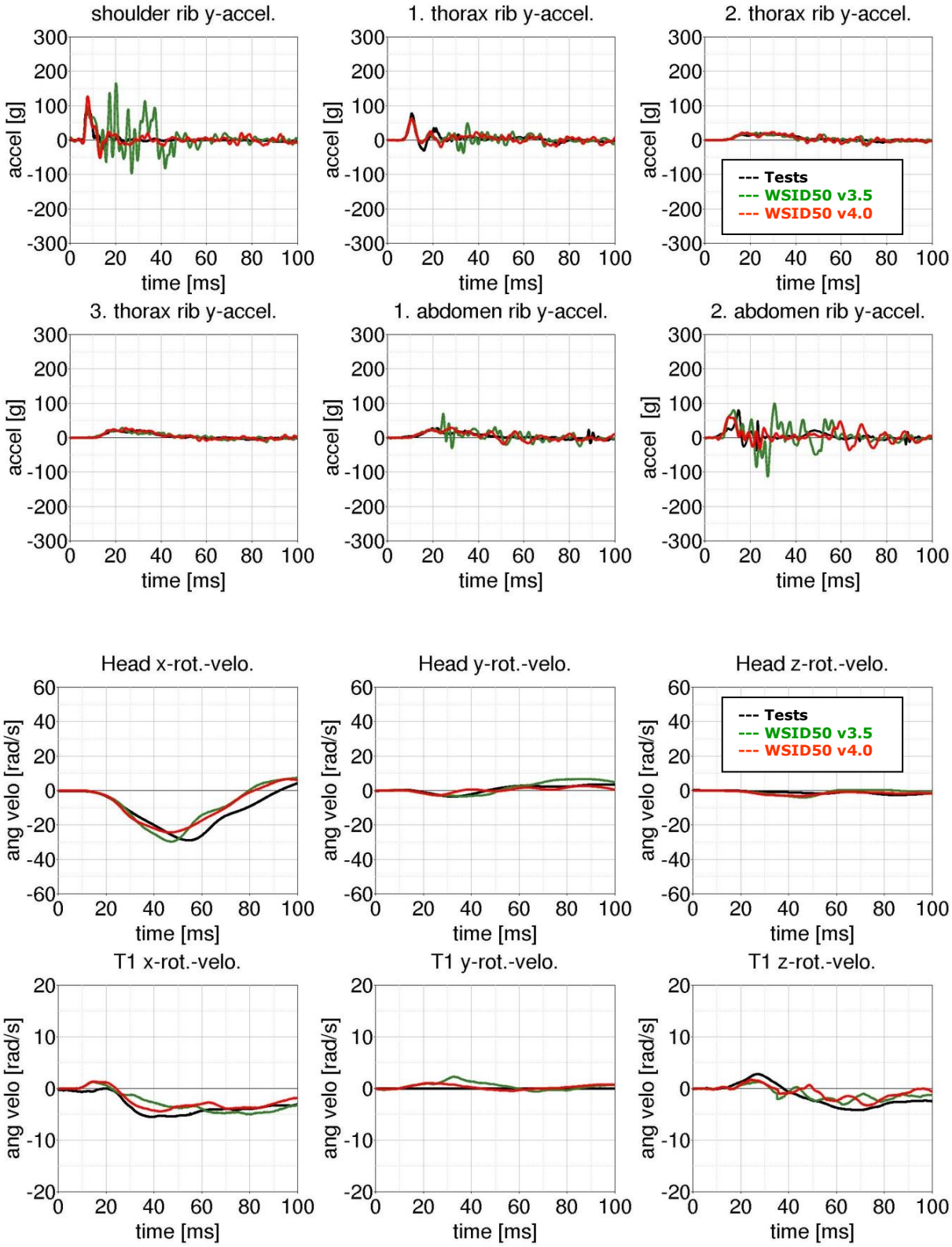
Figure 152: Pelvis barrier and arm second notch.

Low velocity:




shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
disp [mm]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder x-force
shoulder y-force
shoulder z-force
force [kN]
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
moment [Nm]


upper neck y-force
upper neck z-force
upper neck x-moment
lower neck y-force
lower neck z-force
lower neck x-moment
sacro iliac y-force
sacro iliac z-force
sacro iliac z-moment
pubic force
shoulder y-force
force [kN]
moment [Nm]
force kN
time [ms]
disp [mm]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0


shoulder rib y-accel.
1. thorax rib y-accel.
2. thorax rib y-accel.
3. thorax rib y-accel.
1. abdomen rib y-accel.
2. abdomen rib y-accel.
Head x-rot.-velo.
Head y-rot.-velo.
Head z-rot.-velo.
T1 x-rot.-velo.
T1 y-rot.-velo.
T1 z-rot.-velo.
accel [g]
ang velo [rad/s]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0

