Documentation

PDB LS-DYNA

WorldSID 50th – Version 2.0

User's Manual
Manual Release 1.0 for Model v2.0
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Content

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 R4.2.1 MPP	06/08/2009	53450 Product ID 58930
971 R4.2.1 MPP	06/08/2009	50638 Product ID 56728

Table 1: LS-DYNA versions

With the version 1.0 of the WorldSID 50th model the following keyword files are delivered:

File name	Content
worldSID50_pdb_v2.0_mm_ms_kg.key	Dummy model; the file name might vary depending on the system of units
wsid50_position_file_mm_ms_kg.key	Parameterized file to position arms, torso and upper legs (chapter 3.2).
wsid50_pdb_v2.0_mm_ms_kg_COMP-ANY_NAME_DATE1_license_DATE2.asc	License file; the file name might vary depending on the system of units
wsid50_pdb_v2.0_mm_ms_kg_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

Table 2: Delivered Files

The work file wsid50_pdb_v2.0_mm_ms_kg_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 3. On request, we deliver renumbered input decks, according to user specifications.

Component	Min ID	Max ID	Total number
Nodes	10000	179314	168673
Solids	11489	108240	96752
Beams	10000	11488	597
Shells	108241	346083	112359
Discrete elements	10030	10047	14
Accelerometer	1001	1023	23
Set shell	1001	1001	1
Set parts	1001	1501	28
Parts	1	770	602

Materials	1001	1057	52
Sections	1001	1068	65
Hourglass	1001	1009	5
Joints	1001	1023	23
Joint stiffness	1001	1036	36
Contacts	1001	1022	5
Local coordinate systems	1001	1076	70
Load curves / tables	1001	1130	125
Define SD orientation	1001	1008	8
Time history nodes	10001	10028	23
Time history elements	10000	10019	20

Table 3: Model numbering scheme

1.1 Keywords used

The following control and database keywords are used:

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

Table 4: Control cards used

The following database cards are defined:

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

Table 5: Database cards used

The following material models are used:

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

Table 6: Material models used

The following other keywords are used:

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

*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	*KEYWORD *NODE *PART_... *SECTION_BEAM *SECTION_DISCRETE *SECTION_SHELL *SECTION_SOLID *SET_PART_LIST *SET_SHELL_LIST *TITLE

Table 7: 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 8: 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.

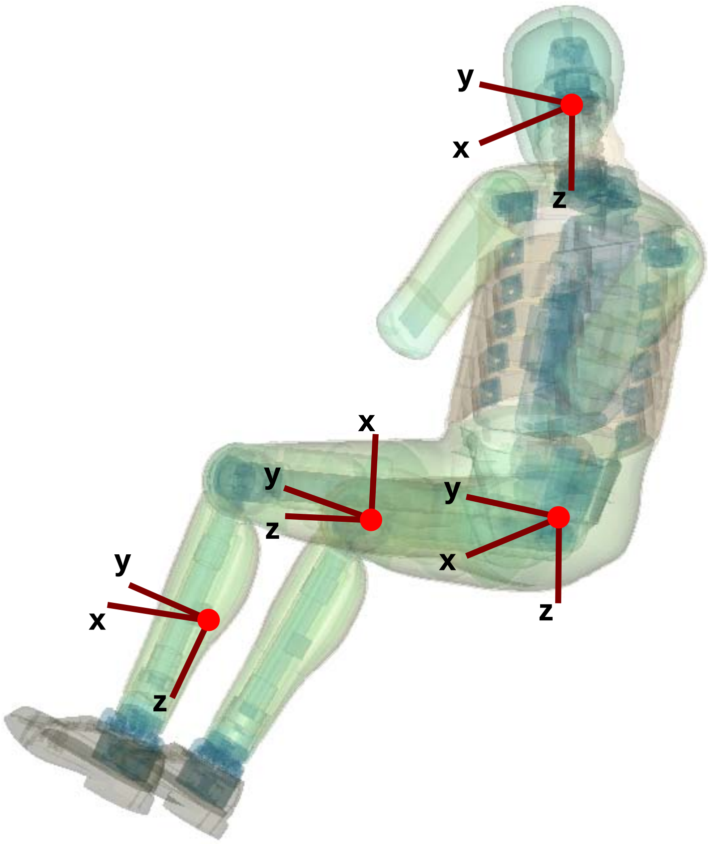


Figure 1: Orientation of the coordinate systems for accelerometers and load cells in the WORLDSID 50^{th} model

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

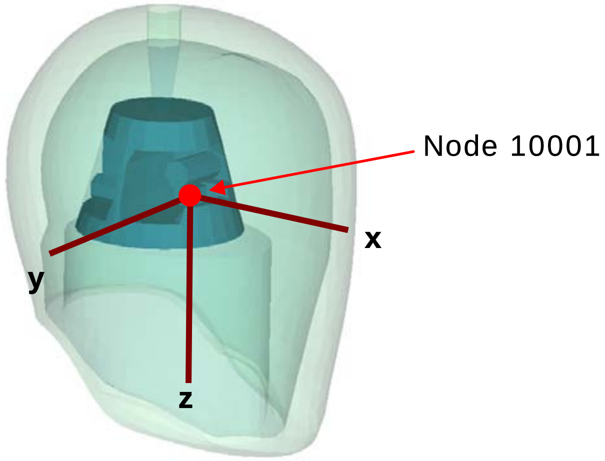


Figure 2: Head accelerometer and local coordinate directions

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 9: Head accelerometer node

2.2.2 T1, T4 and T12 acceleration

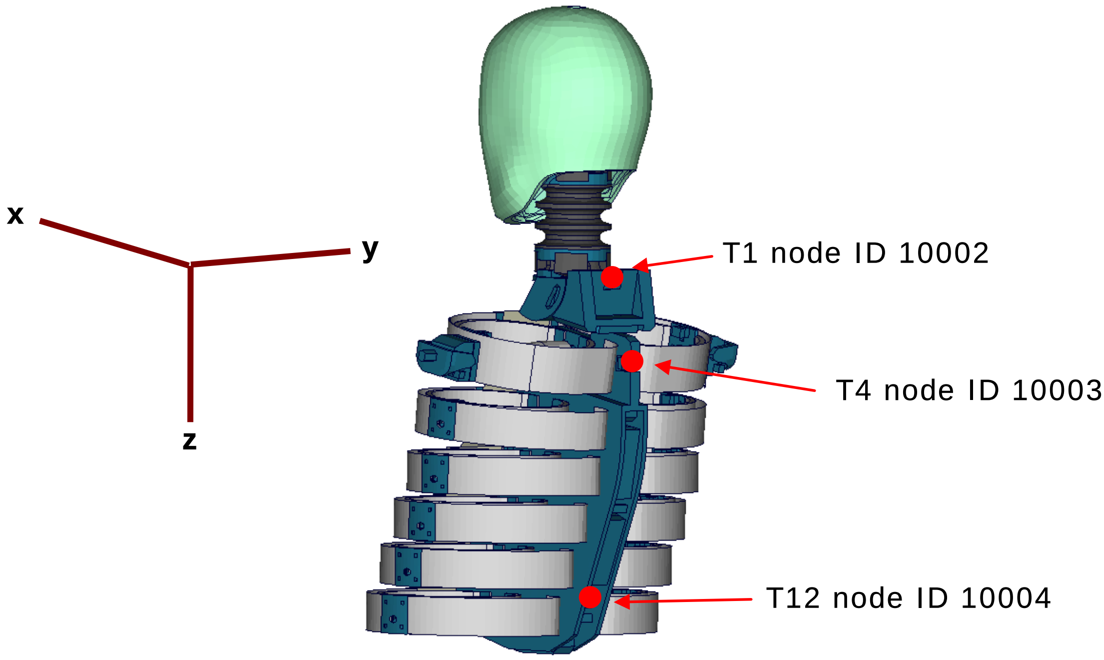


Figure 3: T1, T4 and T12 accelerometer nodes

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 10: T1, T4 and T12 accelerometer nodes

2.2.3 Pelvis acceleration

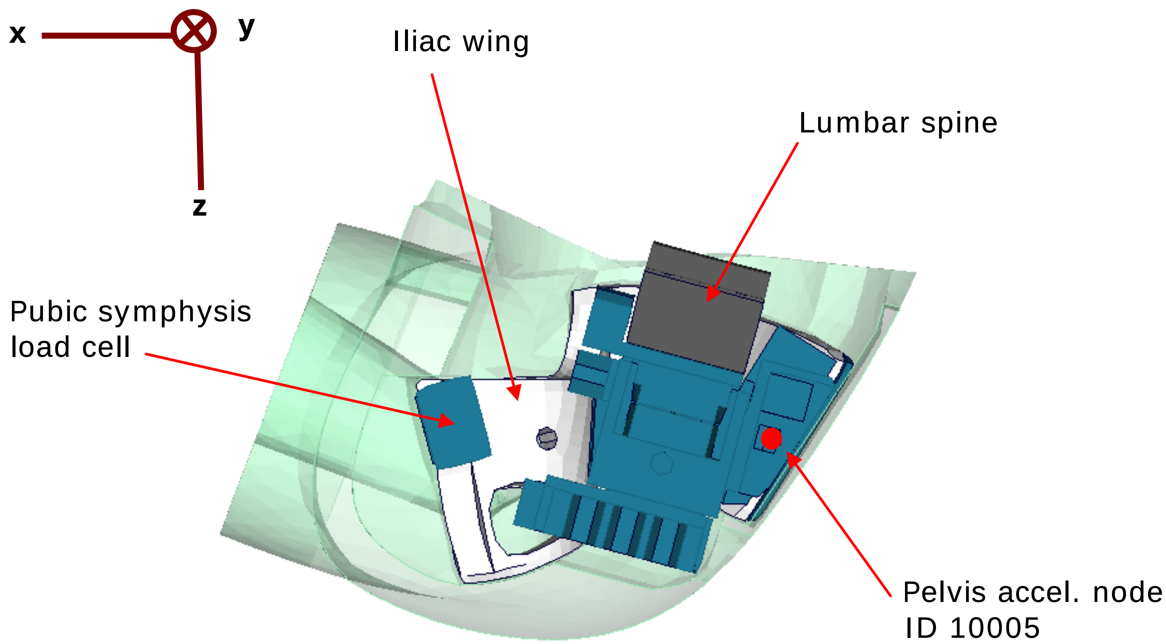


Figure 4: Node to extract pelvis acceleration.

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 11: 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.

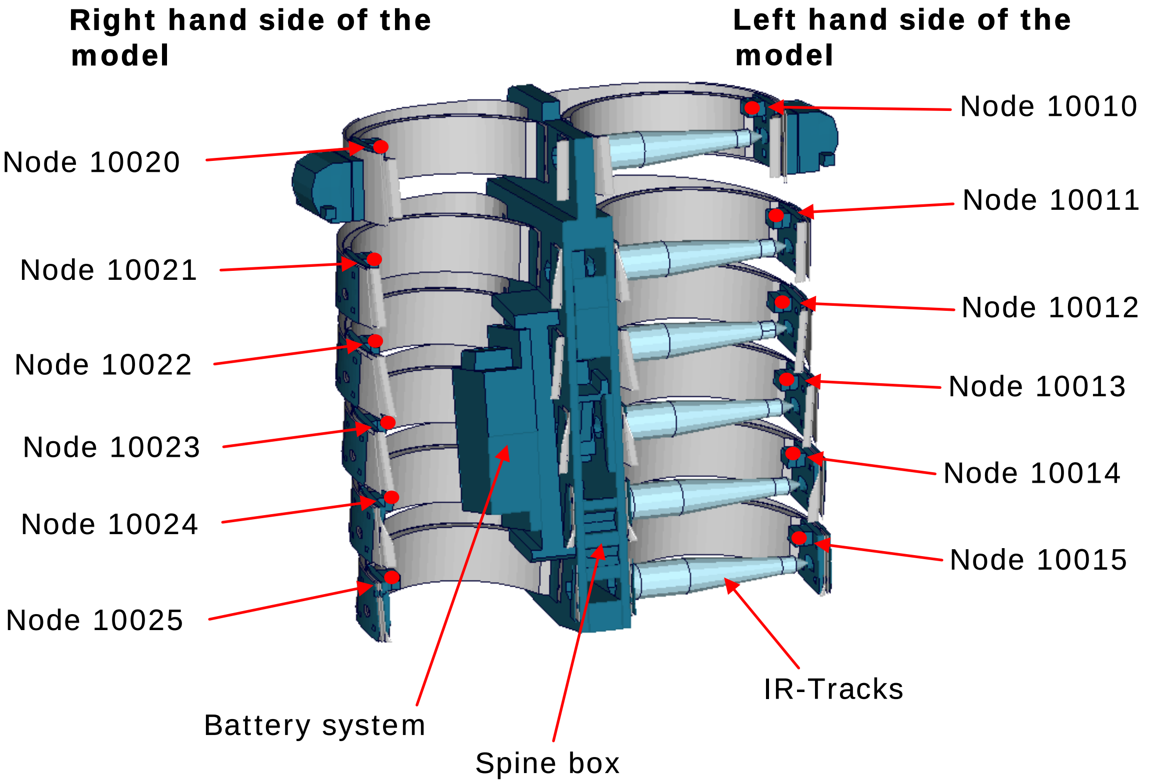


Figure 5: Cut through upper torso and position of rib accelerometer nodes

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 12: 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 13: 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 14.

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 14: Components of ELOUT file for evaluating load cell results

2.3.1 Upper and lower neck load cell

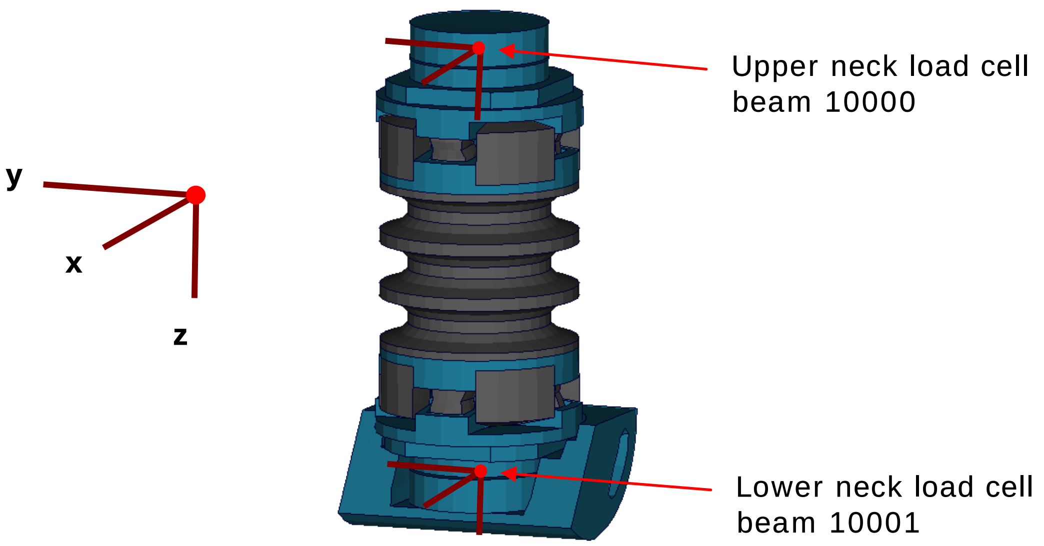


Figure 6: Upper and lower neck load cells

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 15: 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

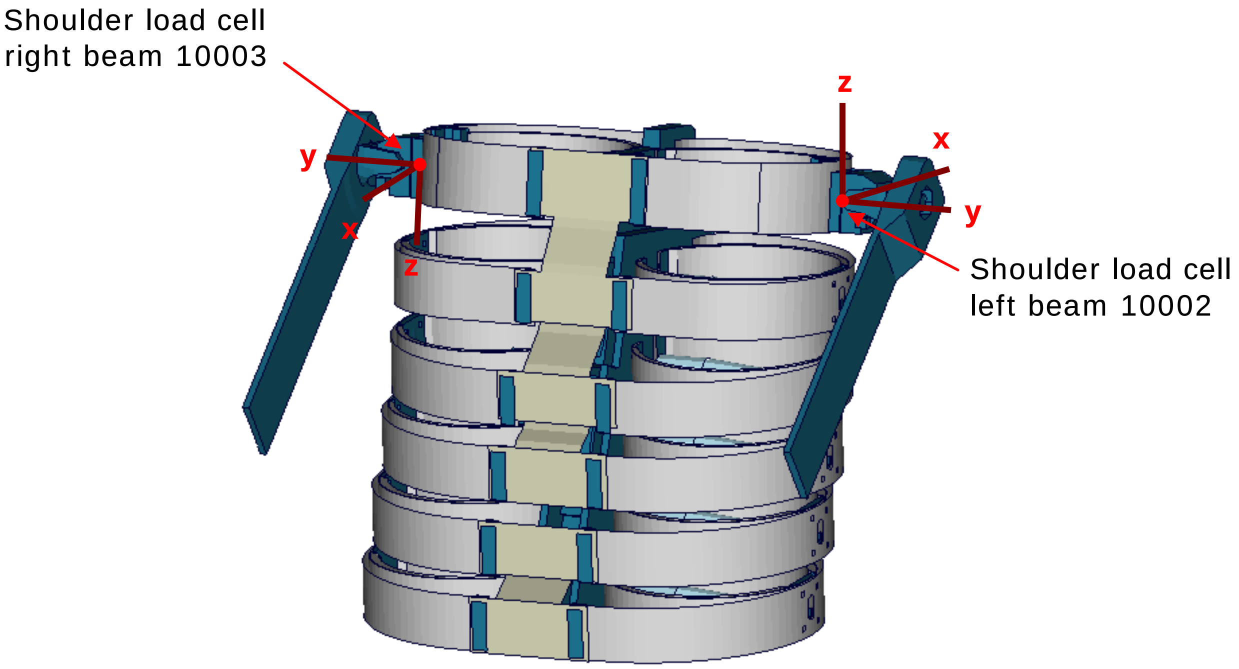


Figure 7: Shoulder load cells, left and right.

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 16: 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

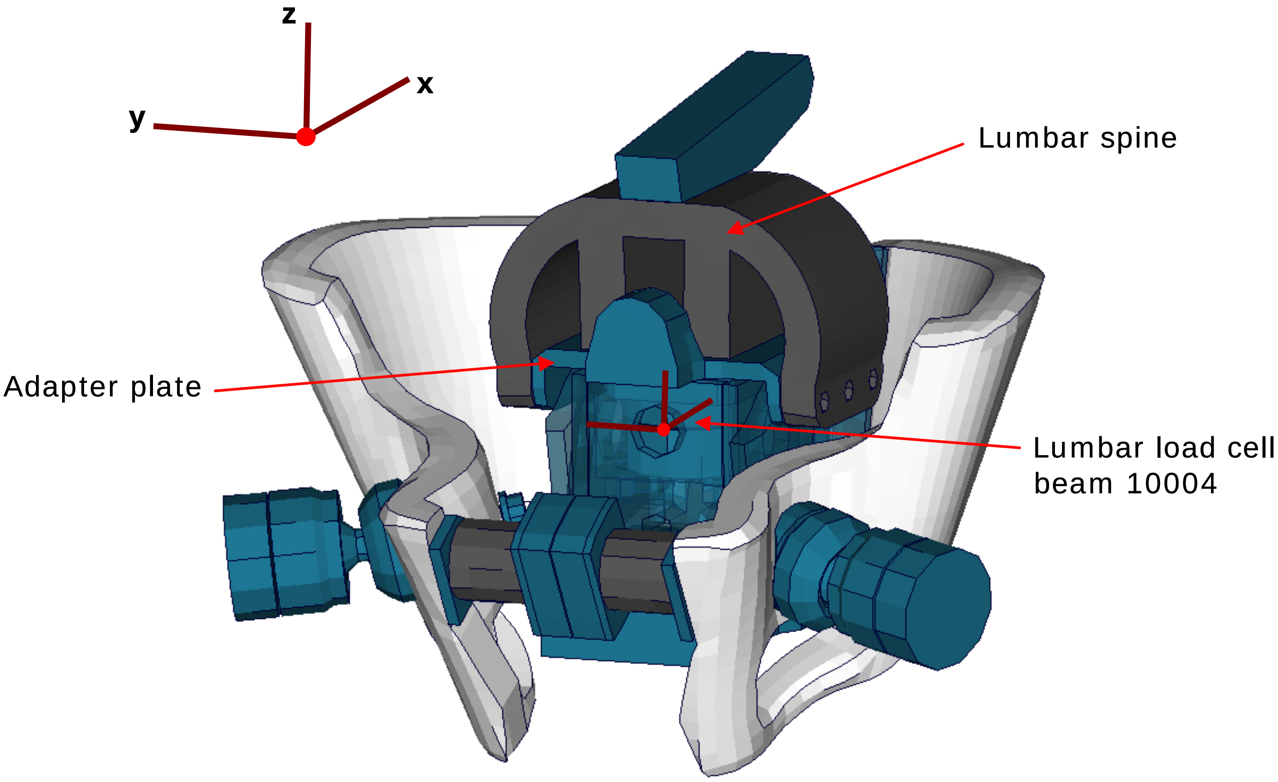


Figure 8: Lumbar load cell in Sacrum block

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 17: 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.

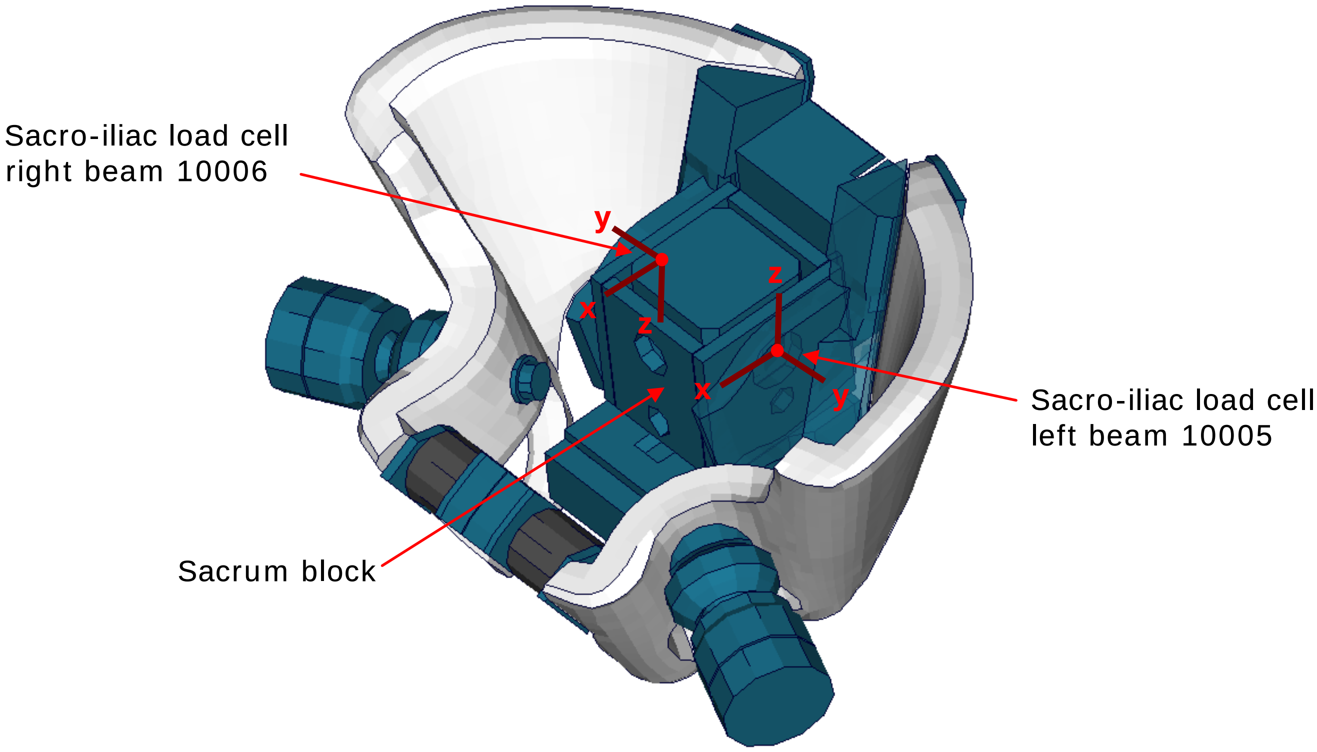


Figure 9: Sacro-iliac load cells, left and right hand side

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 18: 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 19: 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.

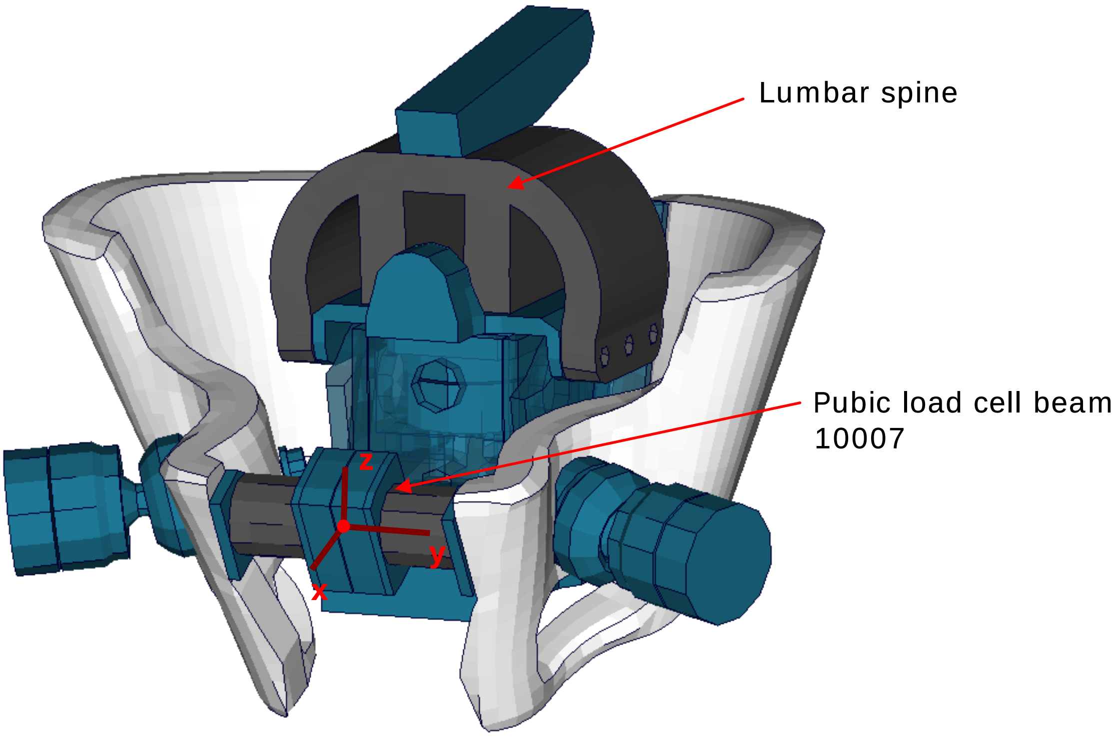


Figure 10: Pubic load cell adapted to pelvis bones

2.3.6 Femoral load cells

The upper legs of the WorldSID are equipped with four load cells. At the neck of the left and right hand side femur, 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 20: 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:

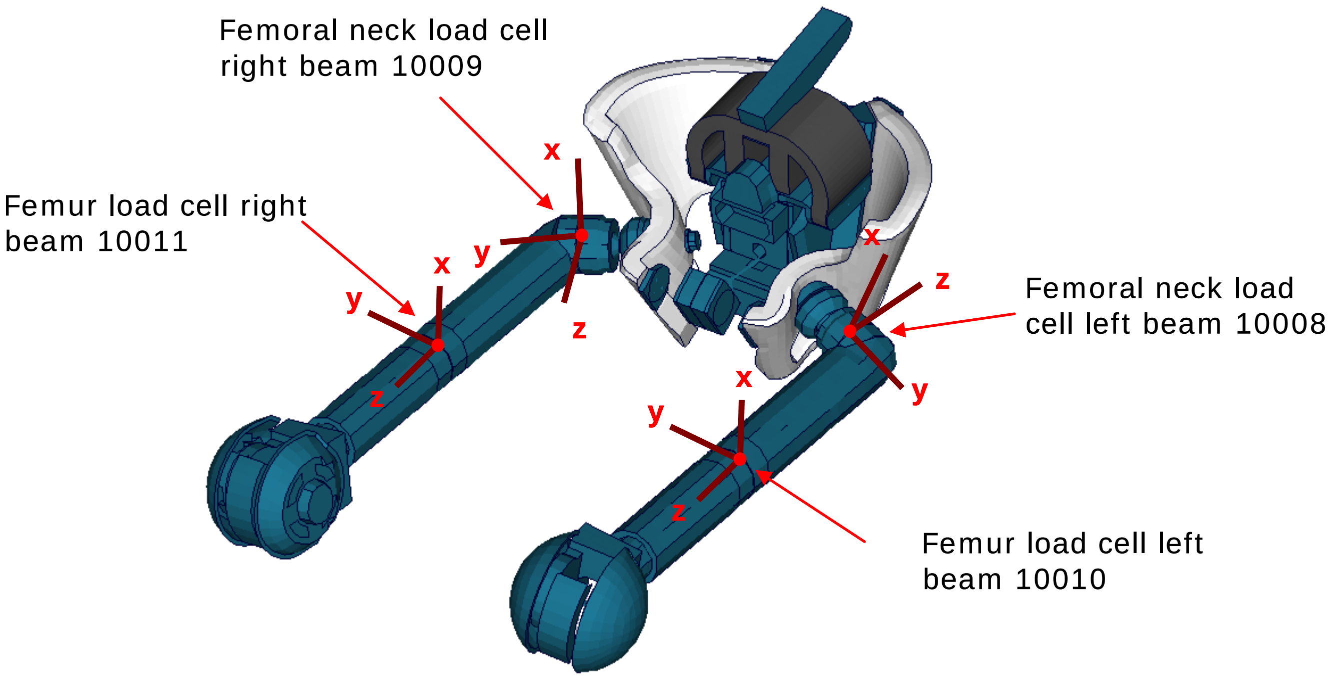


Figure 11: Upper and lower femur load cells

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 21: Knee load cell beams

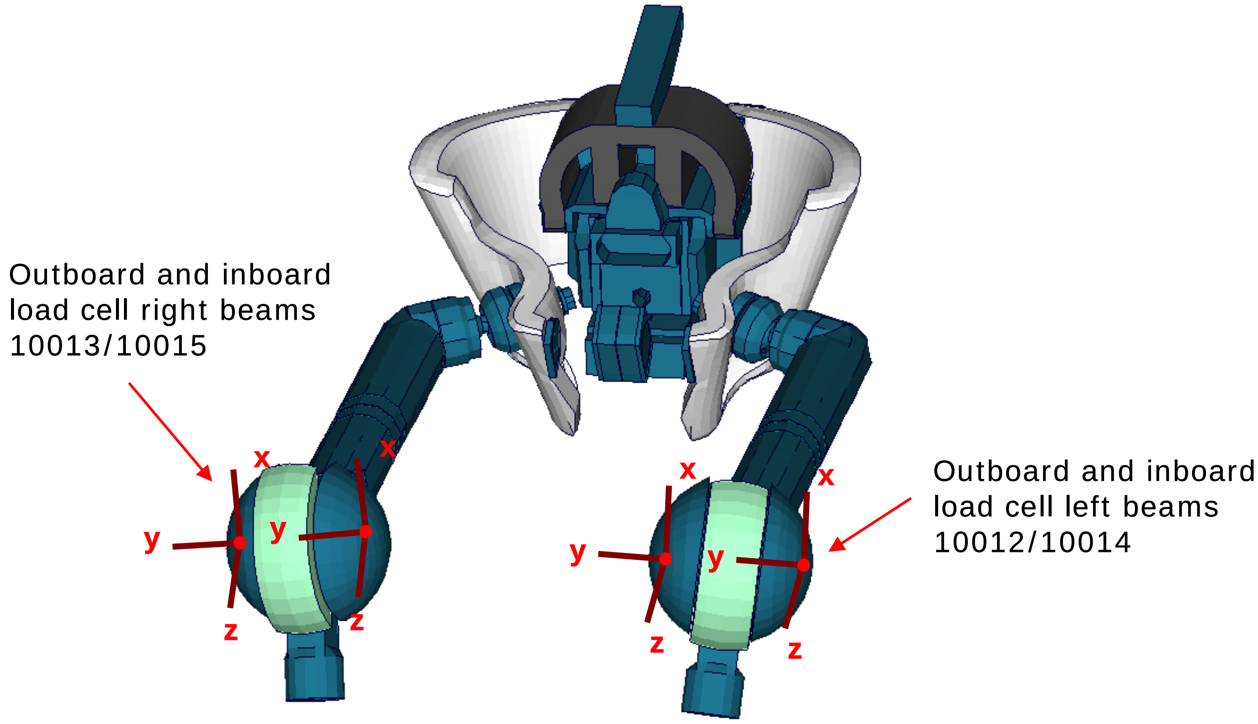


Figure 12: Knee load cell beams

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 22. 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 22: Tibia load cell beams, left and right hand side

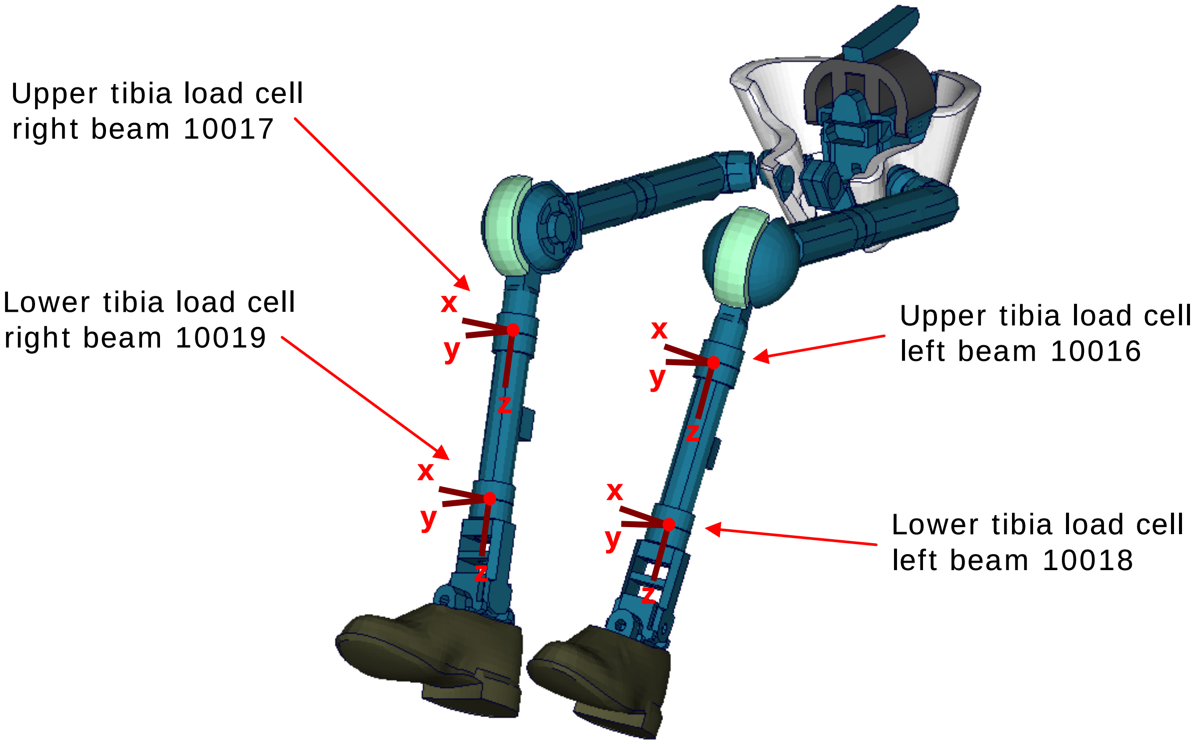


Figure 13: Tibia load cell beams

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.