8.3.1.3 Arm position first notch

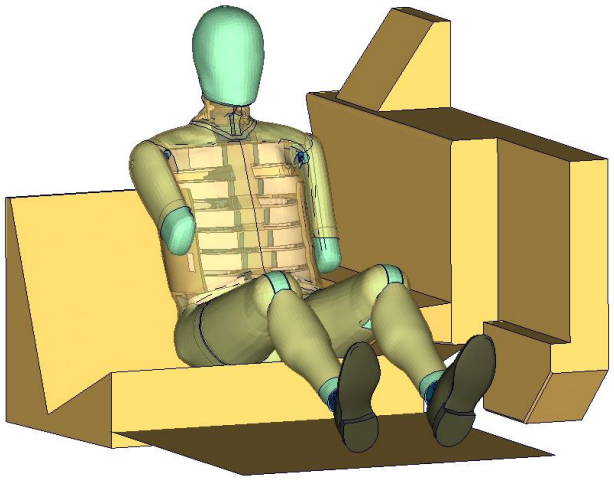
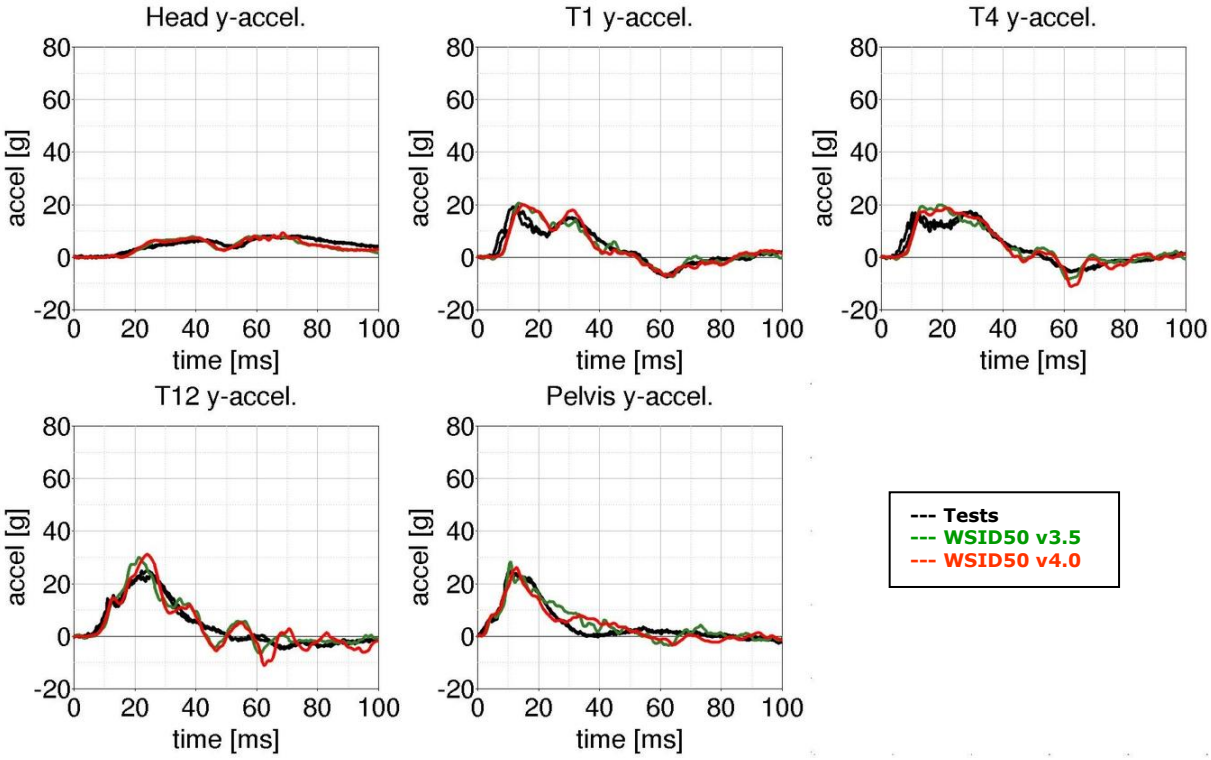
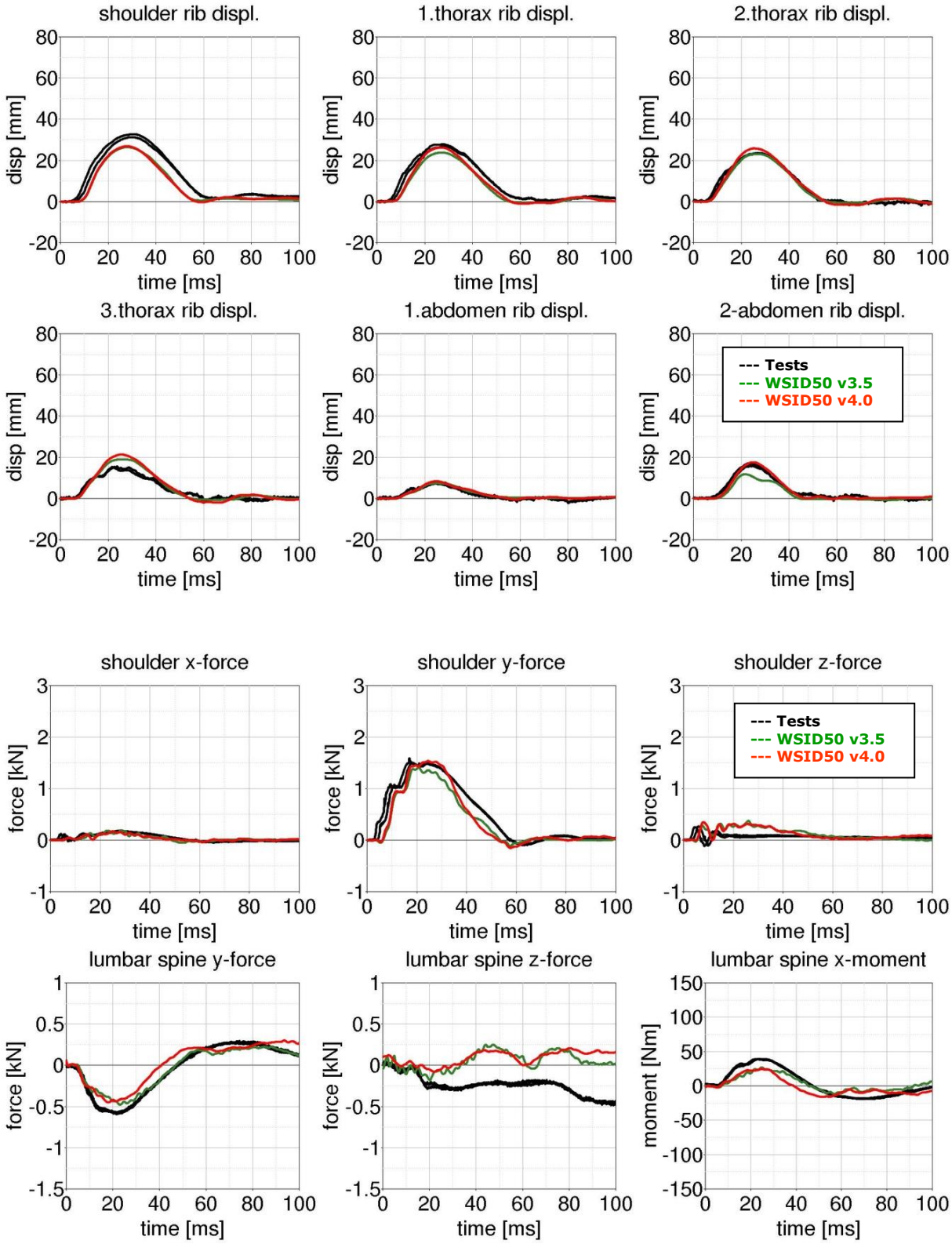
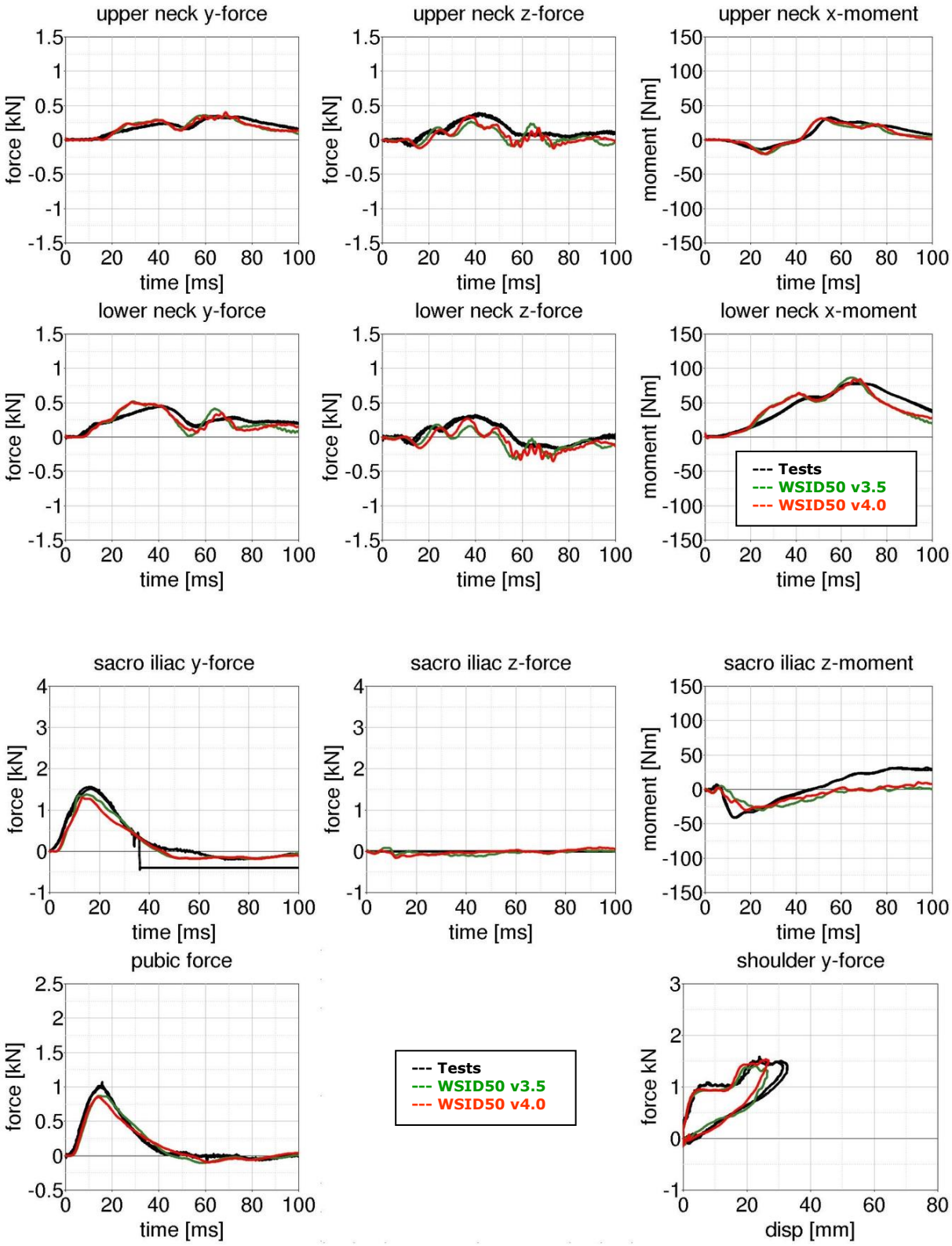