2.4.1 Rib deflections

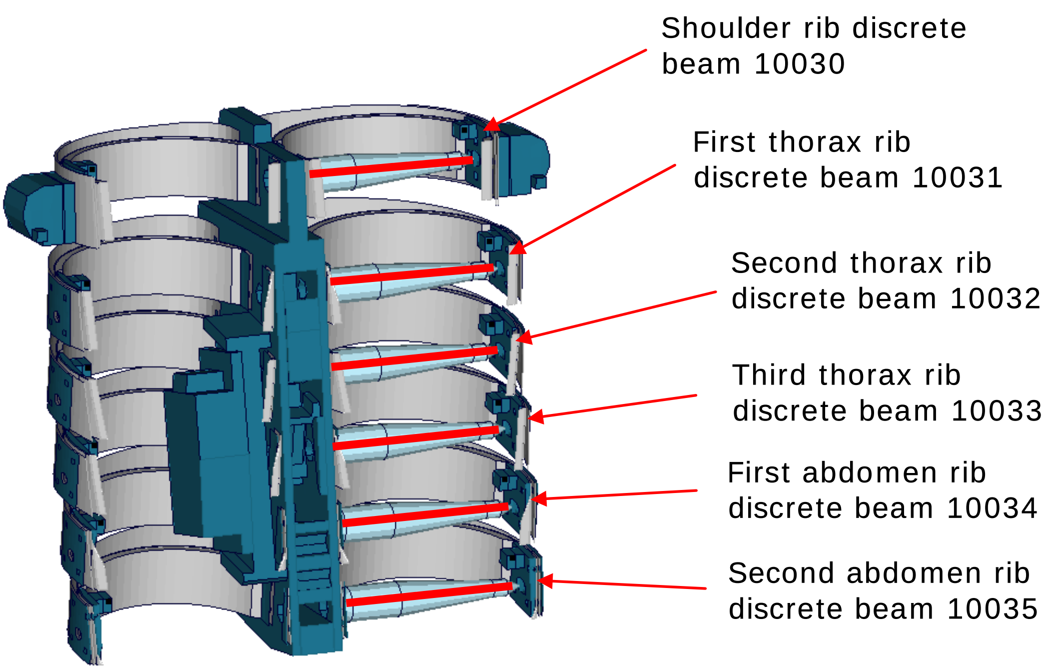


Figure 14: Cut through upper torso and location of rib deflection measurement springs

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 23: Rib deflection measurement using discrete beams

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.

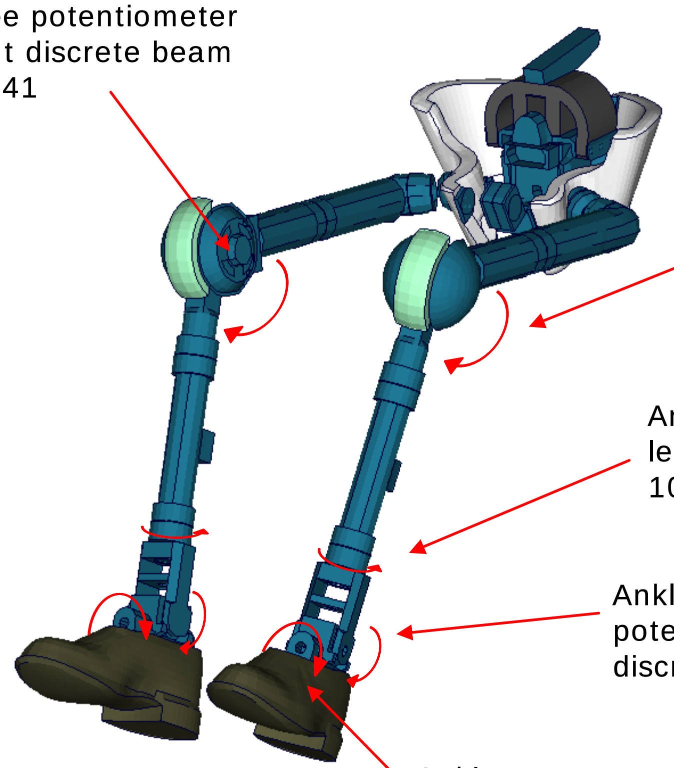


Figure 15: Location of rotation measurement springs in the WorldSID model

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, Tree File and pre-simulation File

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.

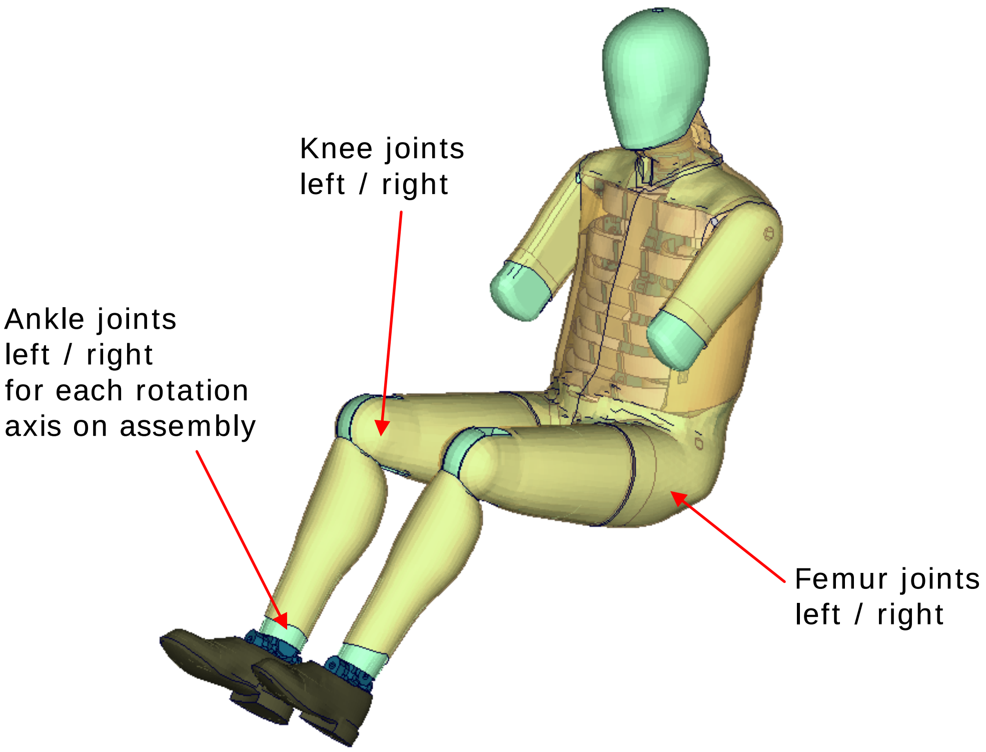


Figure 16: Tree-file assemblies of the WorldSID model.

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 x-axis	stop angle: -21.0 and 21.0 degrees
local y-axis	stop angle: -48.0 and 48.0 degrees
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	stop angle: -1.0 and 1.0 degrees

local y-axis local z-axis	stop angle: -2.5 and 2.0 degrees stop angle: -2.0 and 2.0 degrees

Table 24: 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. But for the hip joint there is no physical blocking in the WorldSID.

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 24. 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 Arm, upper leg and torso rotation by pre-simulation

In the hardware, the geometry is deformed if the position of the upper legs or torso is changed with respect to the pelvis. Also the jacket has to be deformed when the arms are rotated.
A special positioning-file <wsid50_position_file_mm_ms_kg.key> is delivered to perform these rotations by a pre-simulation.
The positioning-file of the WorldSID is very easy to use. At the top of this file you will find a set of parameters you have to define. These parameters are shown in the following table.

Parameter	Description
term	termination time
tmove	time to move parts
trans_x	x-translation of the whole dummy
trans_z	z-translation of the whole dummy
torsor	local y-rotation of torso
larmry	left arm rotation about y
rarmry	right arm rotation about y
llegry	left femur rotation about y
rlegry	right femur rotation about y

Table 25: Positioning file parameters

In case you don't want to translate or rotate the assembly, use a very small value like 1.0E-10. Please do not use zero as the value, because zero as scaling factor is default 1 in LS-DYNA. As the second step you have to add your include-files necessary for positioning the dummy model.
Usually only seat and dummy models are used for the positioning procedure.
Please define a *CONTACT_AUTOMATIC_SURFACE_TO_SURFACE for the contact between the dummy and seat (environment). The WorldSID properties for this contact are defined in the part set 1500.

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.

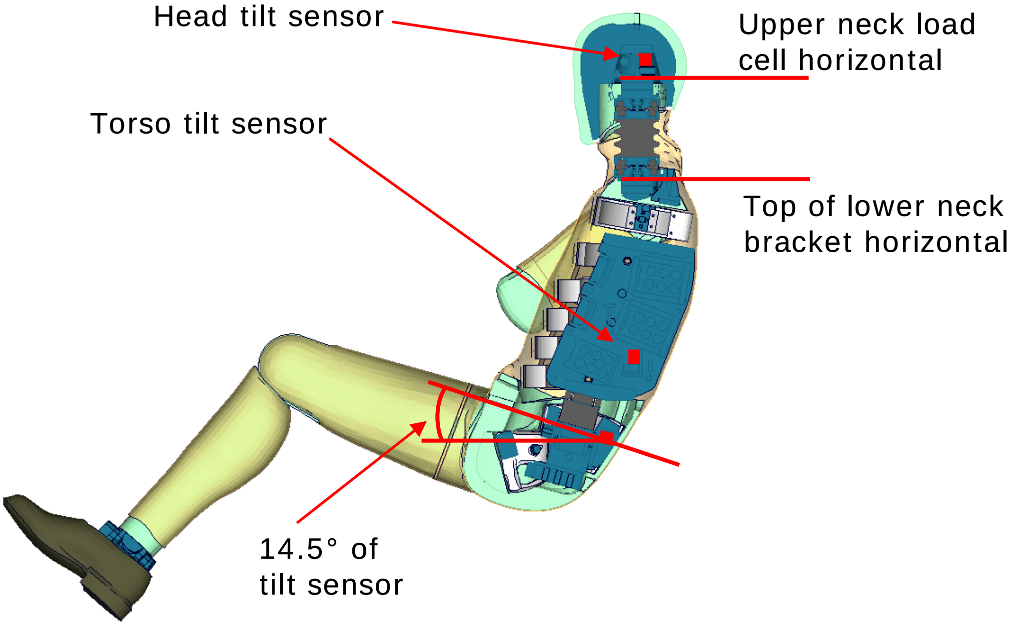


Figure 17: Cut through WorldSID model with positions of tilt sensors

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 3: **Model numbering scheme**Table 3. 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

- The model should be used with a time step size of 0.9 microsecond 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.

4. License file and usage

The WorldSID v2.0 is distributed with a license file which uses an expiry date. The license file is sent to the user with the whole dummy package. Different license files are necessary for different systems of units.

In the license file, all load curves are encrypted. 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 which are encrypted in the normal 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 must 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 **AFTER** the WorldSID file. LS-DYNA has to first read the WorldSID input data and then the PARAMETER_EXPRESSION in the license file. Otherwise LS-DYNA will terminate with an error because of missing parameters.

The expiry date, the owner of the license and the system of units 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.

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

wsid50_pdb_v2.0_mm_ms_kg_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.

5. Release Notes

5.1 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.

5.2 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 fulfils 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. The experience in full car simulations is missing, but the first simulations show sometimes behaviour which is not seen in the sled tests.

Therefore some more validation tests are planed this the WorldSID shoulder and thorax.

In general, the WorldSID is a unique and a very new dummy. The experience with this dummy is much lower than for others like ES-2 or ES-2re. Thus, it is possible that some behaviour, which has not been covered by the huge validation databases of the WorldSID model, appears in the future.

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 18: 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 26: 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.

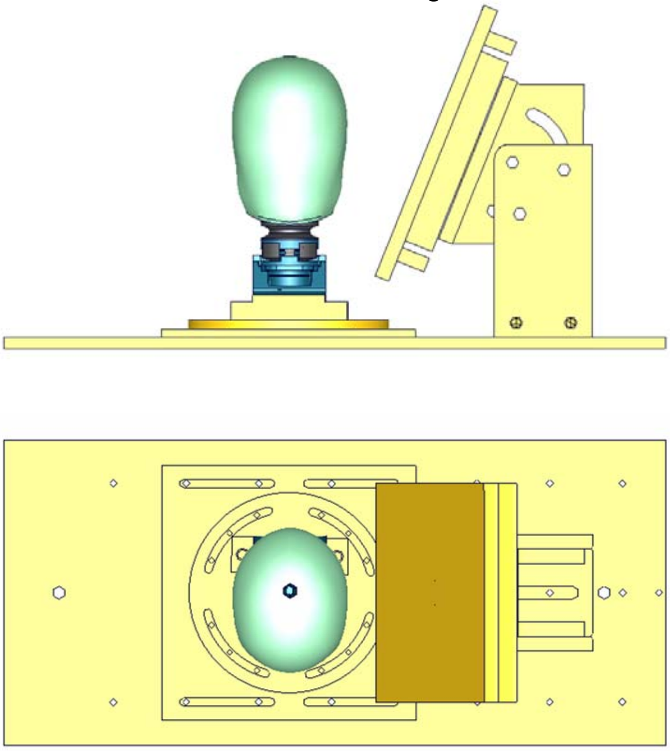


Figure 19: Head-neck test setup - 90 degree, side and top view

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 27: Test configurations of head-neck test

Results of 90 degree, 20g configuration:

Head accelerometer

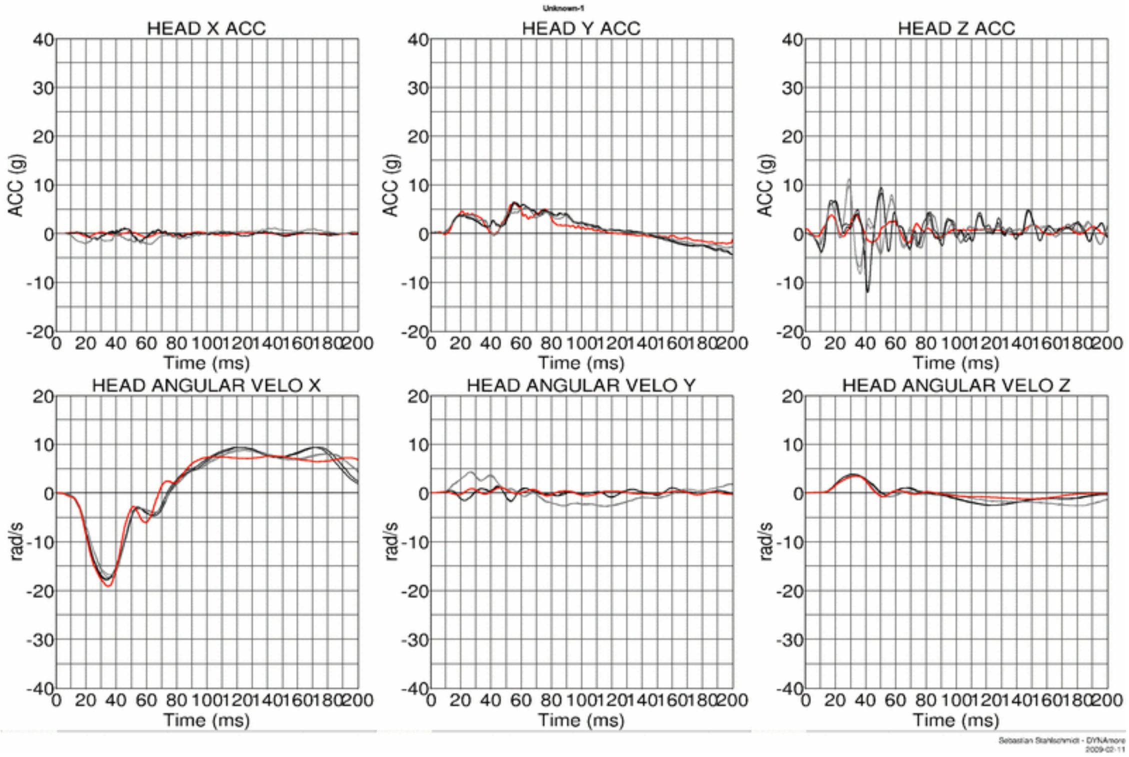


Figure 20: Result of head-neck test -- 20g, 90 degree (Head acceleration)

Upper neck load cell

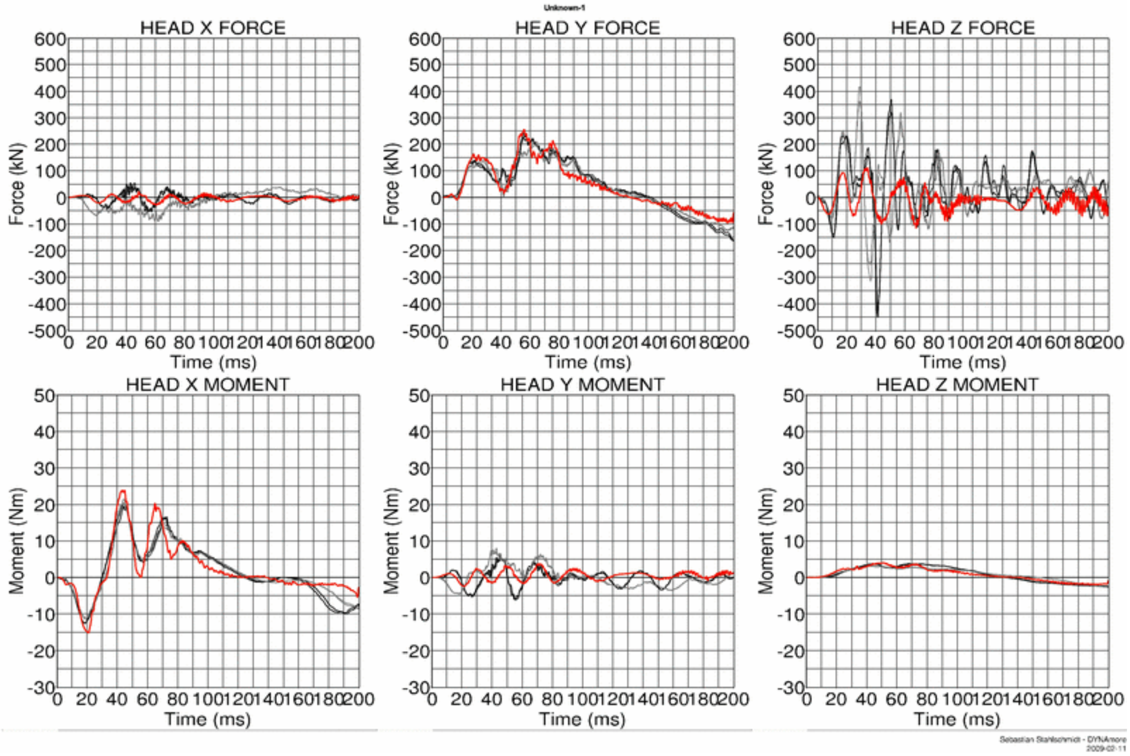


Figure 21: Result of head-neck test -- 20g, 90 degree (Upper neck forces and moments)

Lower neck load cell

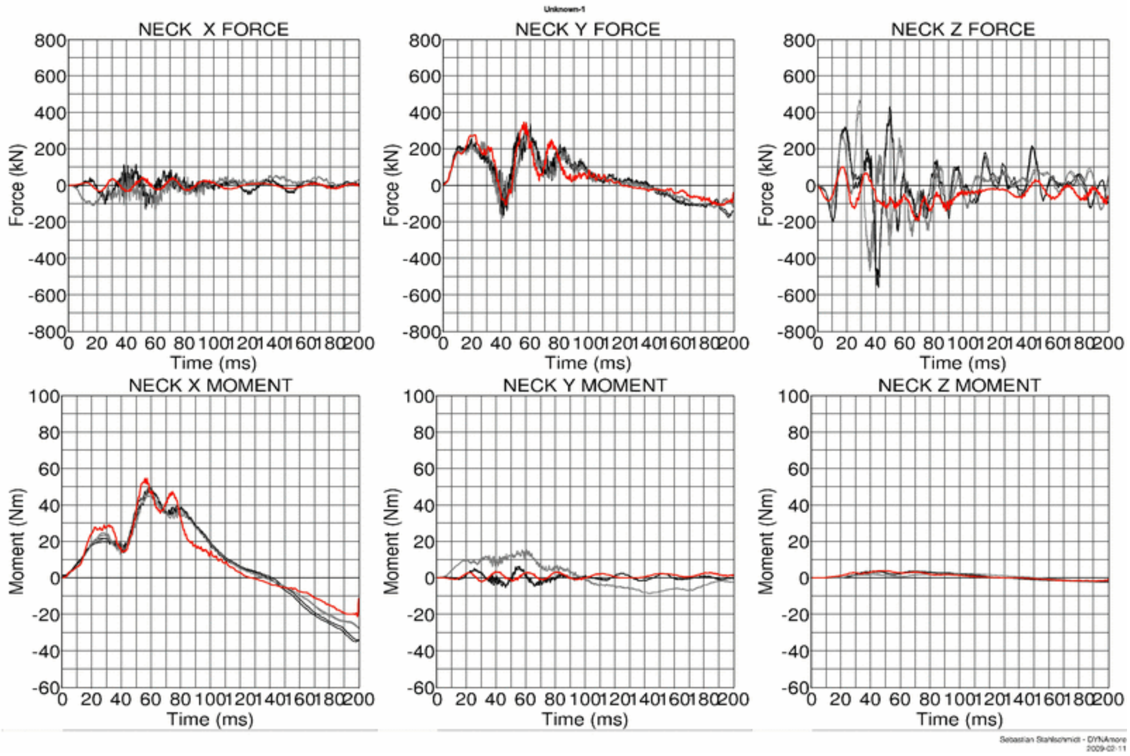


Figure 22: Result of head-neck test -- 20g, 90 degree (Lower neck forces and moments)

Results of 90 degree, 35g configuration:

Head accelerometer

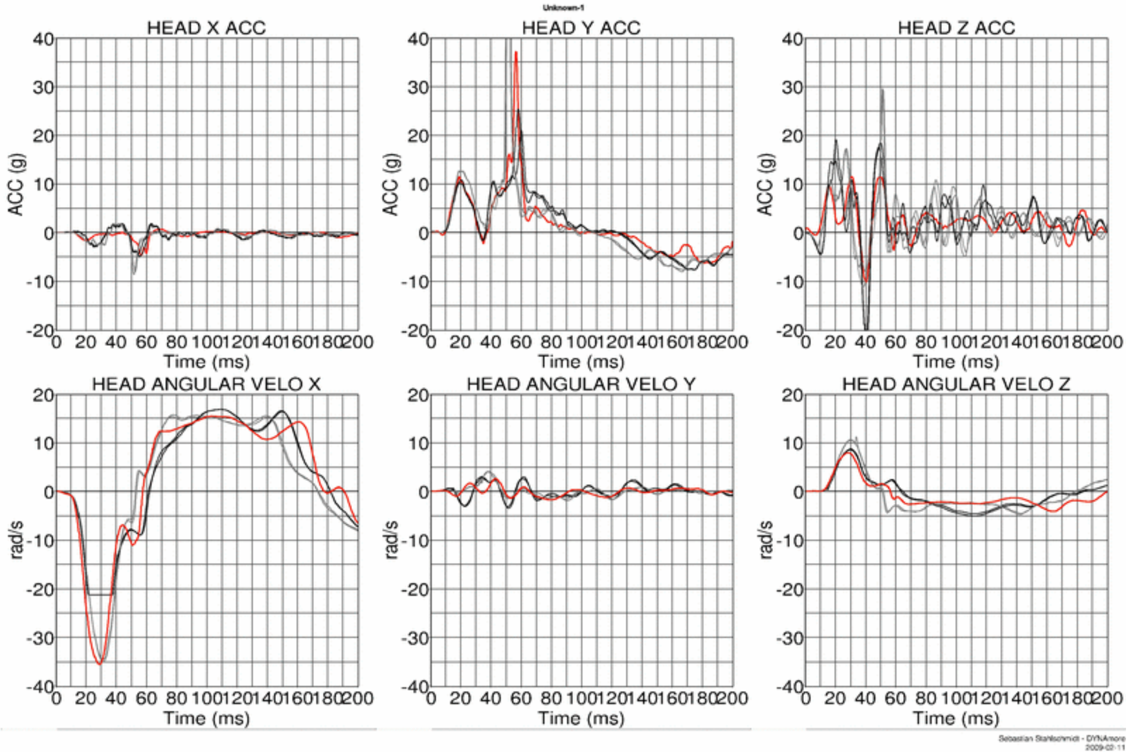


Figure 23: Result of head-neck test -- 35g, 90 degree (Head acceleration)

Upper neck load cell

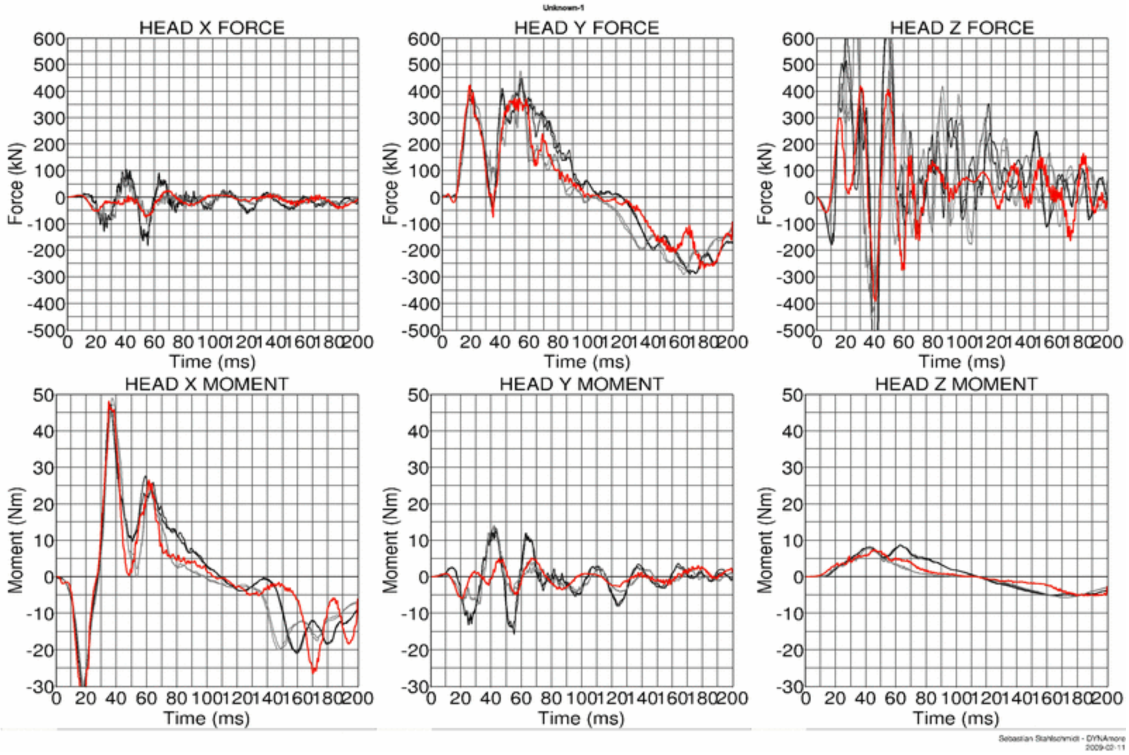


Figure 24: Result of head-neck test -- 35g, 90 degree (Upper neck forces and moments)

Lower neck load cell

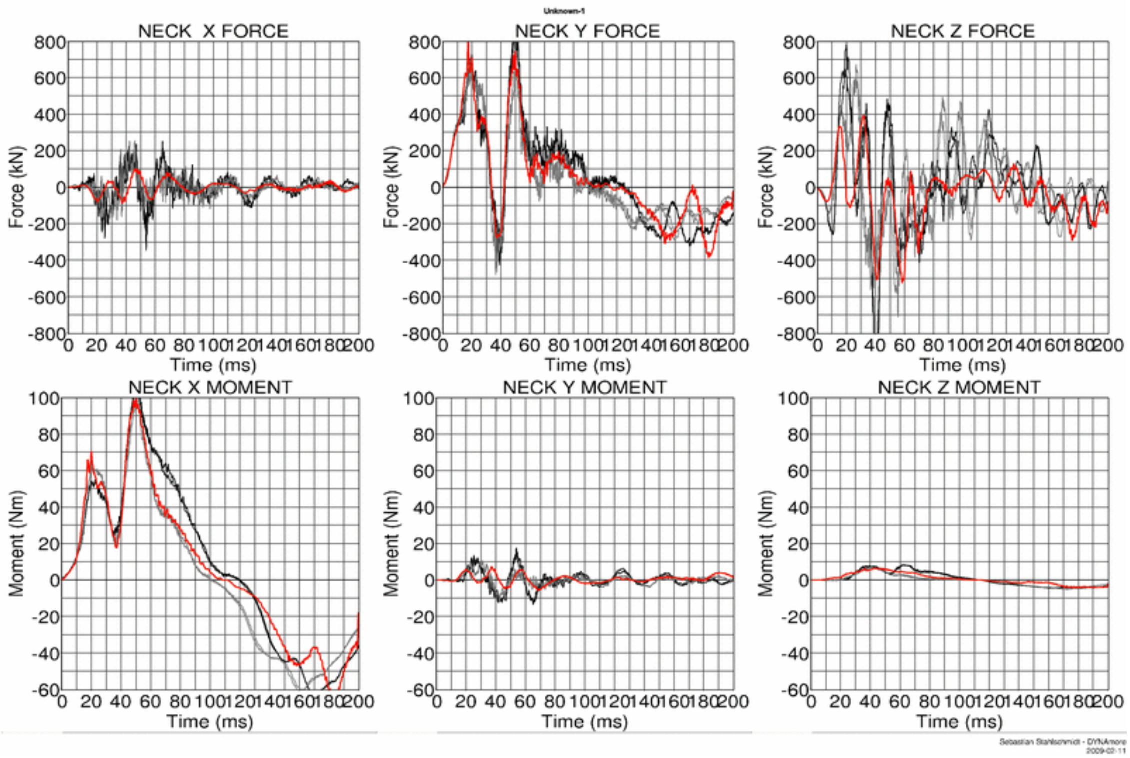


Figure 25: Result of head-neck test -- 35g, 90 degree (Lower neck forces and moments)

Results of 75 degree, 20g configuration:

Head accelerometer

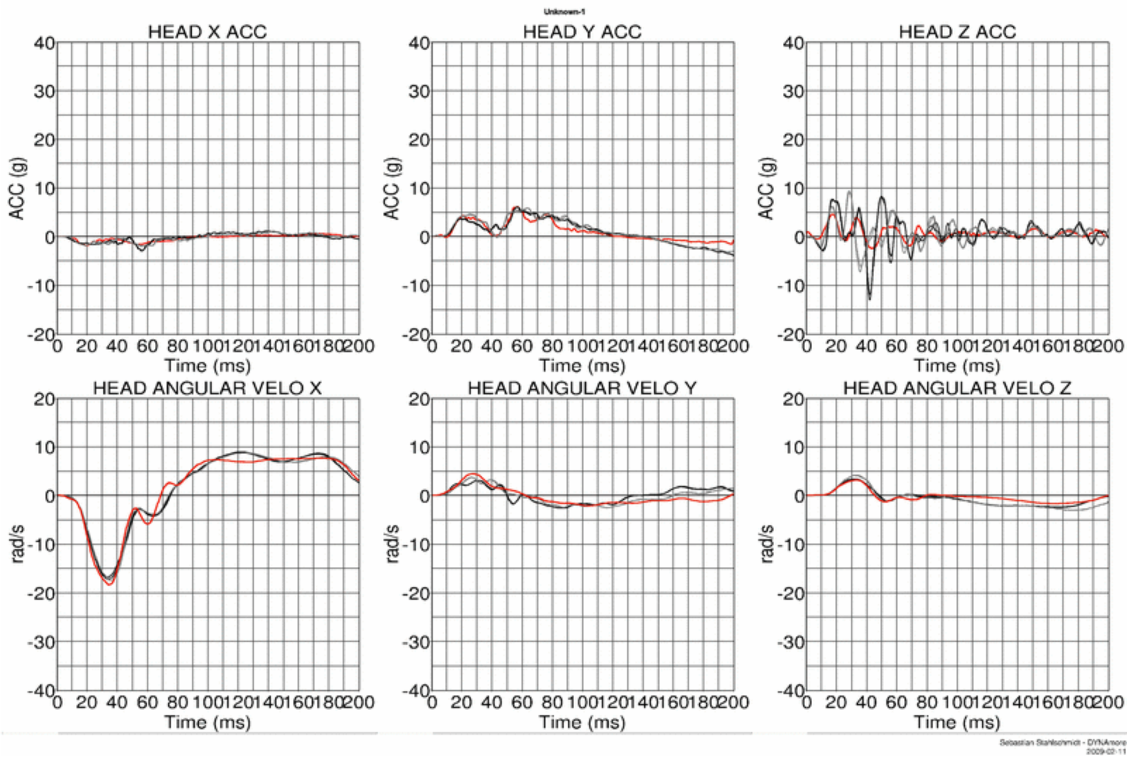


Figure 26: Result of head-neck test -- 20g, 75 degree (Head acceleration)

Upper neck load cell

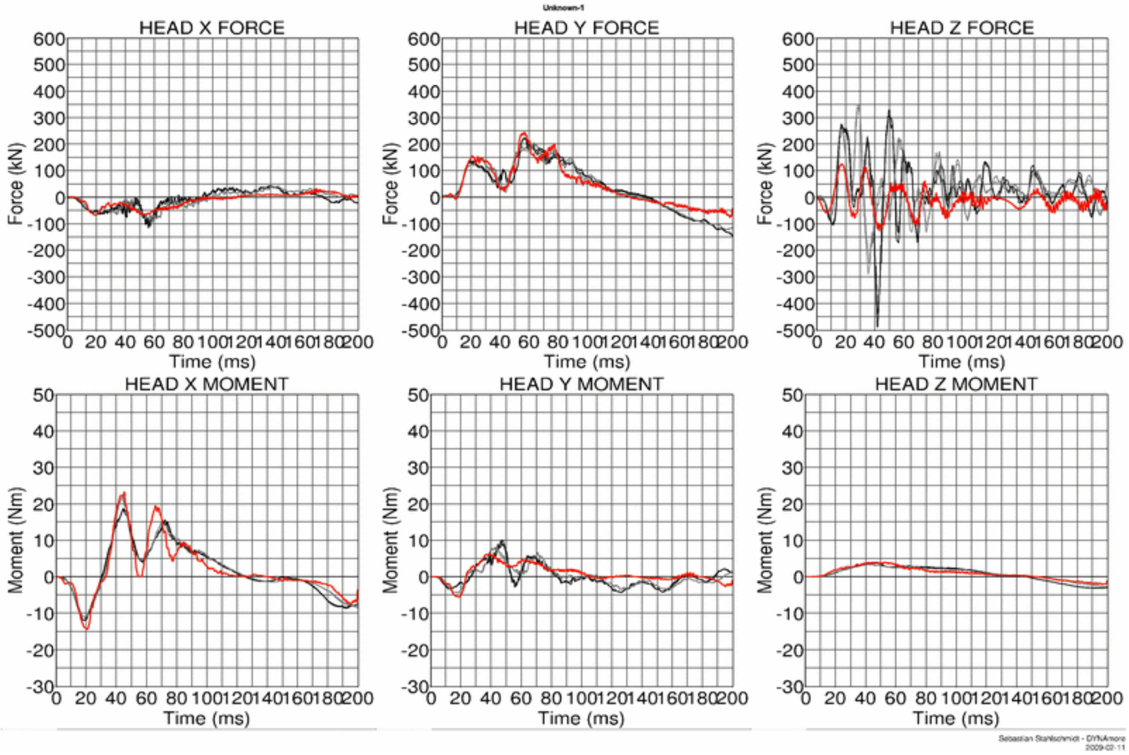


Figure 27: Result of head-neck test -- 20g, 75 degree (Upper neck forces and moments)