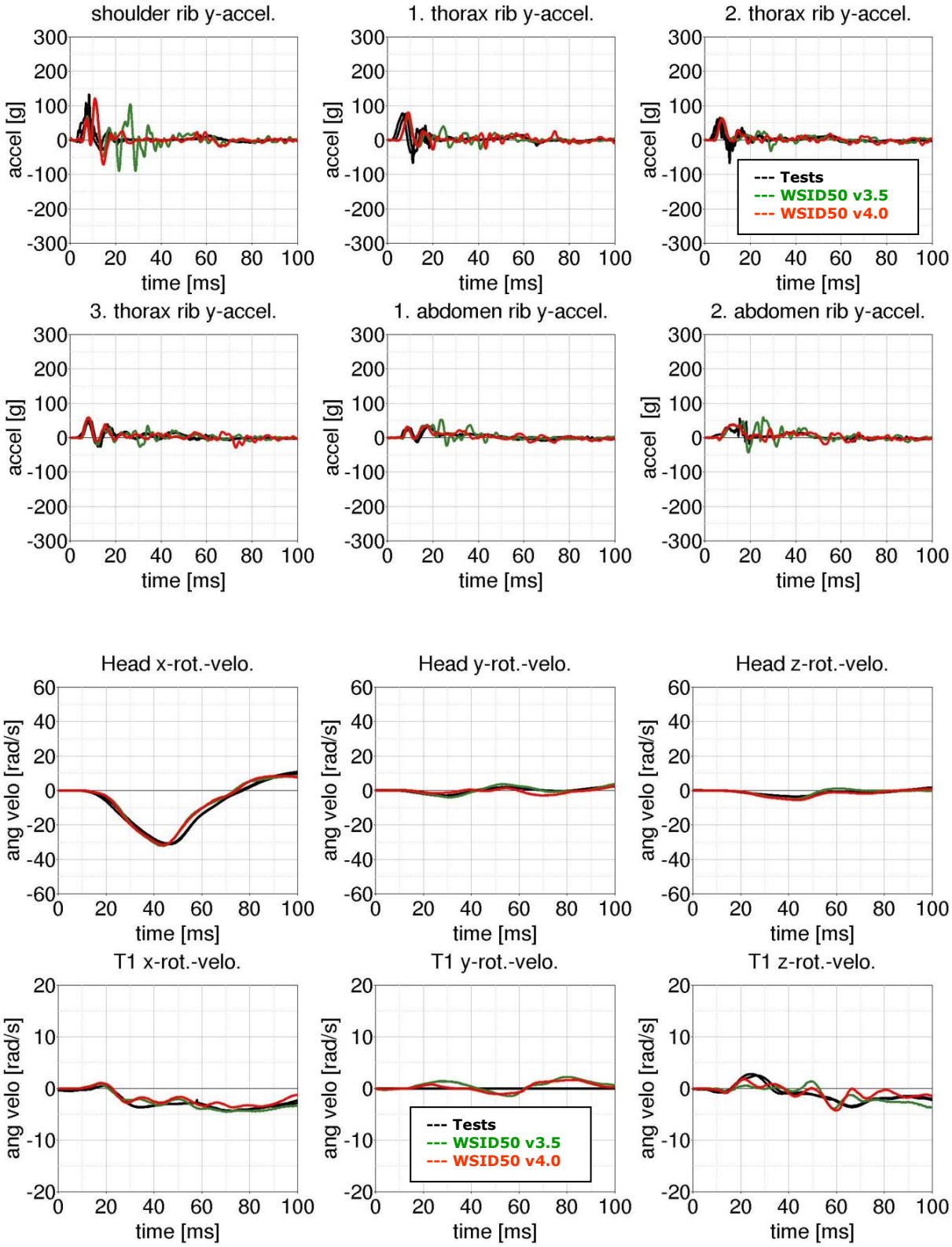
Figure 153: Pelvis barrier and arm first notch.

Low velocity:

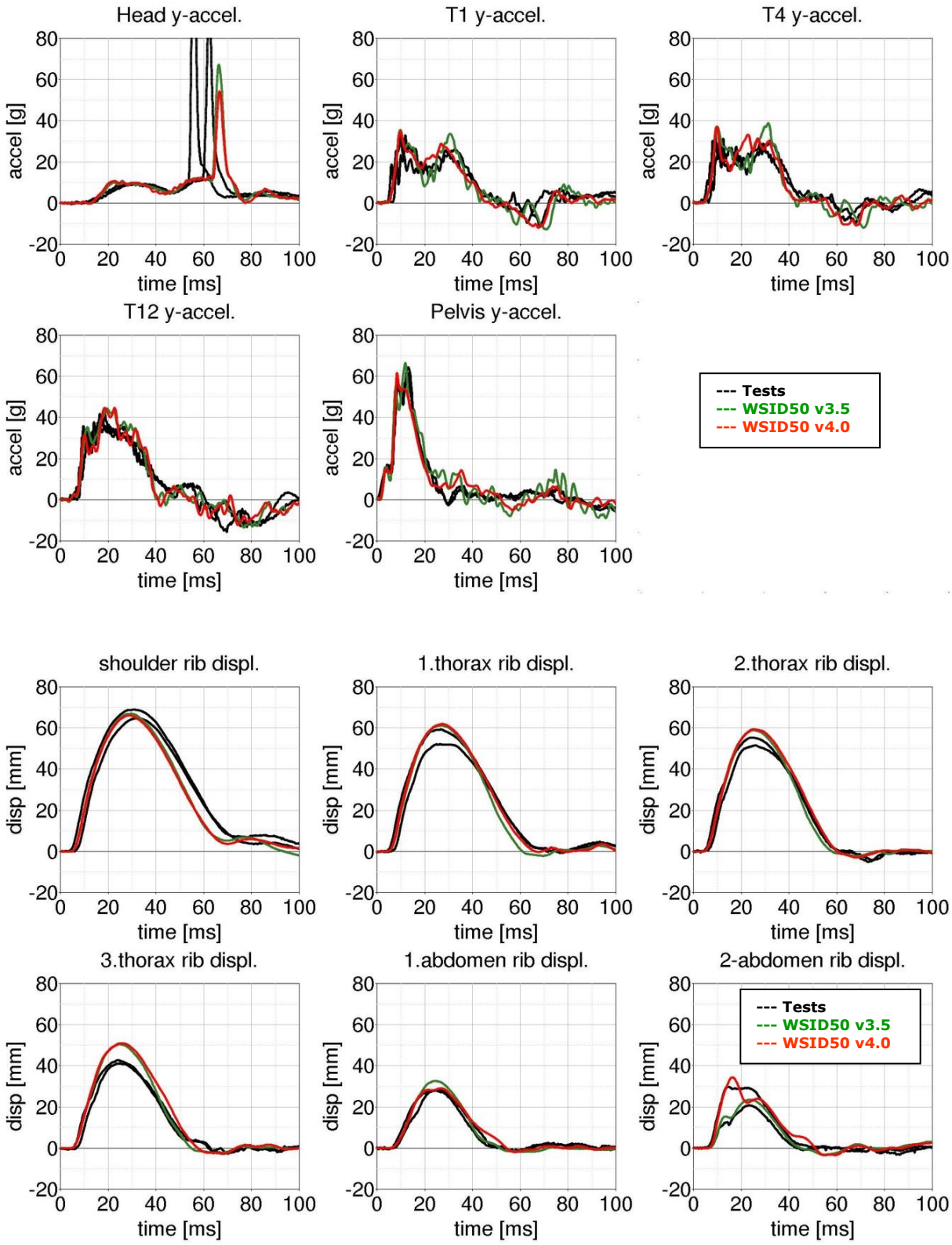


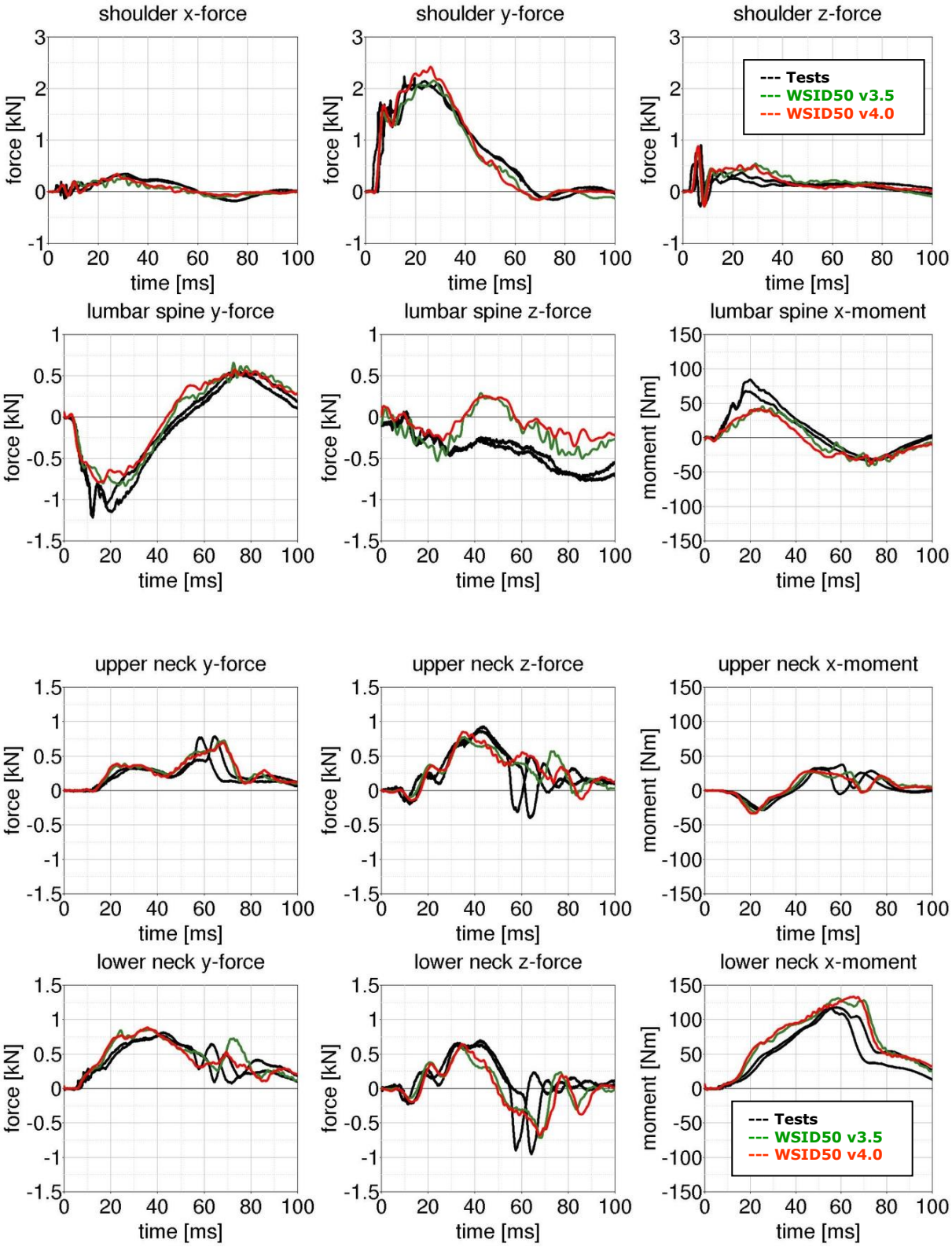

shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
disp [mm]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder x-force
shoulder y-force
shoulder z-force
force [kN]
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
moment [Nm]