Lower neck load cell

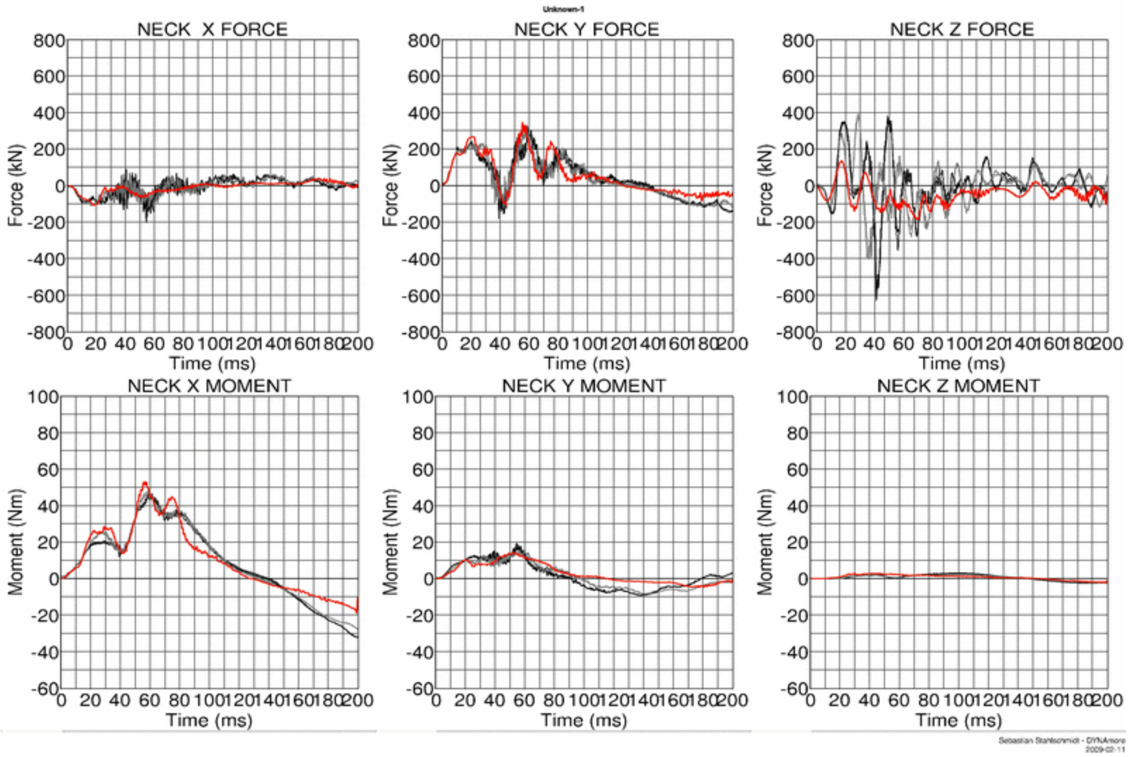


Figure 28: Result of head-neck test -- 20g, 75 degree (Lower neck forces and moments)

Results of 75 degree, 35g configuration:

Head accelerometer

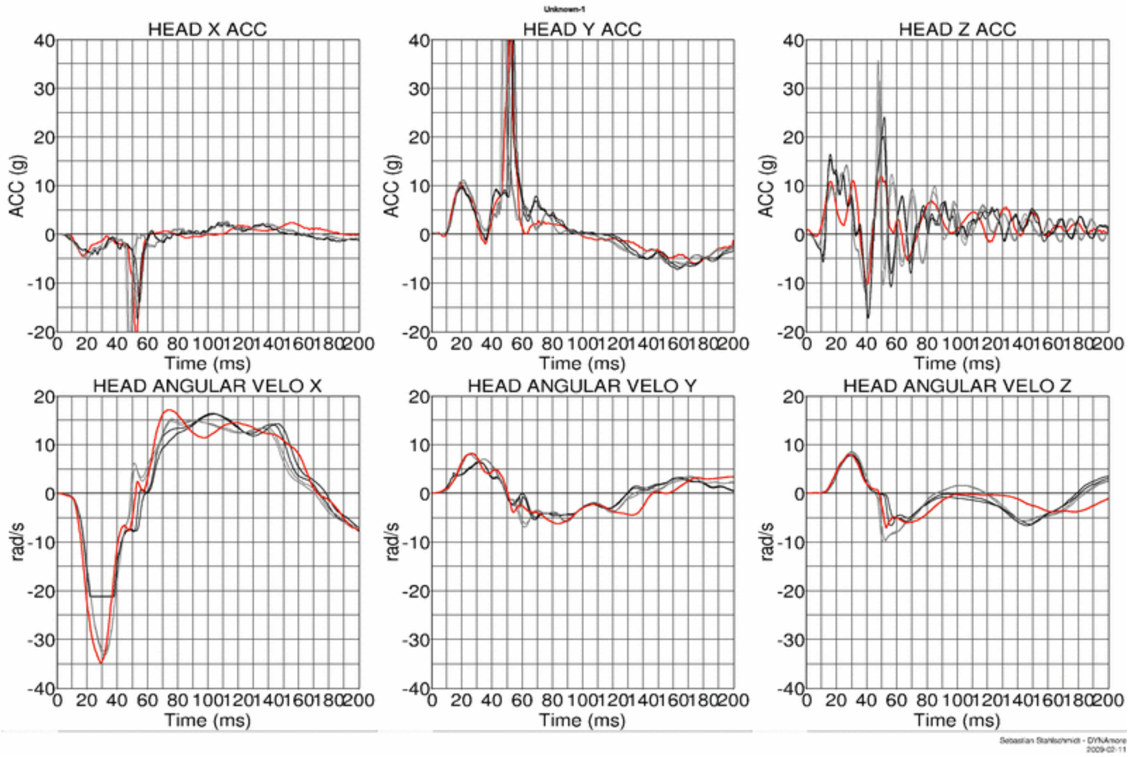


Figure 29: Result of head-neck test -- 35g, 75 degree (Head acceleration)

Upper neck load cell

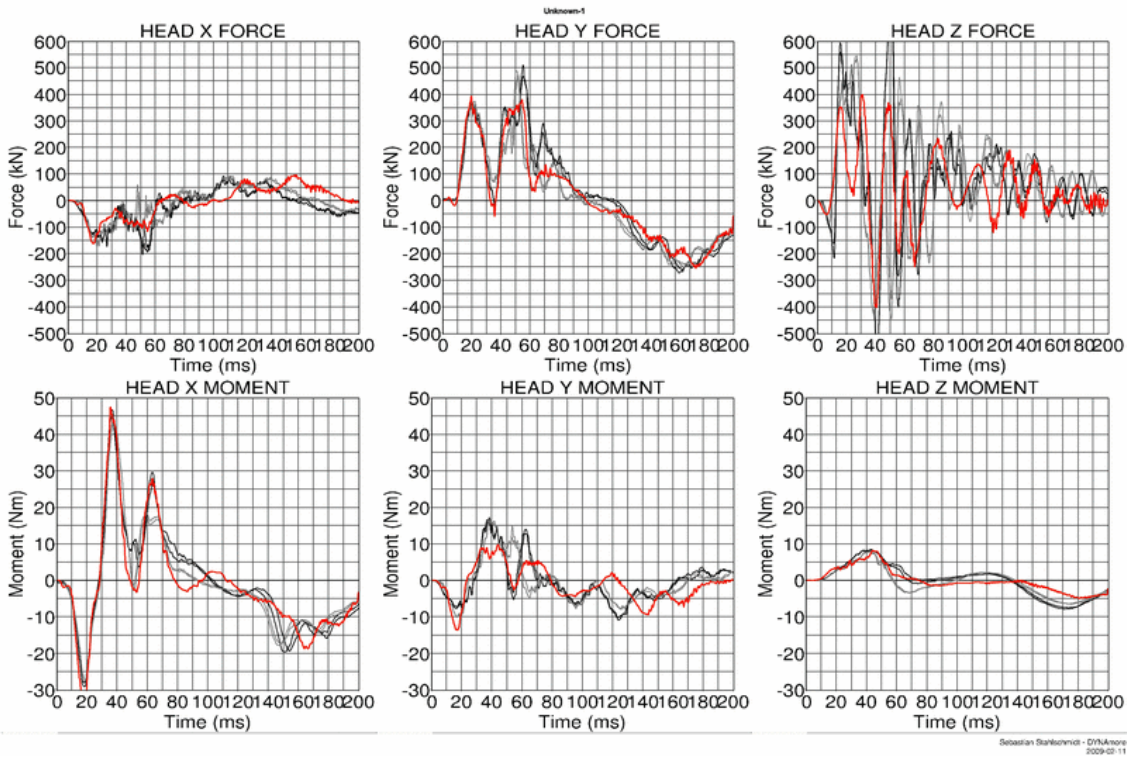


Figure 30: Result of head-neck test -- 35g, 75 degree (Upper neck forces and moments)

Lower neck load cell

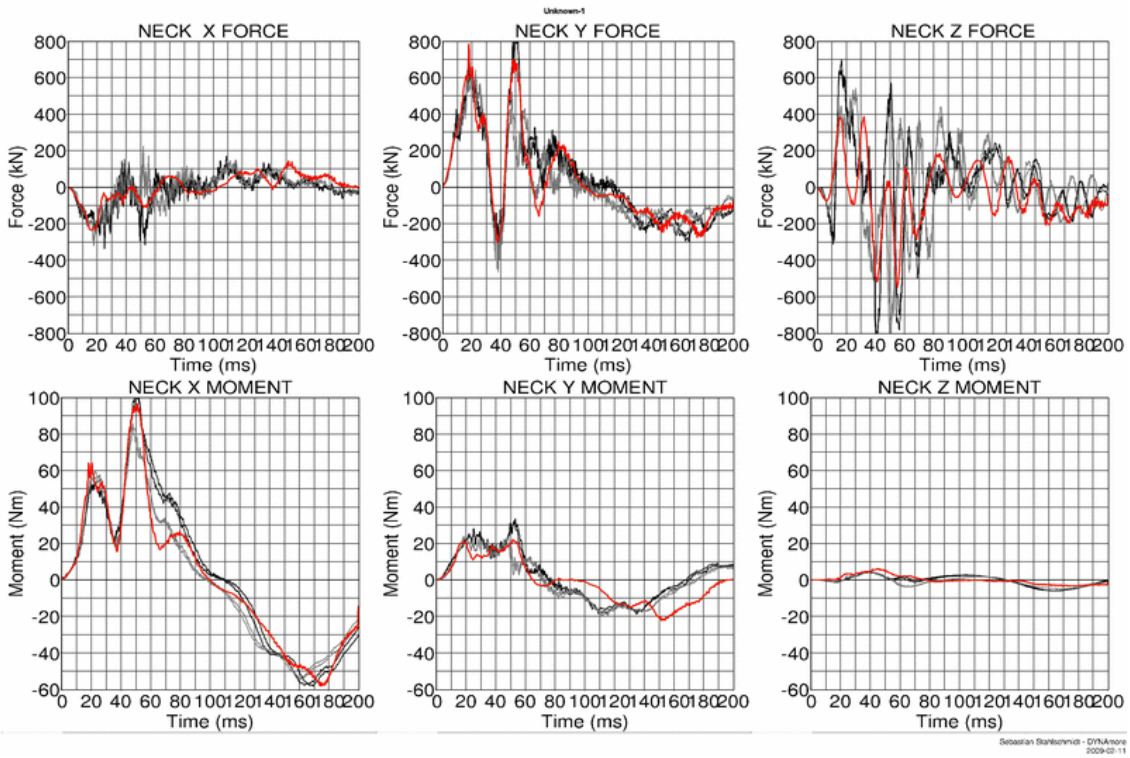


Figure 31: Result of head-neck test -- 35g, 75 degree (Lower neck forces and moments)

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 28 all test setup configurations are listed.

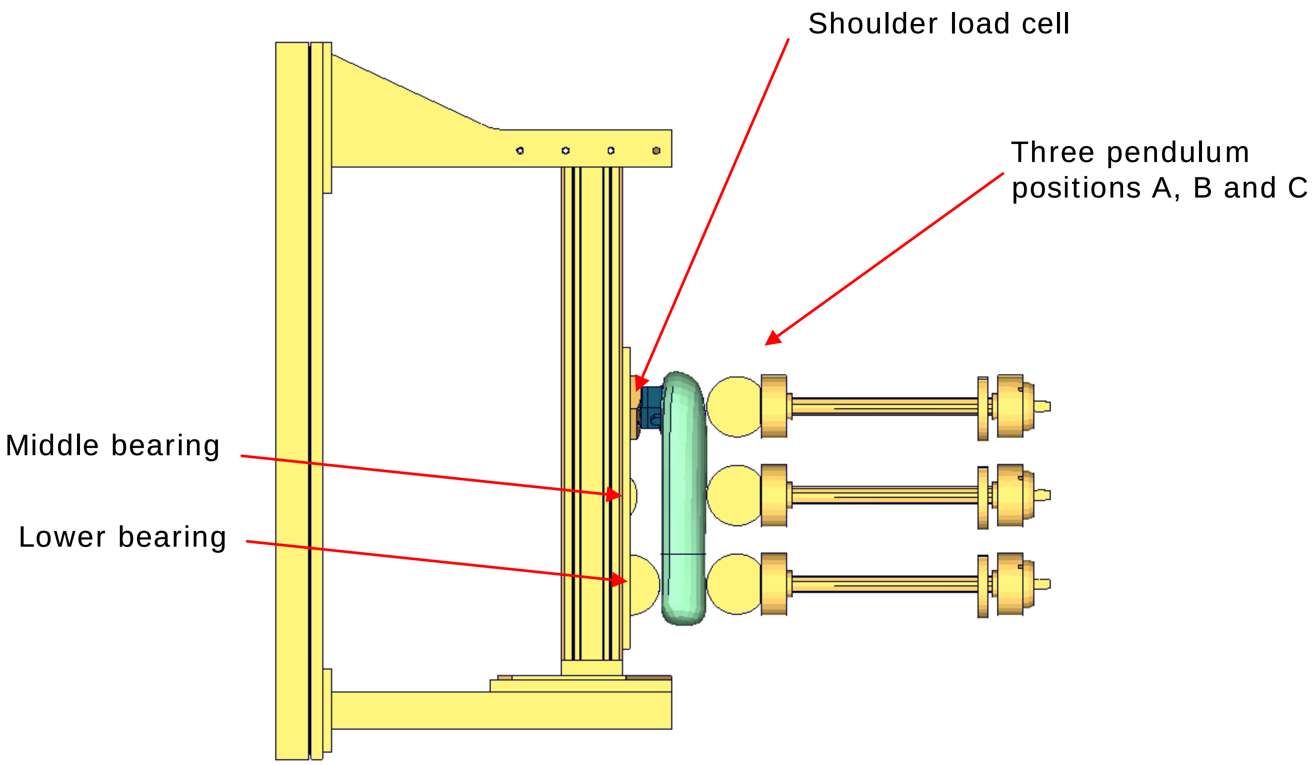


Figure 32: Half arm test setup with all pendulum positions

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 28: 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

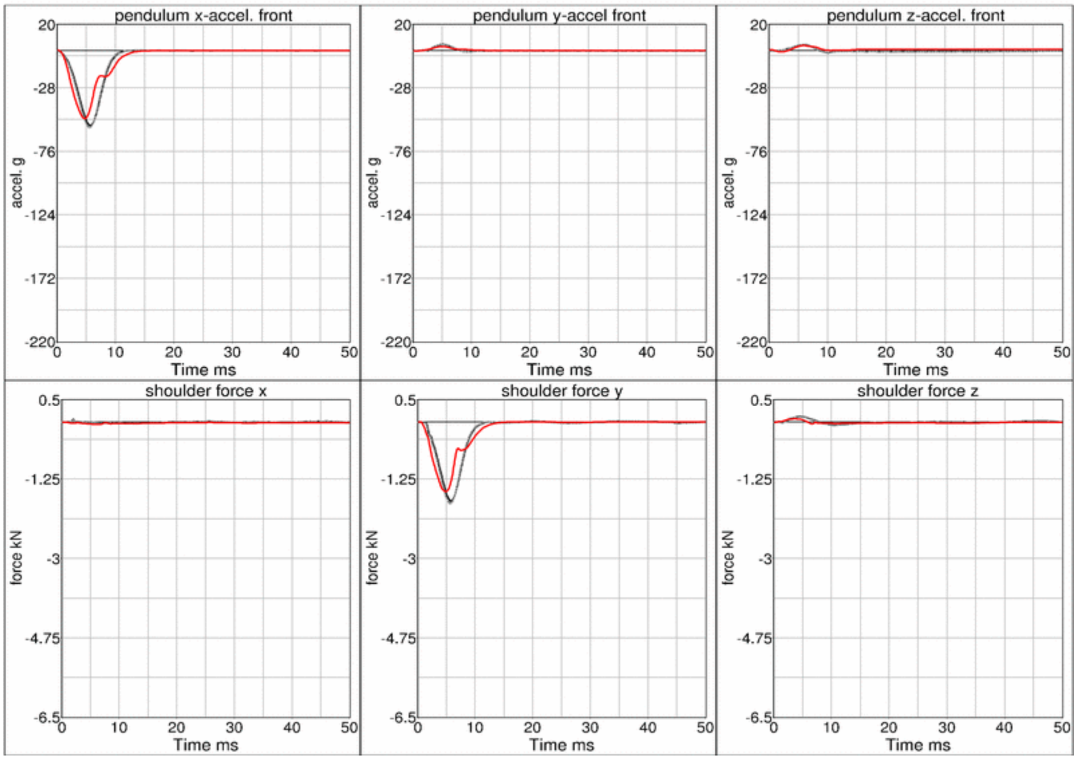


Figure 33: Results - target point A, 2 m/s velocity, 48 degree load cell position

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

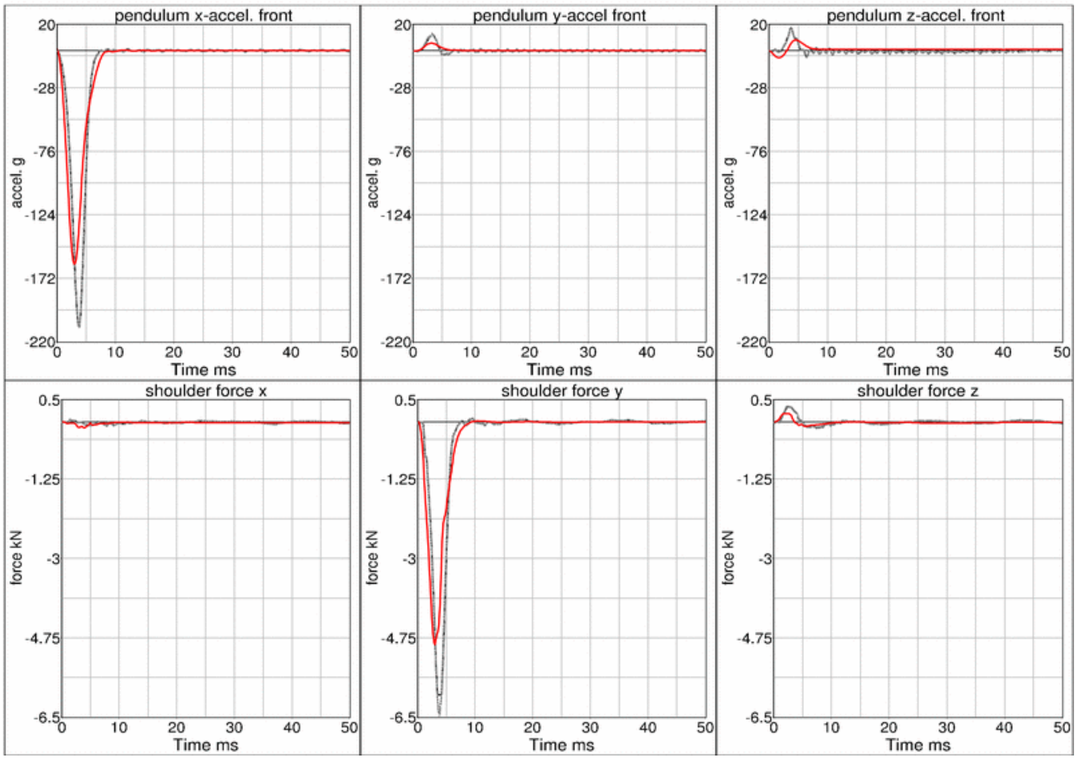


Figure 34: Results - Target point A, 4 m/s velocity, 48 degree load cell position

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

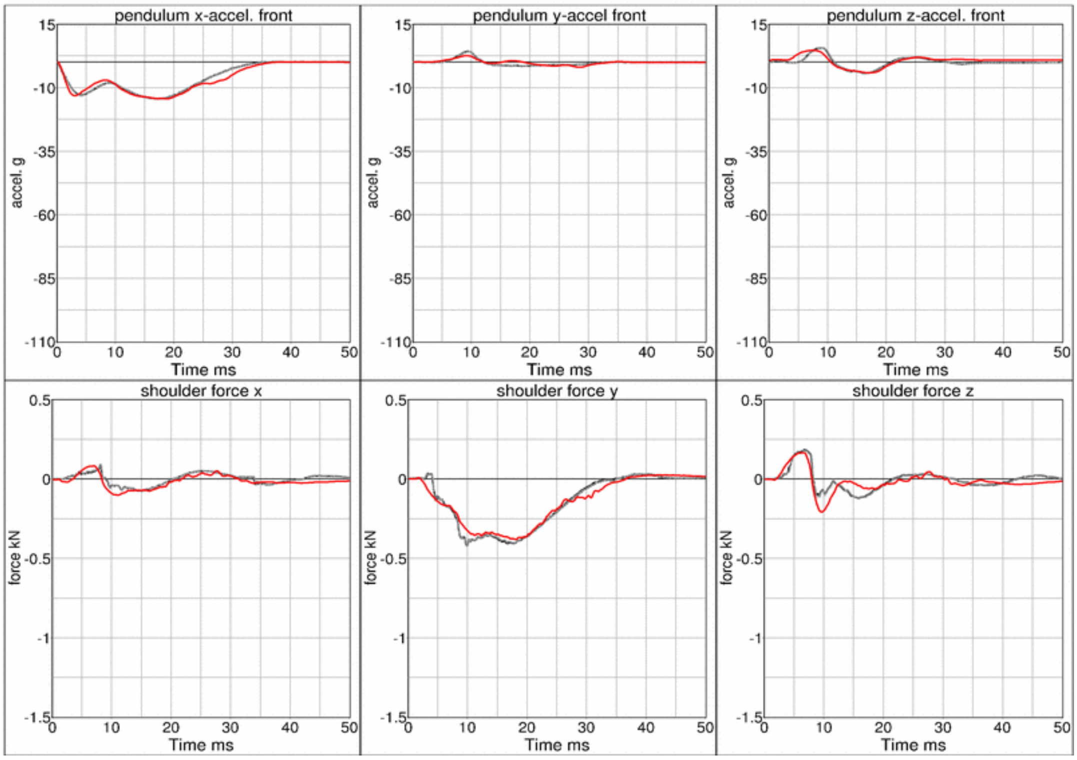


Figure 35: Results - Target point B, 2 m/s velocity, 48 degree load cell position

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

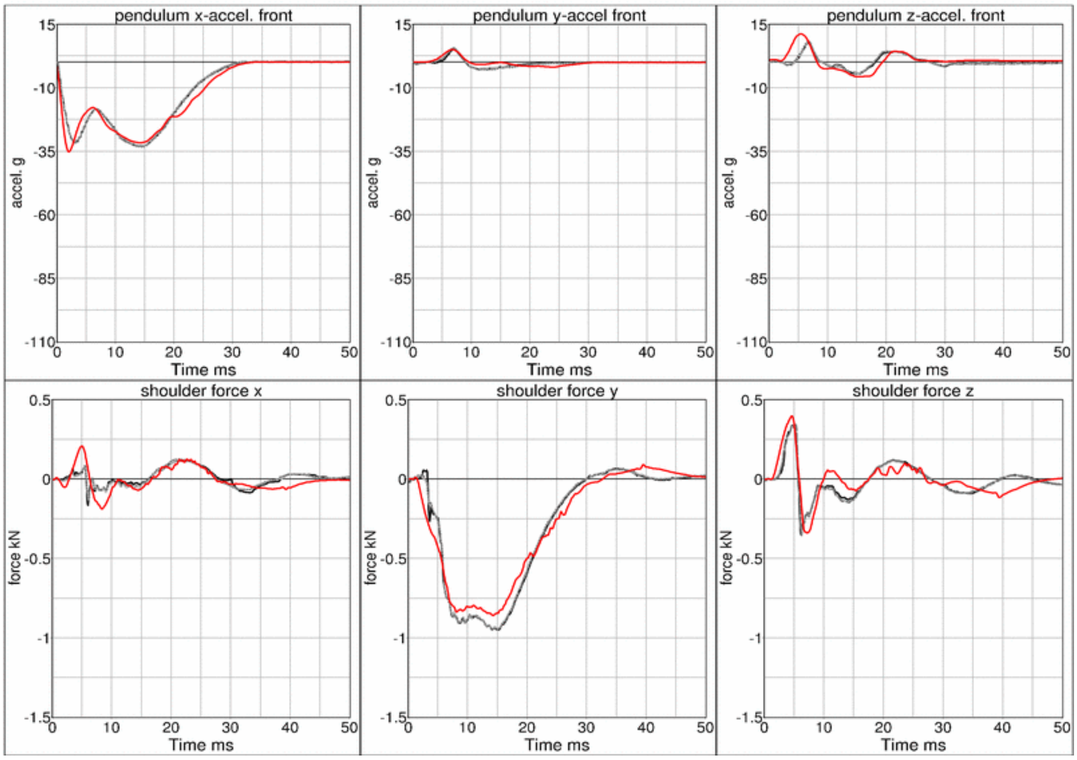


Figure 36: Results - Target point B, 4 m/s velocity, 48 degree load cell position

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

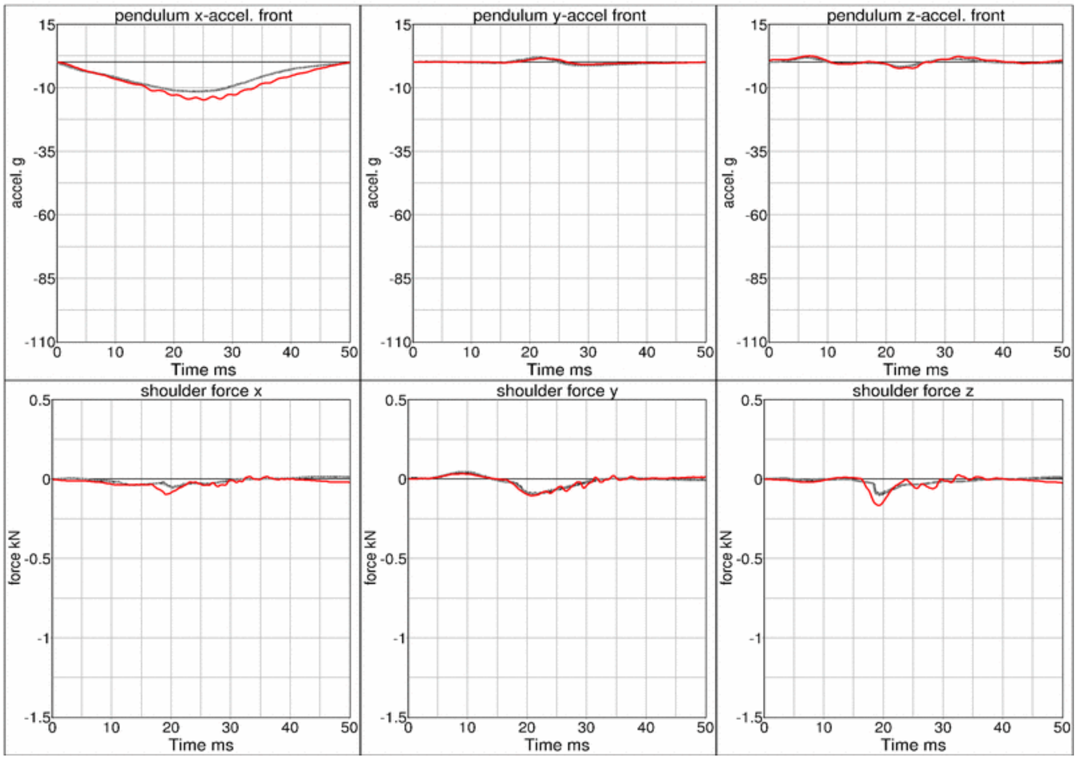


Figure 37: Results - Target point C, 2 m/s velocity, 48 degree load cell position

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

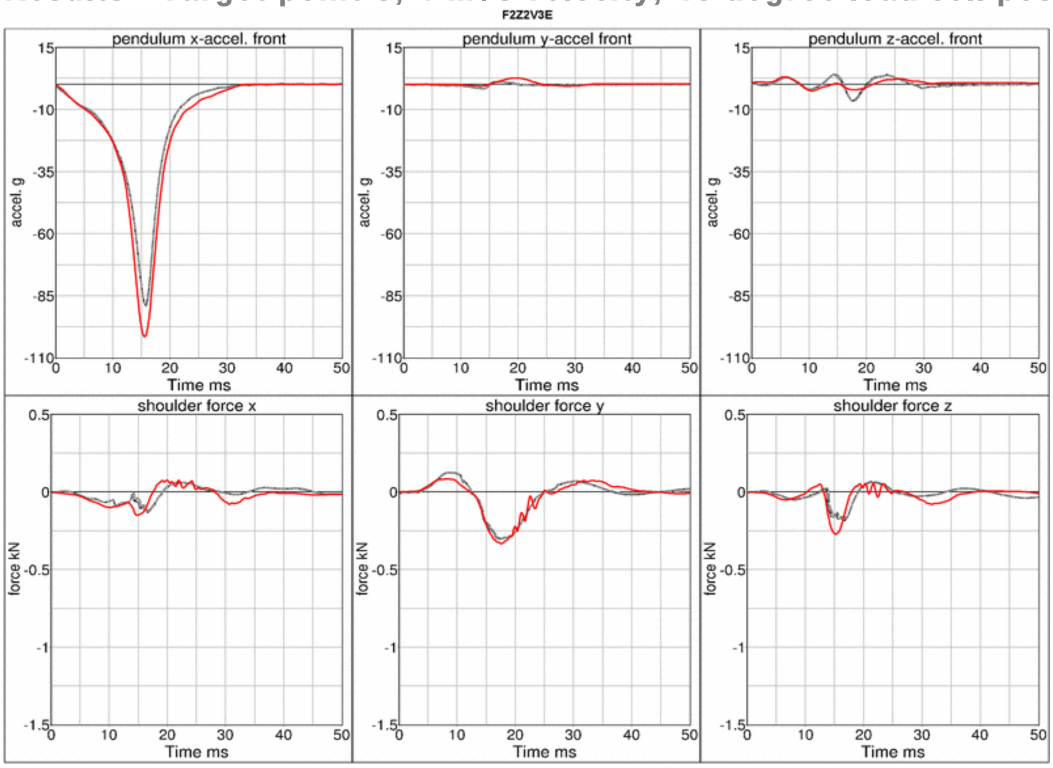


Figure 38: Results - Target point C, 4 m/s velocity, 48 degree load cell position