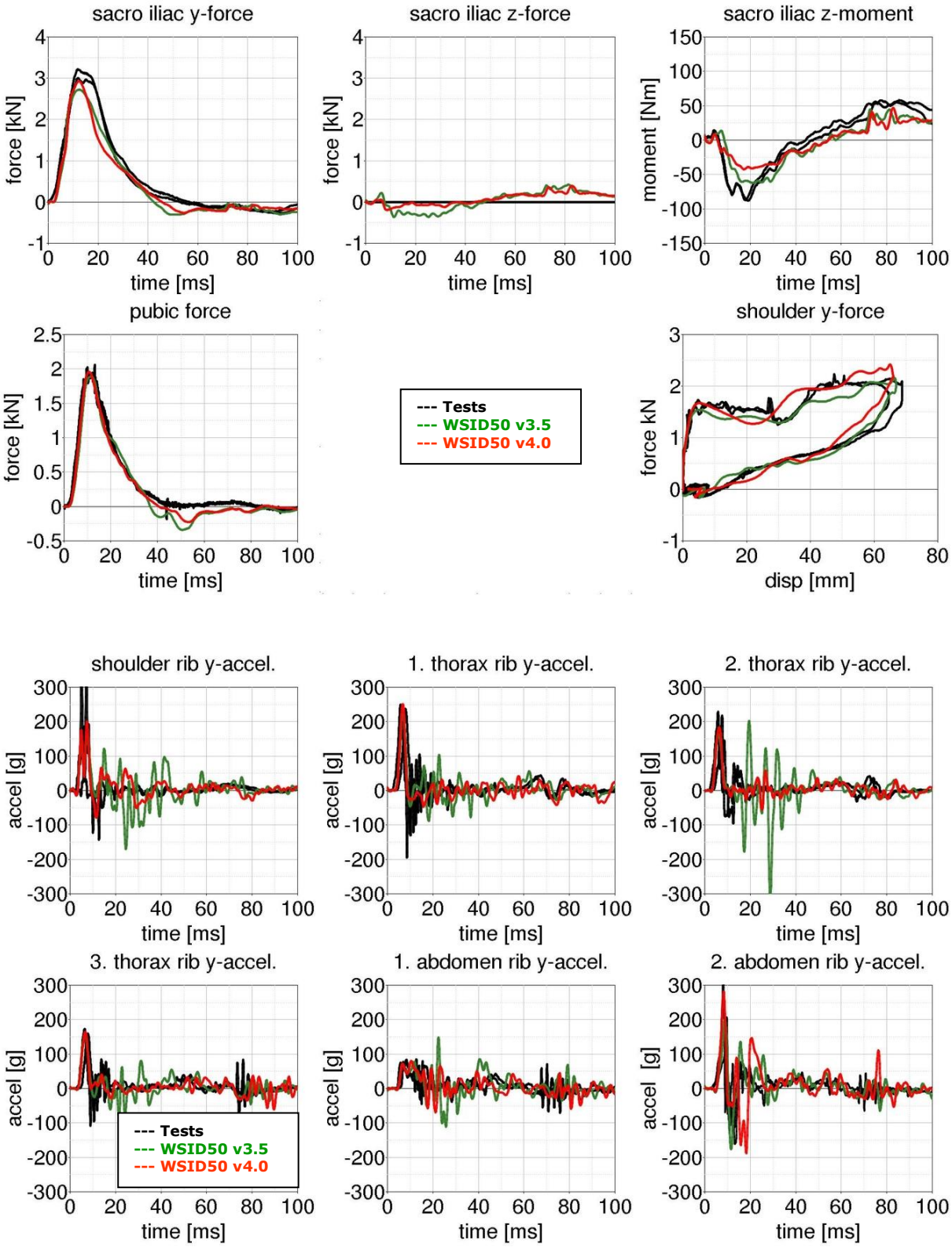

upper neck y-force
force [kN]
time [ms]
upper neck z-force
force [kN]
time [ms]
upper neck x-moment
moment [Nm]
time [ms]
lower neck y-force
force [kN]
time [ms]
lower neck z-force
force [kN]
time [ms]
lower neck x-moment
moment [Nm]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
sacro iliac y-force
force [kN]
time [ms]
sacro iliac z-force
force [kN]
time [ms]
sacro iliac z-moment
moment [Nm]
time [ms]
pubic force
force [kN]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder y-force
force kN
disp [mm]

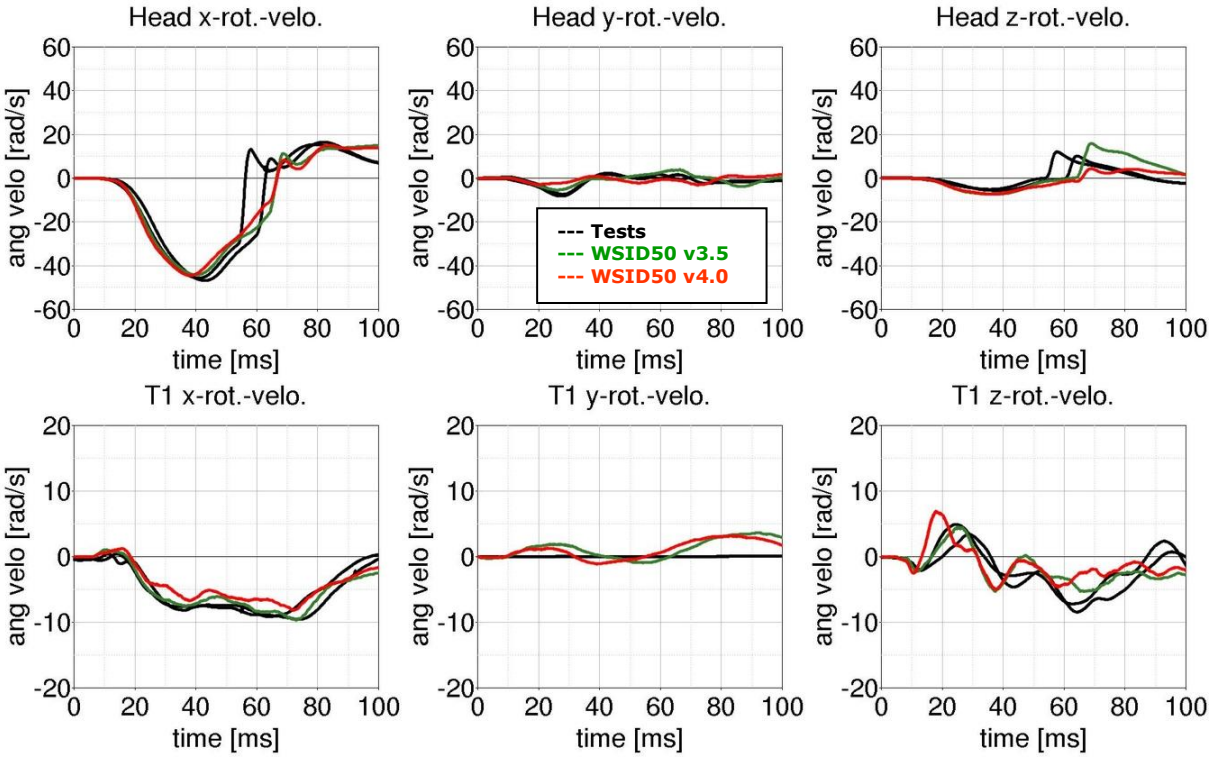

shoulder rib y-accel.
1. thorax rib y-accel.
2. thorax rib y-accel.
3. thorax rib y-accel.
1. abdomen rib y-accel.
2. abdomen rib y-accel.
accel [g]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
Head x-rot.-velo.
Head y-rot.-velo.
Head z-rot.-velo.
T1 x-rot.-velo.
T1 y-rot.-velo.
T1 z-rot.-velo.
ang velo [rad/s]

High velocity:




shoulder x-force
shoulder y-force
shoulder z-force
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
upper neck y-force
upper neck z-force
upper neck x-moment
lower neck y-force
lower neck z-force
lower neck x-moment
force [kN]
moment [Nm]
time [ms]


sacro iliac y-force
force [kN]
time [ms]
sacro iliac z-force
force [kN]
time [ms]
sacro iliac z-moment
moment [Nm]
time [ms]
pubic force
force [kN]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder y-force
force kN
disp [mm]
shoulder rib y-accel.
accel [g]
time [ms]
1. thorax rib y-accel.
accel [g]
time [ms]
2. thorax rib y-accel.
accel [g]
time [ms]
3. thorax rib y-accel.
accel [g]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
1. abdomen rib y-accel.
accel [g]
time [ms]
2. abdomen rib y-accel.
accel [g]
time [ms]


Head x-rot.-velo.
Head y-rot.-velo.
Head z-rot.-velo.
T1 x-rot.-velo.
T1 y-rot.-velo.
T1 z-rot.-velo.
ang velo [rad/s]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0

Flat barrier and WorldSID without arm

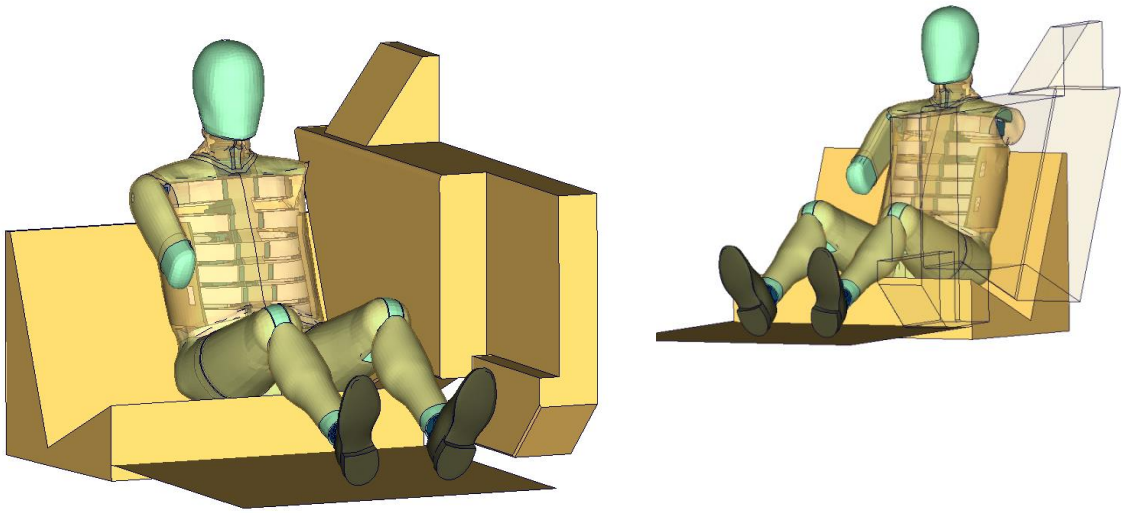
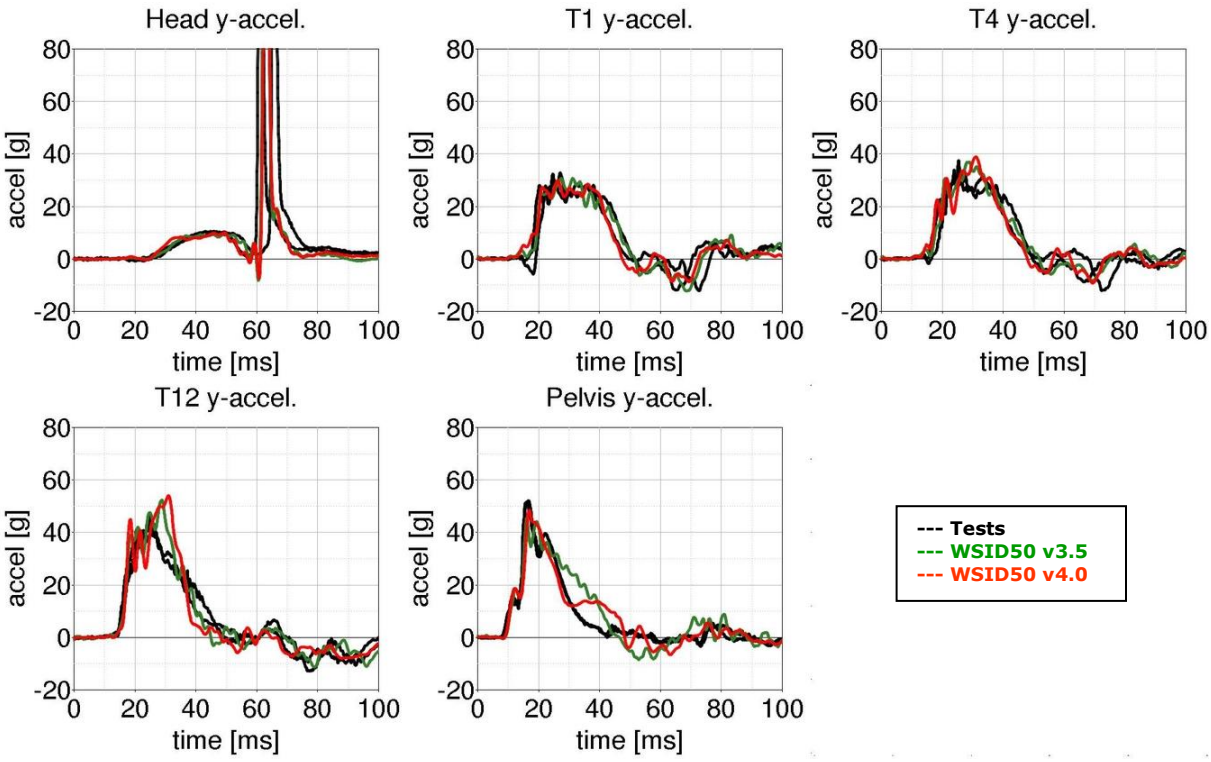
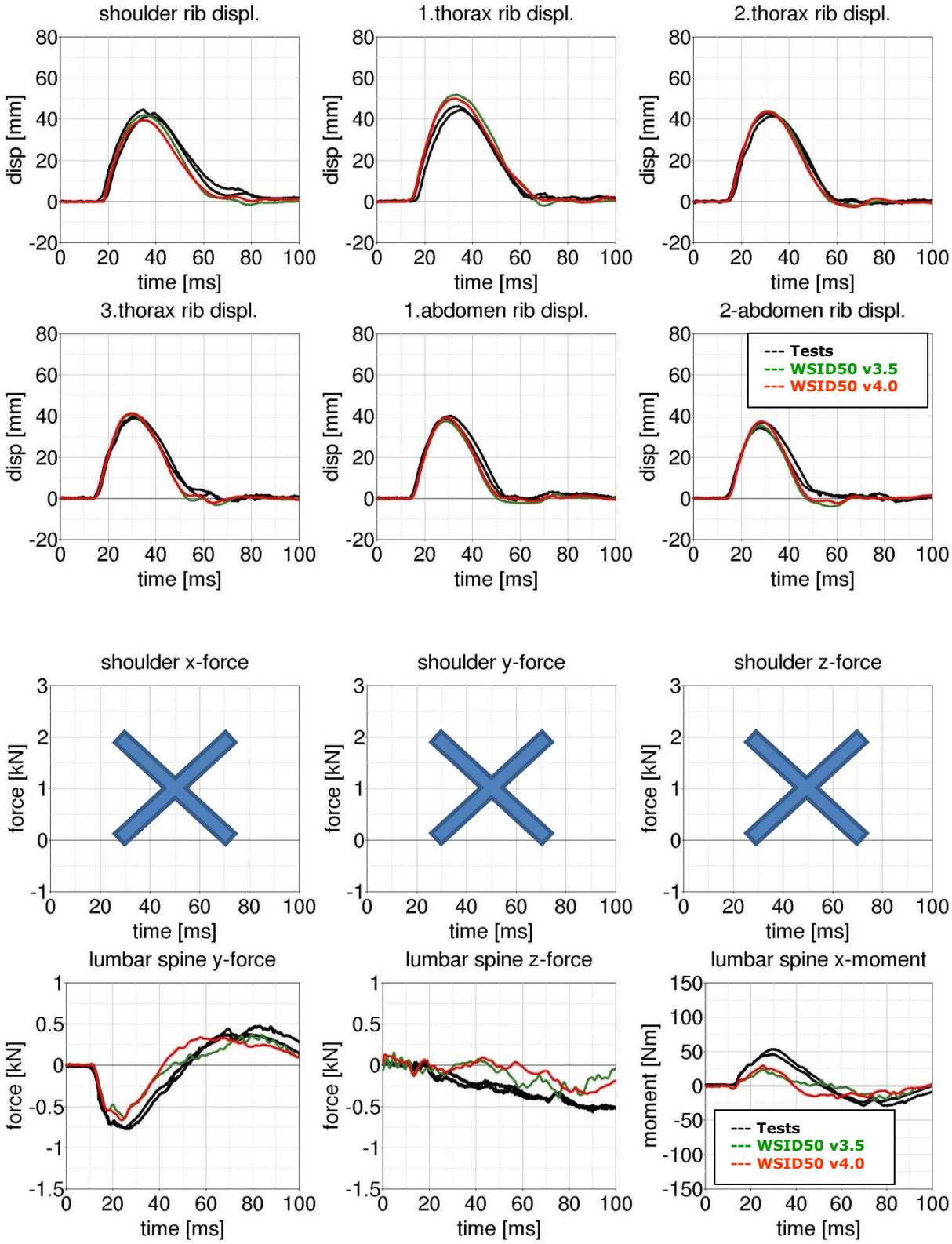
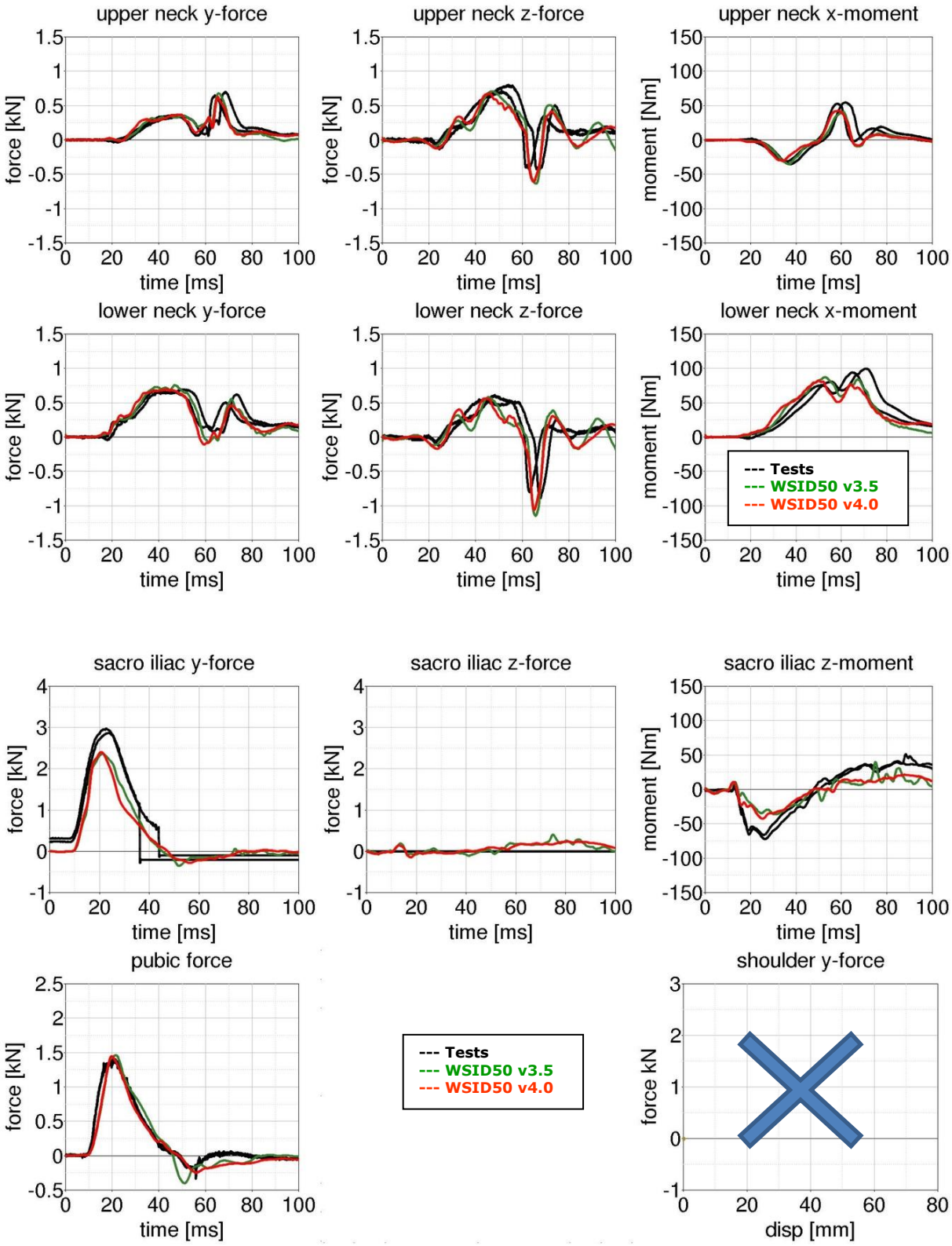