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

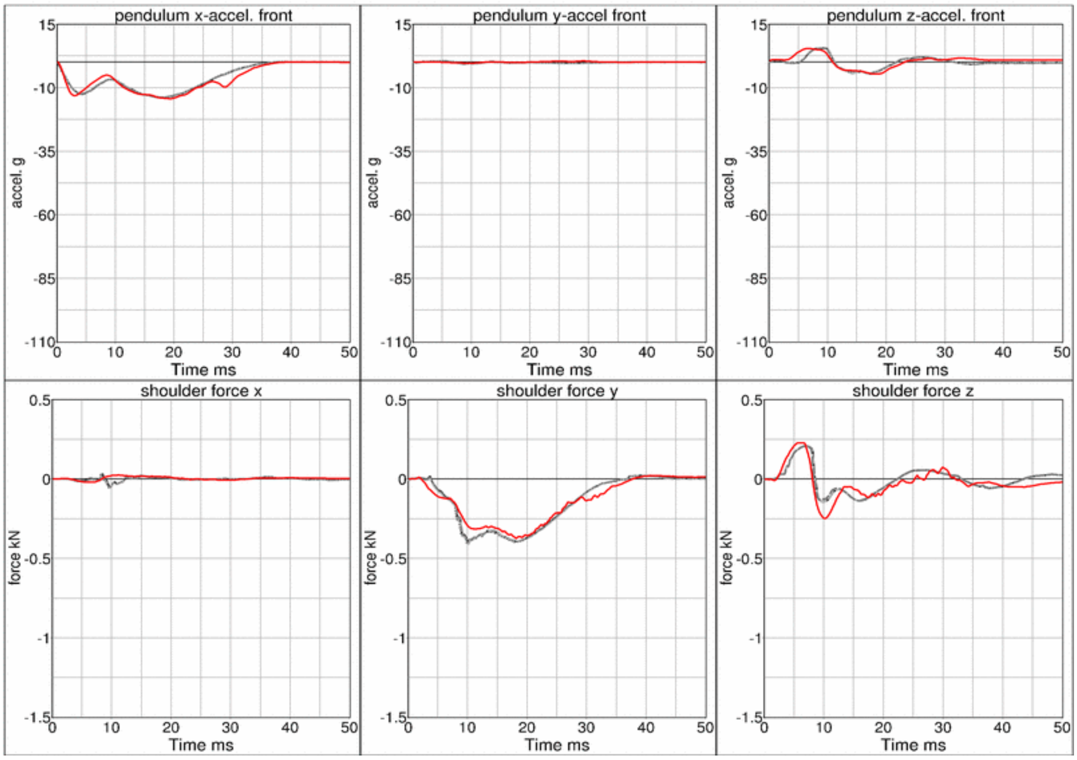


Figure 39: Results - Target point B, 2 m/s velocity, 8 degree load cell position

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

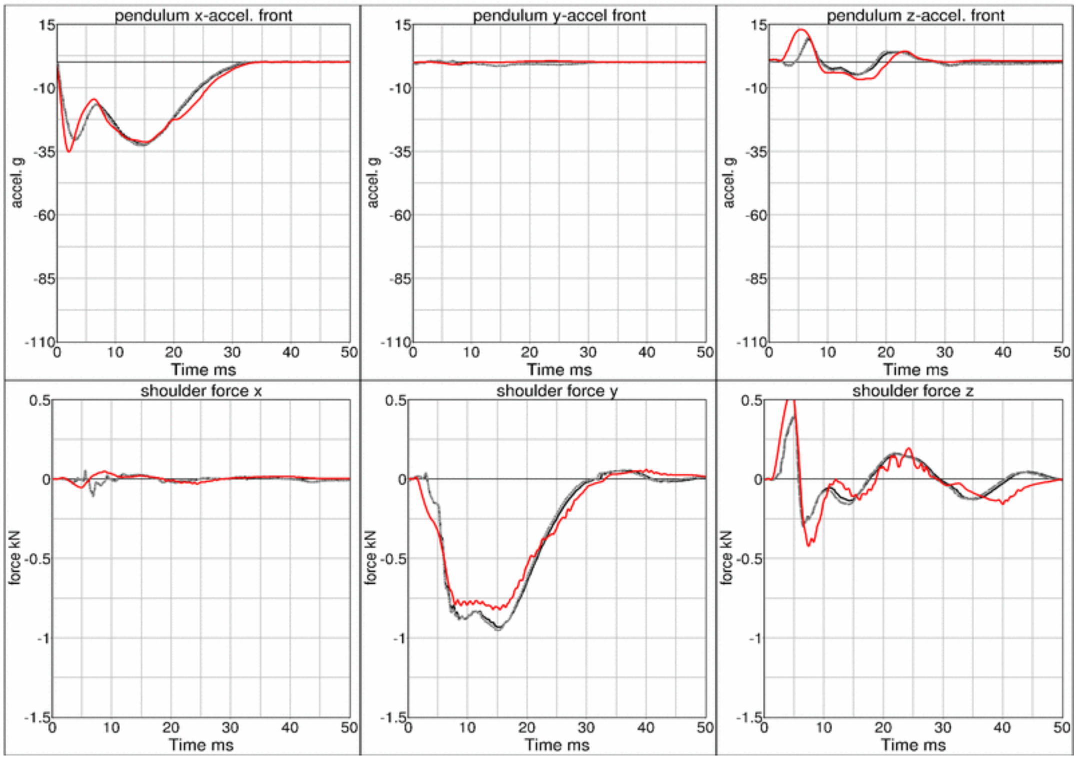


Figure 40: Results - Target point B, 4 m/s velocity, 8 degree load cell position

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

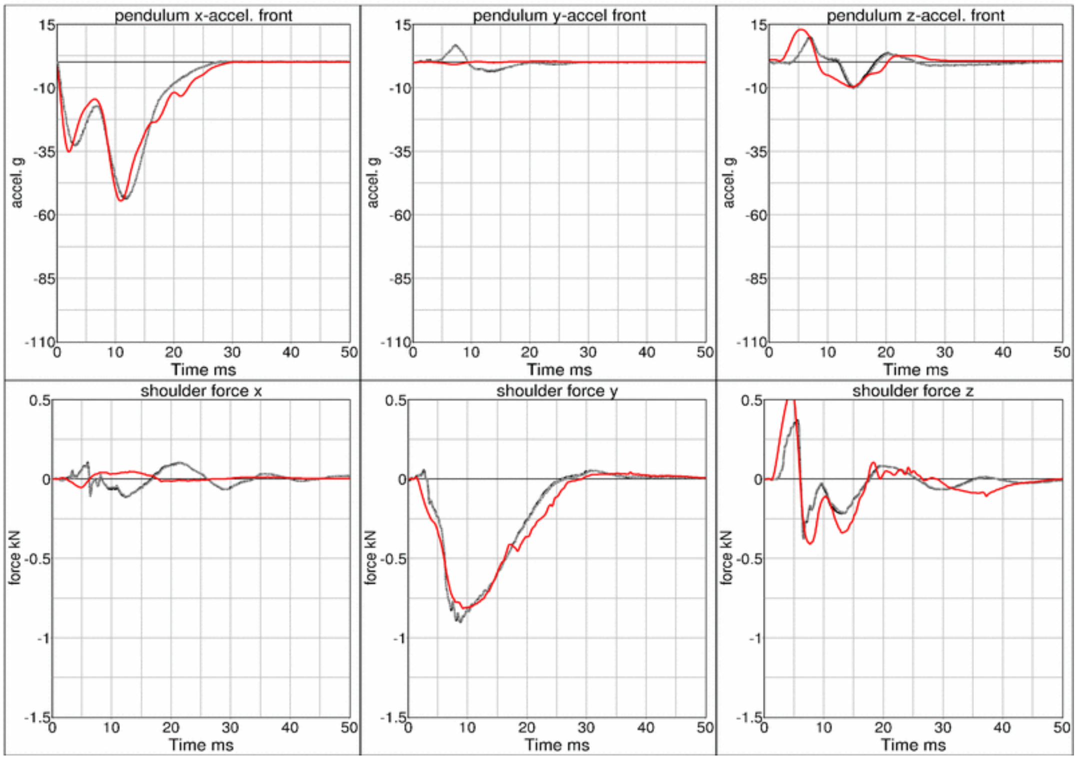


Figure 41: Results - Target point B, 4 m/s velocity, 8 degree load cell position, modified middle bearing

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

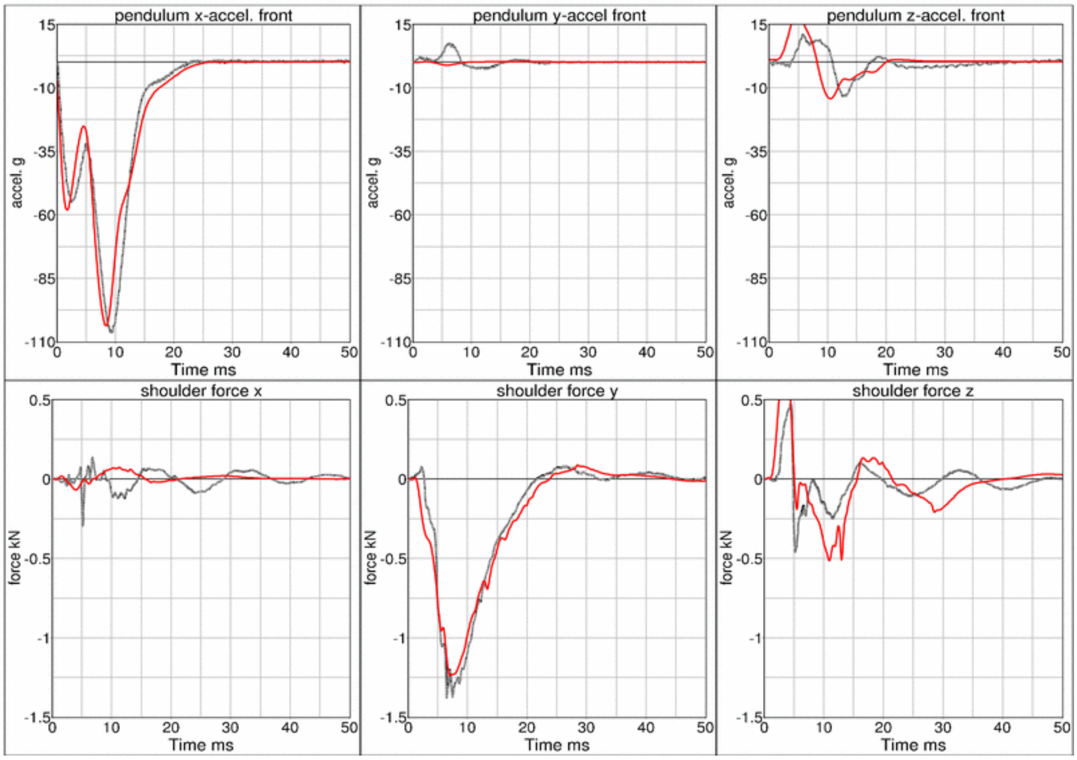


Figure 42: Results - Target point B, 6 m/s velocity, 8 degree load cell position, modified middle bearing

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:

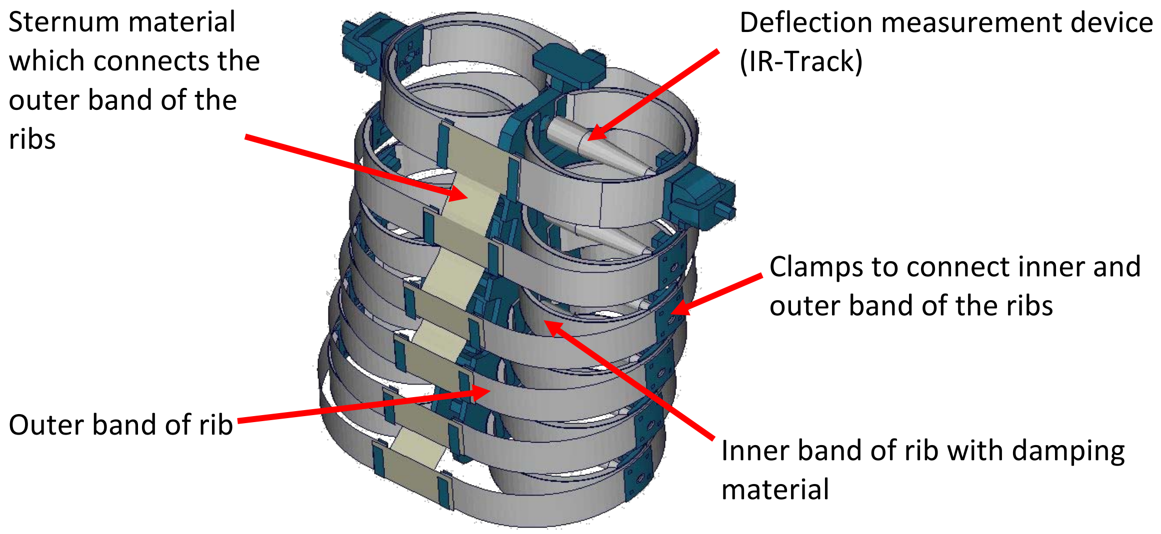


Figure 43: Thorax construction of WorldSID

8.1.3.1 Inner rib band without damping material

The inner rib bands of the shoulder and the third thorax rib are tested without the damping material. Here, a pendulum test is performed with two different velocities on the single rib band as depicted below.

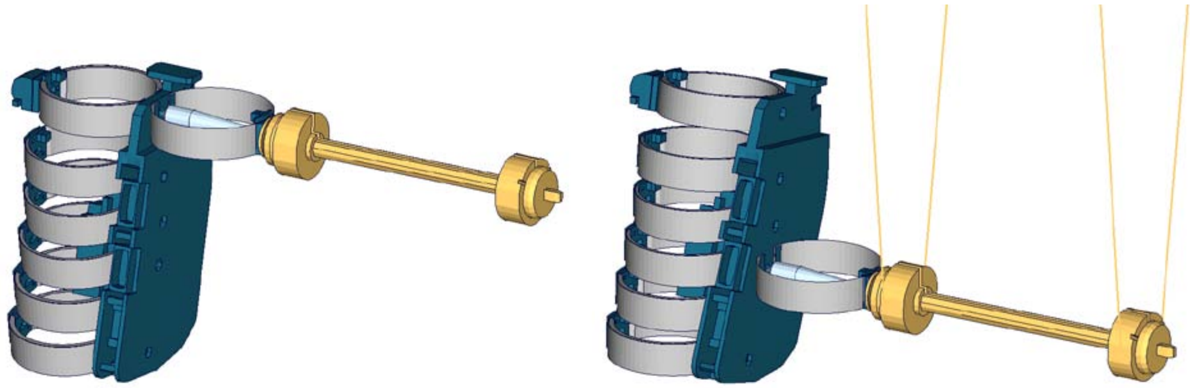


Figure 44: Rib test on inner band without damping material; Left: Shoulder rib; Right: Third thorax rib

The pendulum mass is 1.9 kg and a high and a low velocity are used. As results, the rib deflection (IR-Track), pendulum accelerations and the movement of the rib clamp from a video evaluation in global x- and y-direction are used.
The results of the tests are shown in the following pictures.

Shoulder rib inner band without damping material, low velocity

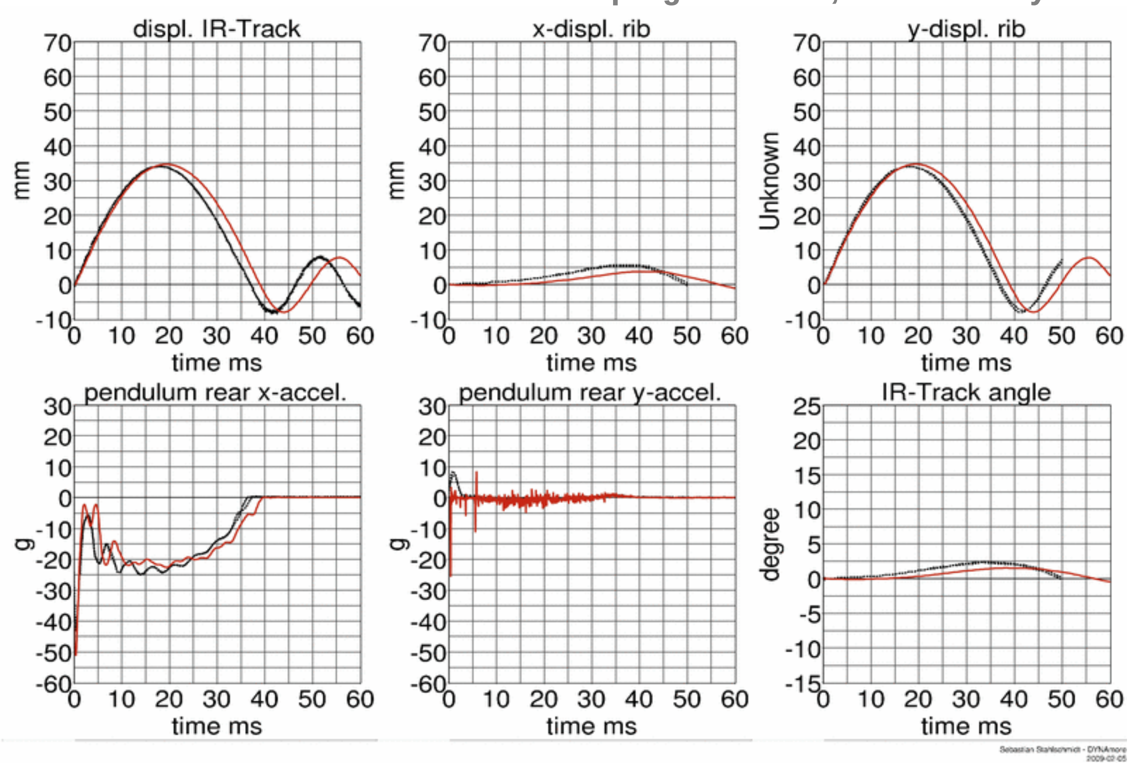


Figure 45: Shoulder rib test on inner band without damping material, low velocity

Shoulder rib inner band without damping material, high velocity

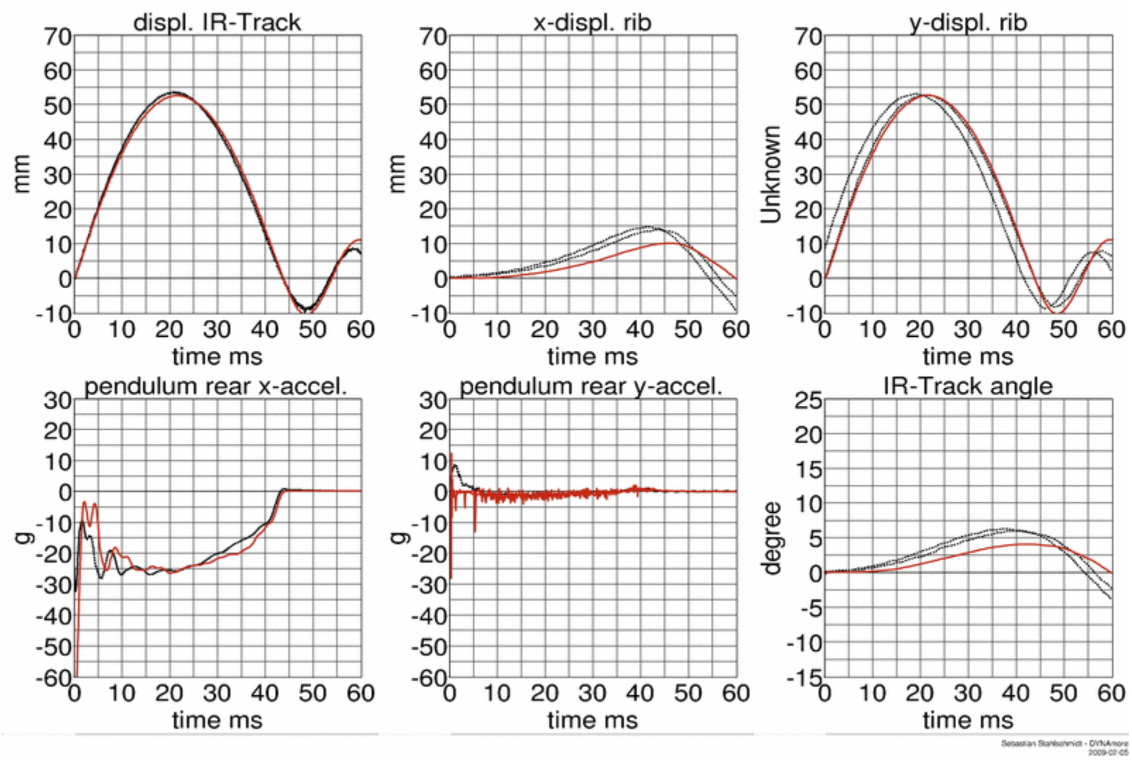


Figure 46: Shoulder rib test on inner band without damping material, high velocity