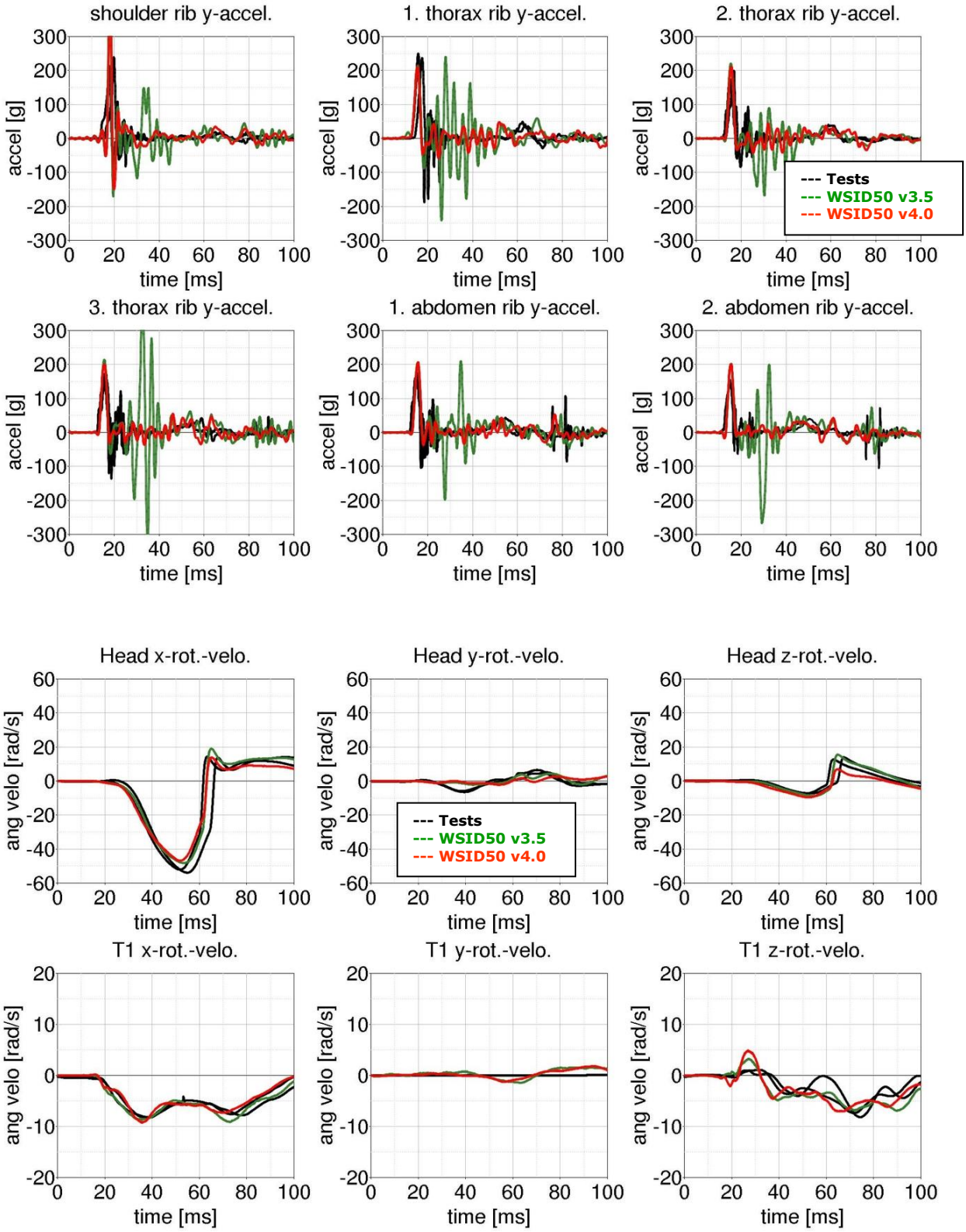
Figure 154: Flat barrier and without arm.

High velocity:




shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
disp [mm]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder x-force
shoulder y-force
shoulder z-force
force [kN]
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
moment [Nm]


upper neck y-force
force [kN]
time [ms]
upper neck z-force
force [kN]
time [ms]
upper neck x-moment
moment [Nm]
time [ms]
lower neck y-force
force [kN]
time [ms]
lower neck z-force
force [kN]
time [ms]
lower neck x-moment
moment [Nm]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
sacro iliac y-force
force [kN]
time [ms]
sacro iliac z-force
force [kN]
time [ms]
sacro iliac z-moment
moment [Nm]
time [ms]
pubic force
force [kN]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder y-force
force kN
disp [mm]


shoulder rib y-accel.
1. thorax rib y-accel.
2. thorax rib y-accel.
3. thorax rib y-accel.
1. abdomen rib y-accel.
2. abdomen rib y-accel.
accel [g]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
Head x-rot.-velo.
Head y-rot.-velo.
Head z-rot.-velo.
T1 x-rot.-velo.
T1 y-rot.-velo.
T1 z-rot.-velo.
ang velo [rad/s]

Pelvis shape barrier and WorldSID without Jacket

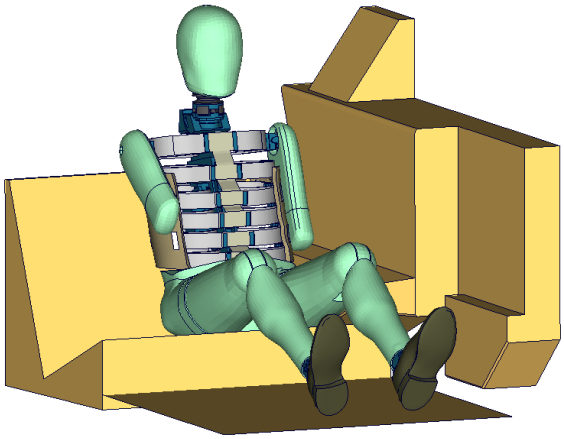
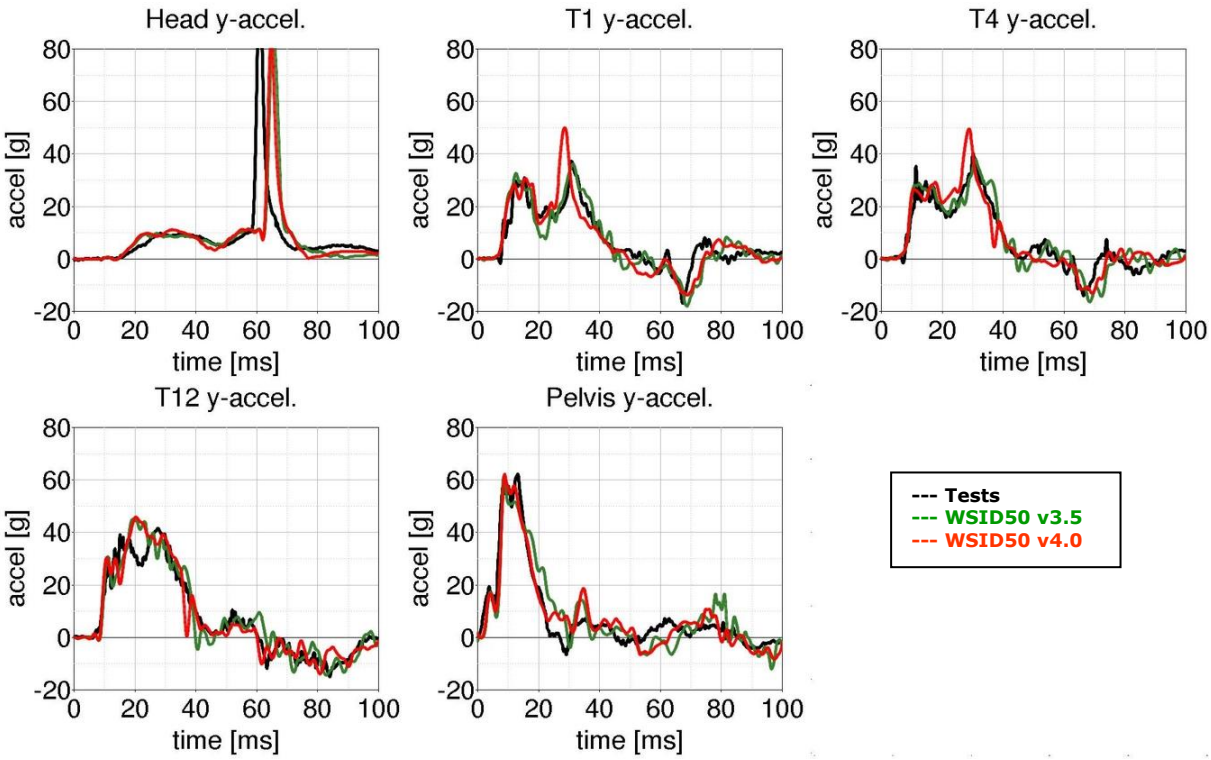
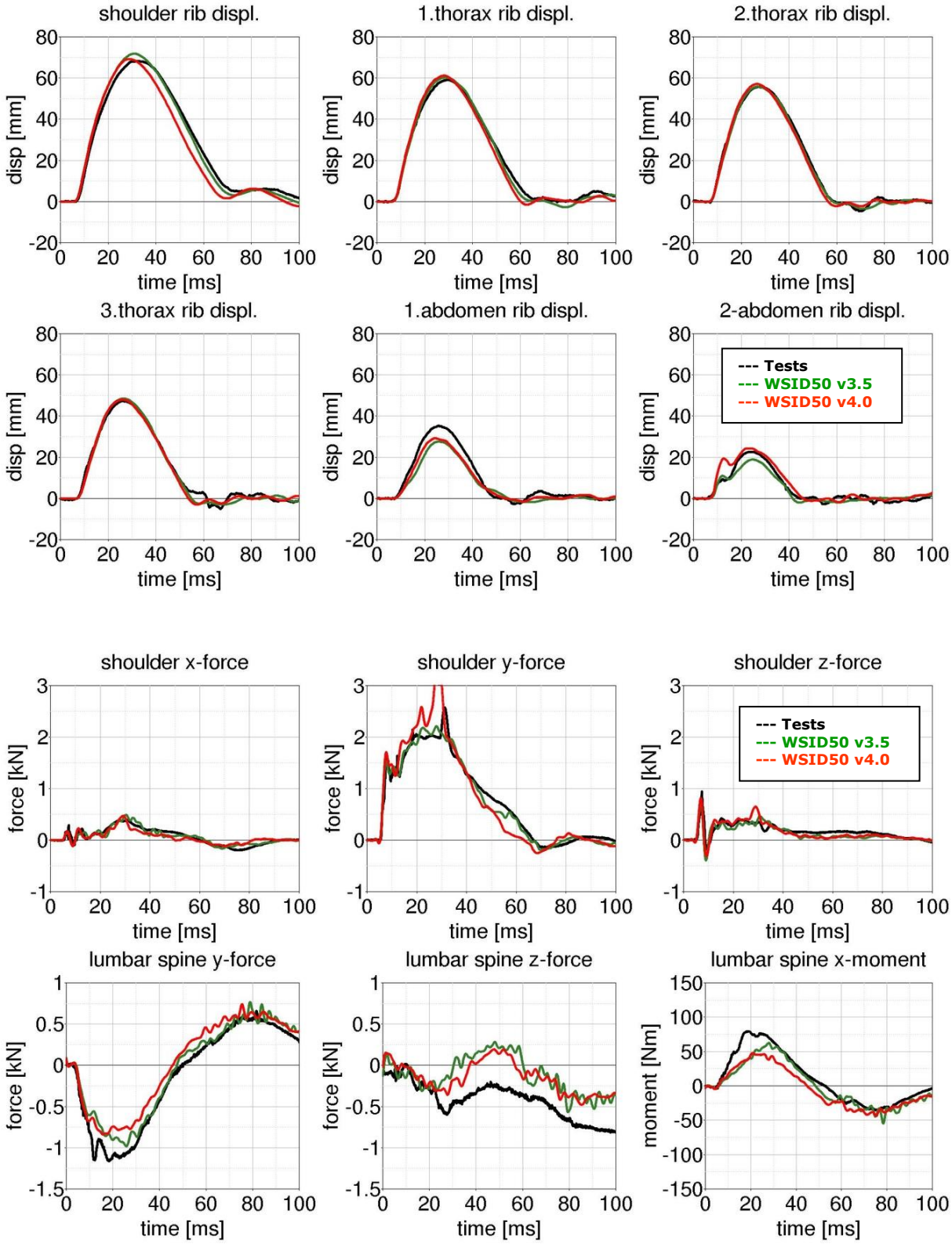
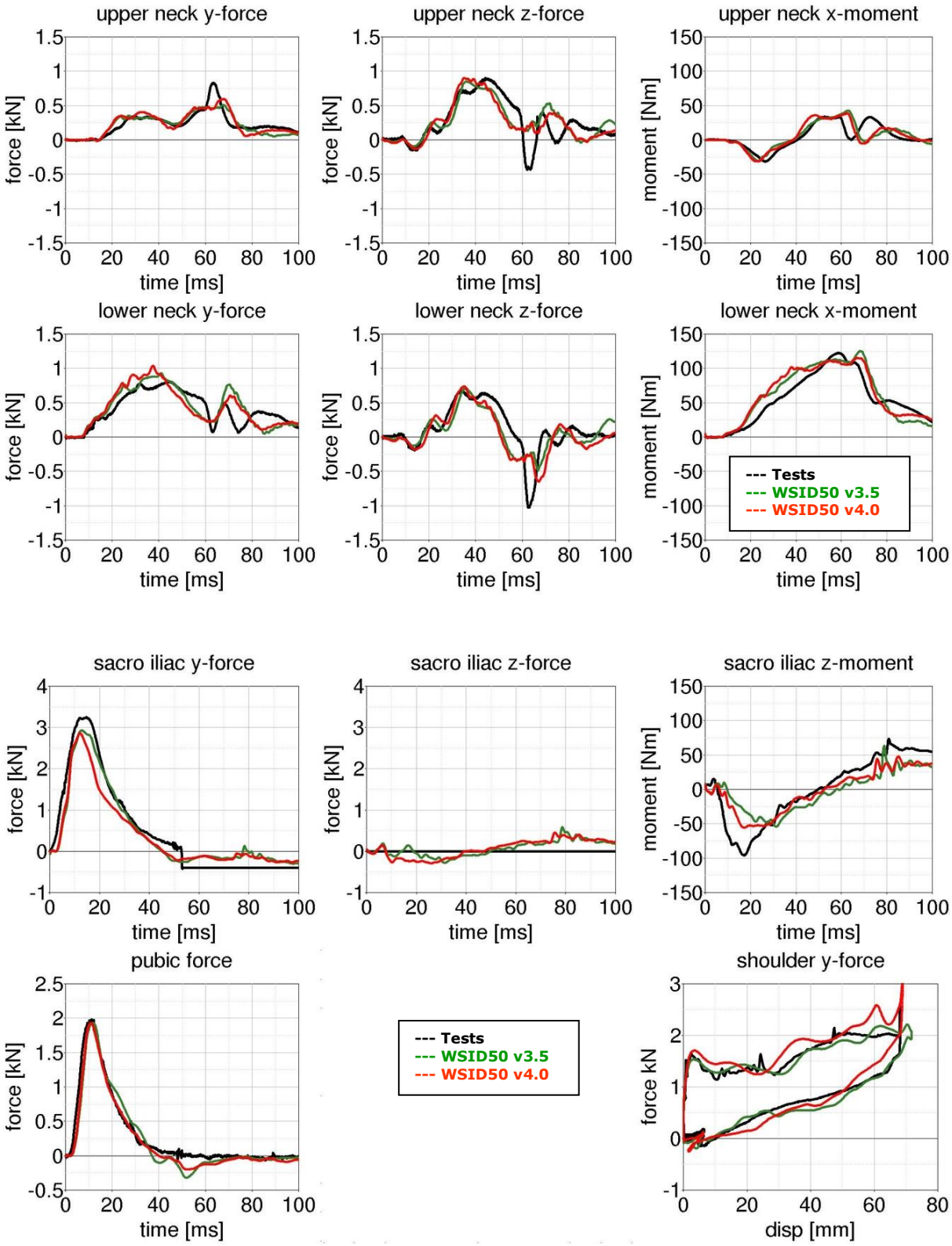


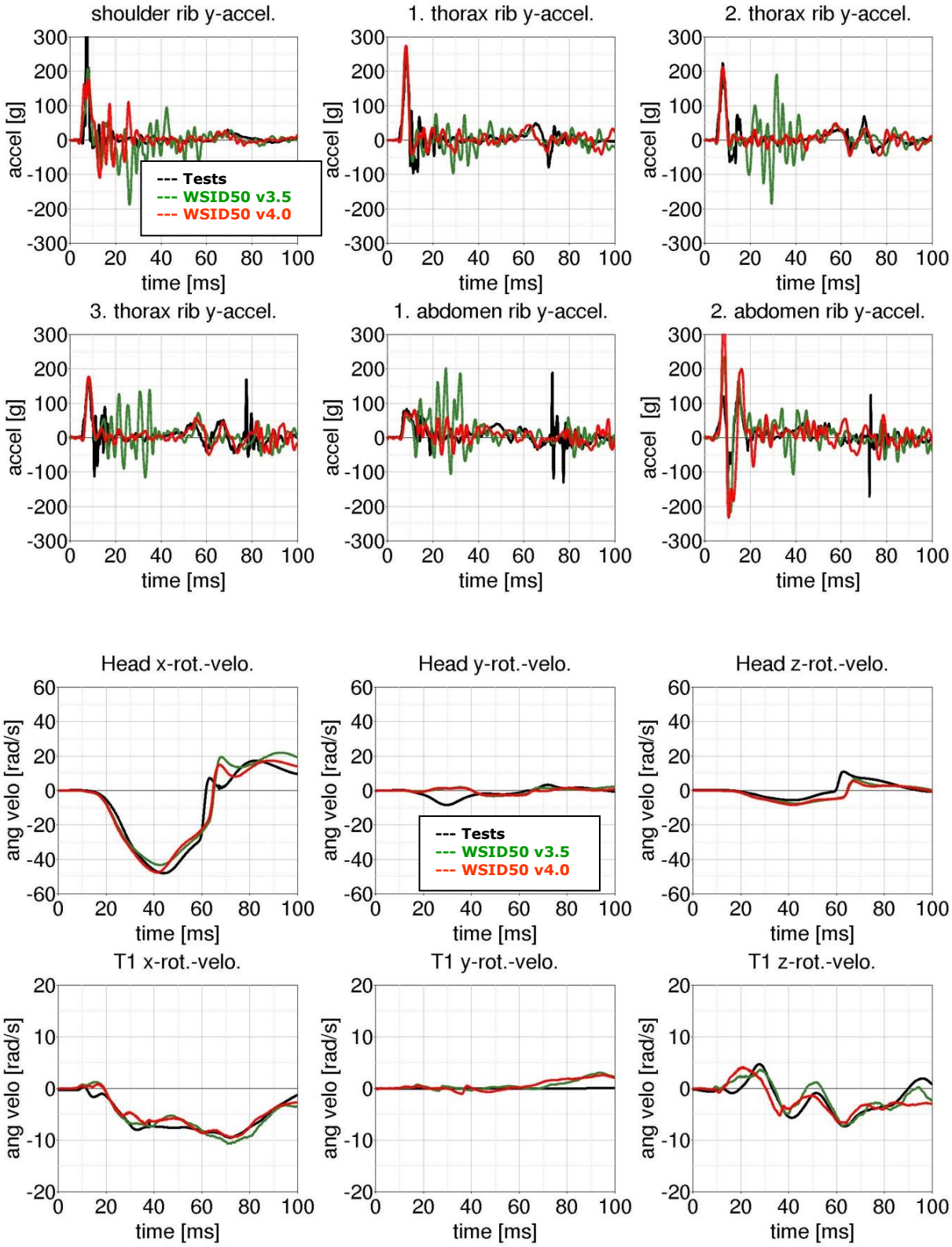
Figure 155: Pelvis barrier and arm first notch without jacket.

High velocity:




shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder x-force
shoulder y-force
shoulder z-force
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
disp [mm]
force [kN]
moment [Nm]
time [ms]


upper neck y-force
force [kN]
time [ms]
upper neck z-force
force [kN]
time [ms]
upper neck x-moment
moment [Nm]
time [ms]
lower neck y-force
force [kN]
time [ms]
lower neck z-force
force [kN]
time [ms]
lower neck x-moment
moment [Nm]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
sacro iliac y-force
force [kN]
time [ms]
sacro iliac z-force
force [kN]
time [ms]
sacro iliac z-moment
moment [Nm]
time [ms]
pubic force
force [kN]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0
shoulder y-force
force kN
disp [mm]


shoulder rib y-accel.
1. thorax rib y-accel.
2. thorax rib y-accel.
3. thorax rib y-accel.
1. abdomen rib y-accel.
2. abdomen rib y-accel.
Head x-rot.-velo.
Head y-rot.-velo.
Head z-rot.-velo.
T1 x-rot.-velo.
T1 y-rot.-velo.
T1 z-rot.-velo.
accel [g]
ang velo [rad/s]
time [ms]
--- Tests
--- WSID50 v3.5
--- WSID50 v4.0

9. Literature

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