Third thorax rib inner band without damping material, low velocity

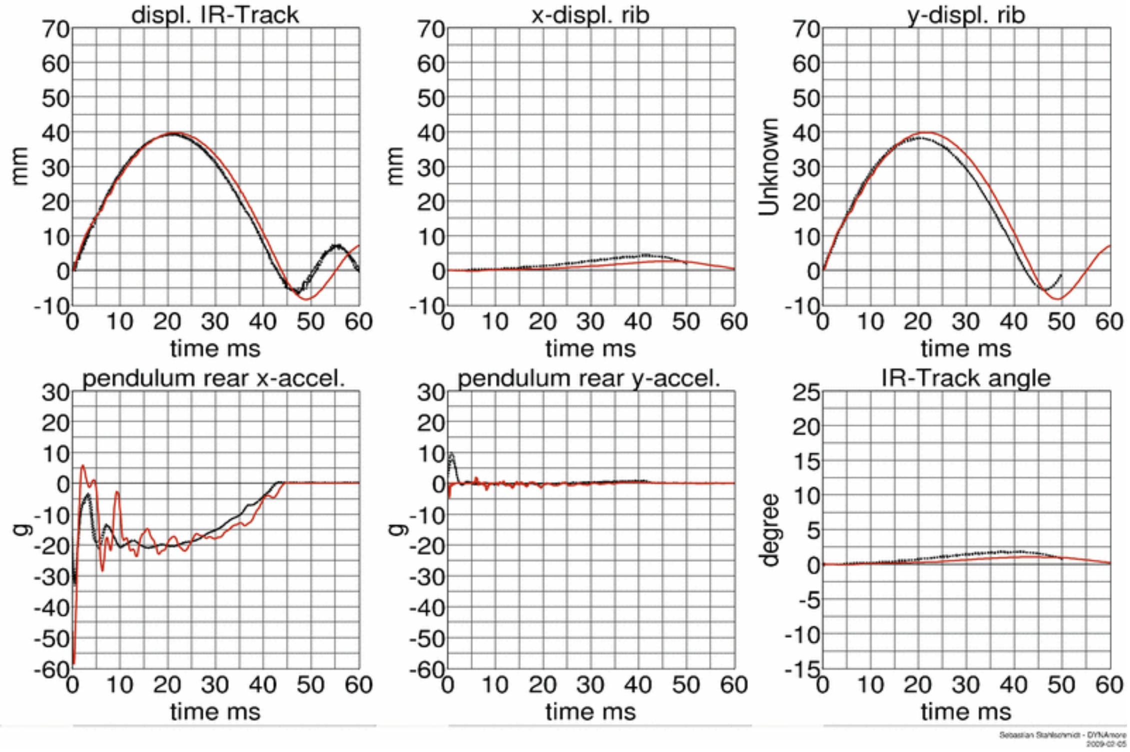


Figure 47: Third thorax rib test on inner band without damping material, low velocity

Third thorax rib inner band without damping material, high velocity

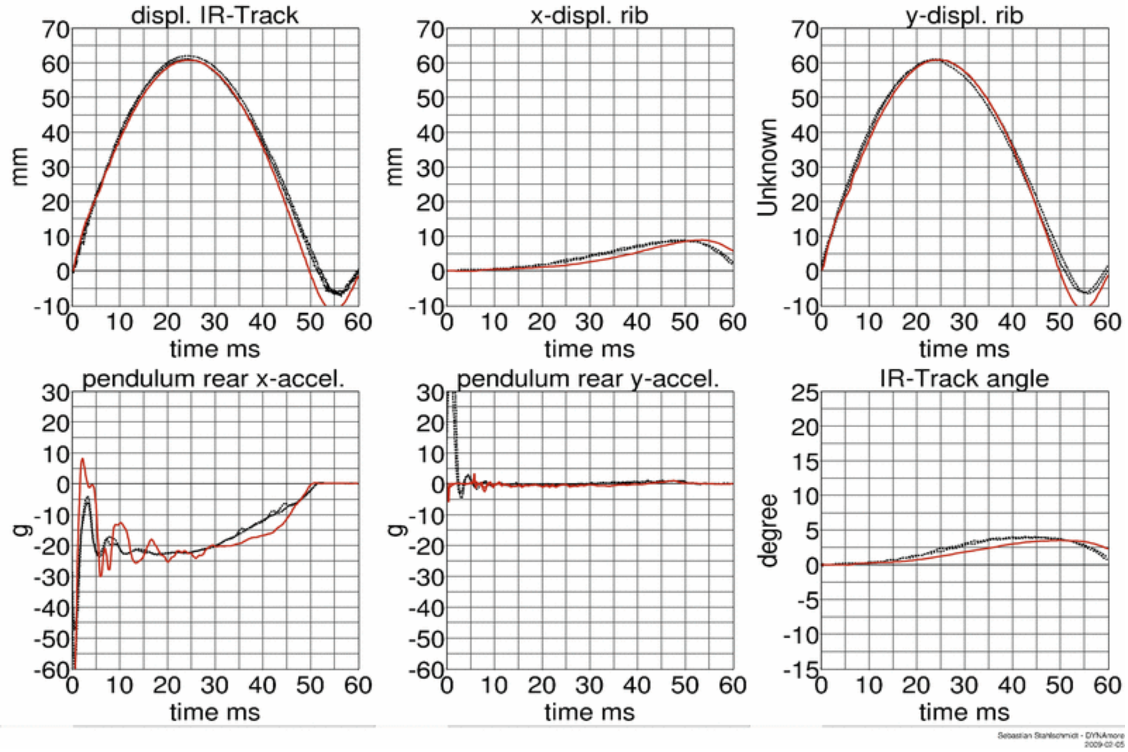


Figure 48: Third thorax rib test on inner band without damping material, high velocity

8.1.3.2 Inner rib band with damping material:

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:

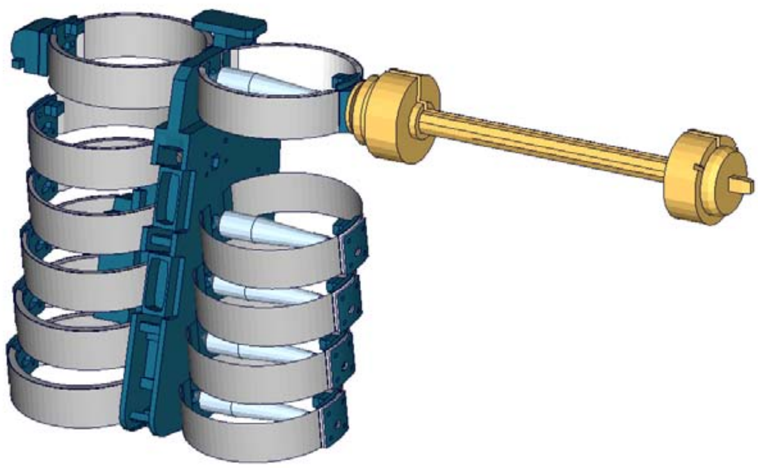


Figure 49: Shoulder rib test on inner band with damping material

Shoulder rib inner band with damping material, low velocity

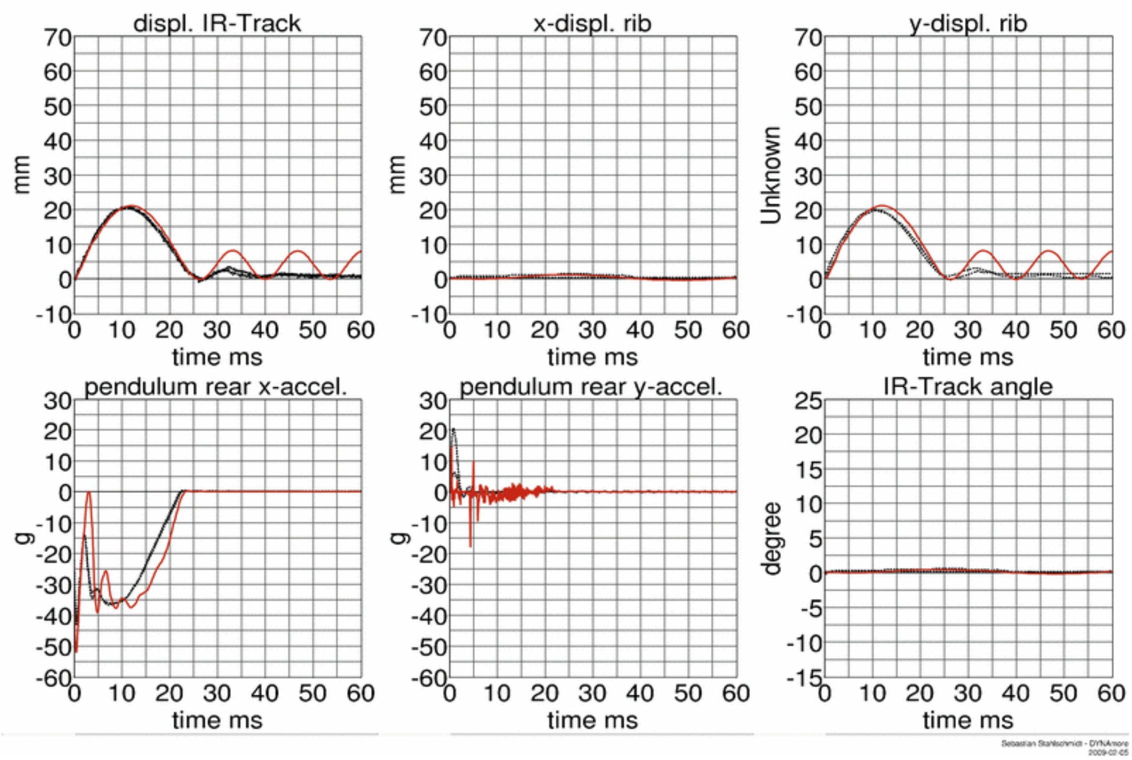


Figure 50: Shoulder rib test on inner band with damping material, low velocity

Shoulder rib inner band with damping material, high velocity

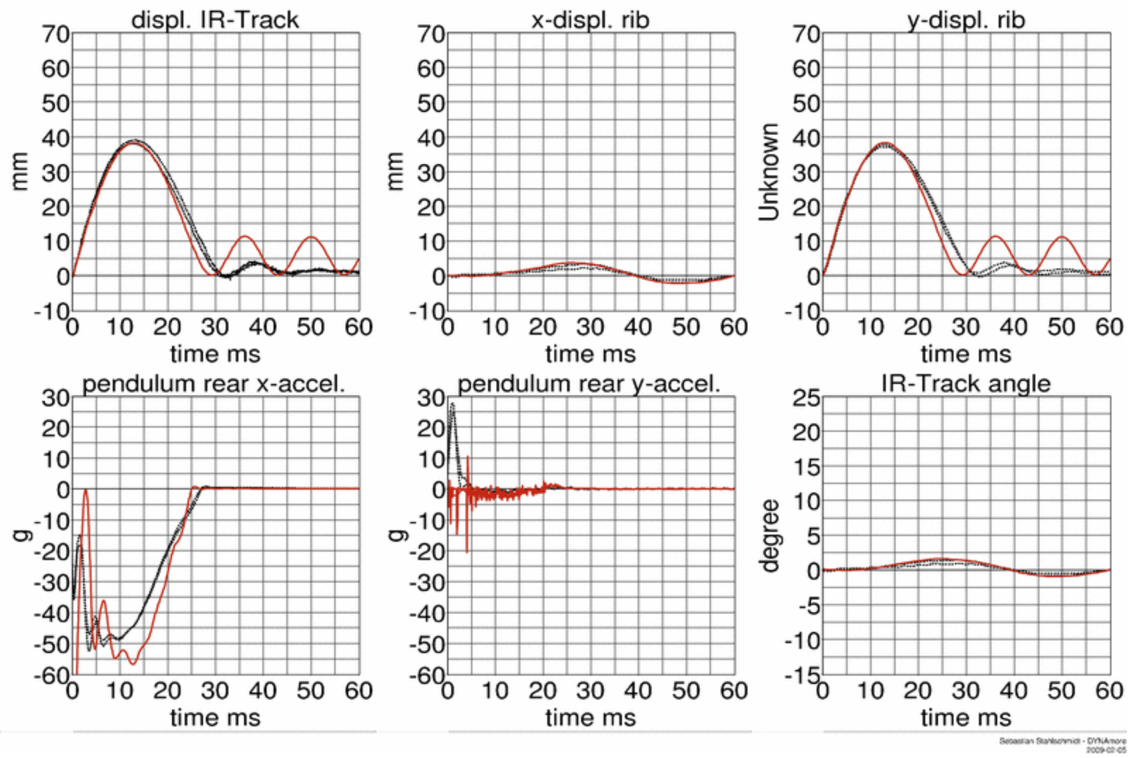


Figure 51: Shoulder rib test on inner band with damping material, high velocity

Third thorax rib:

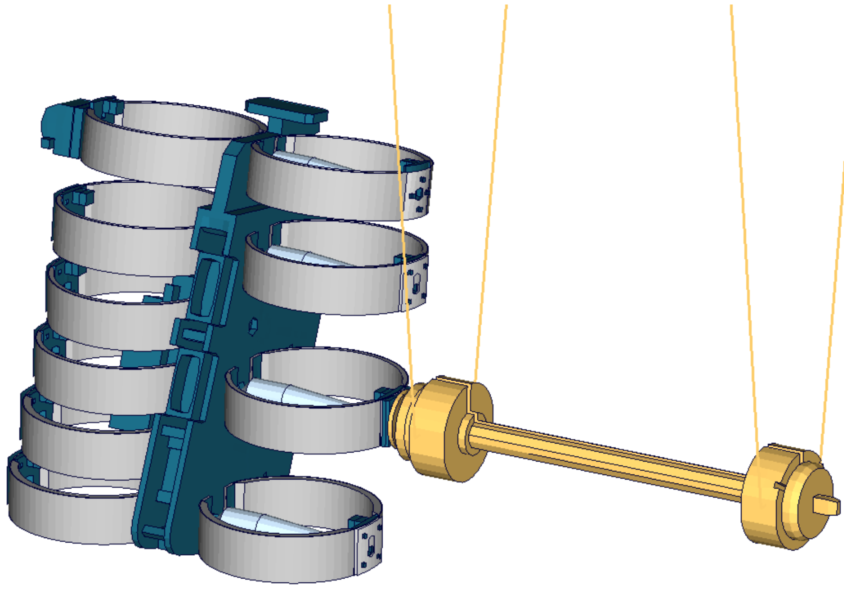


Figure 52: Third thorax rib test on inner band with damping material

Third thorax rib inner band with damping material, low velocity

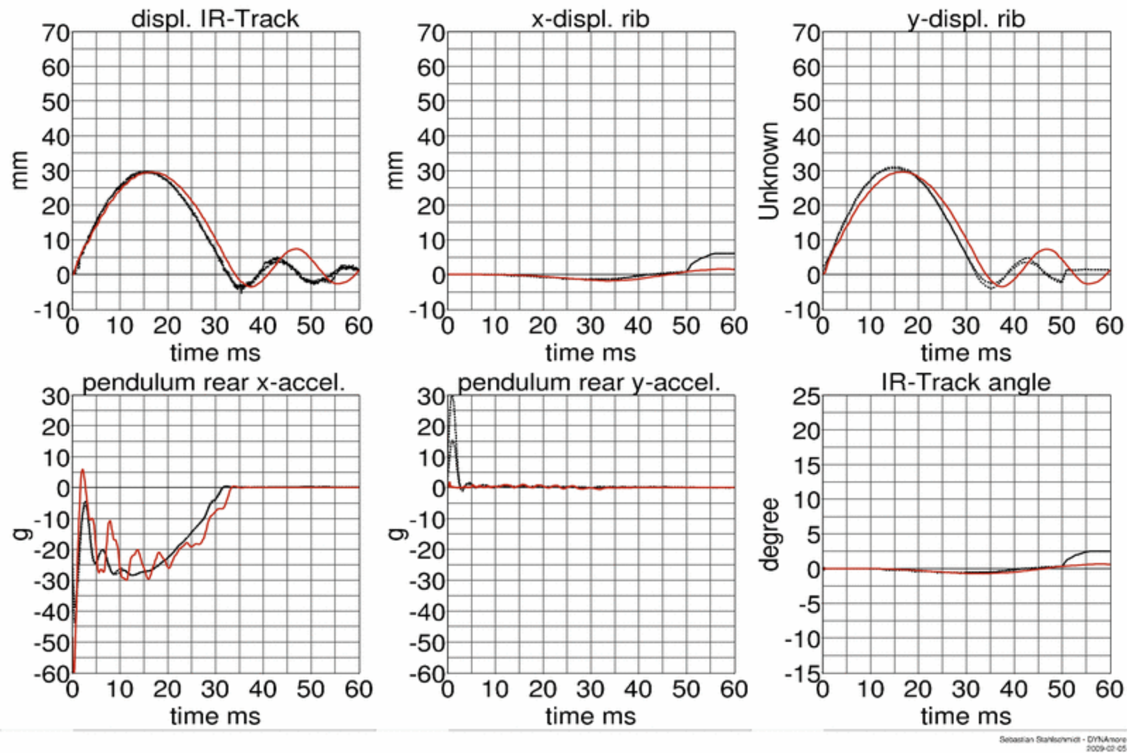


Figure 53: Shoulder rib test on inner band with damping material, low velocity

Third thorax rib inner band with damping material, high velocity

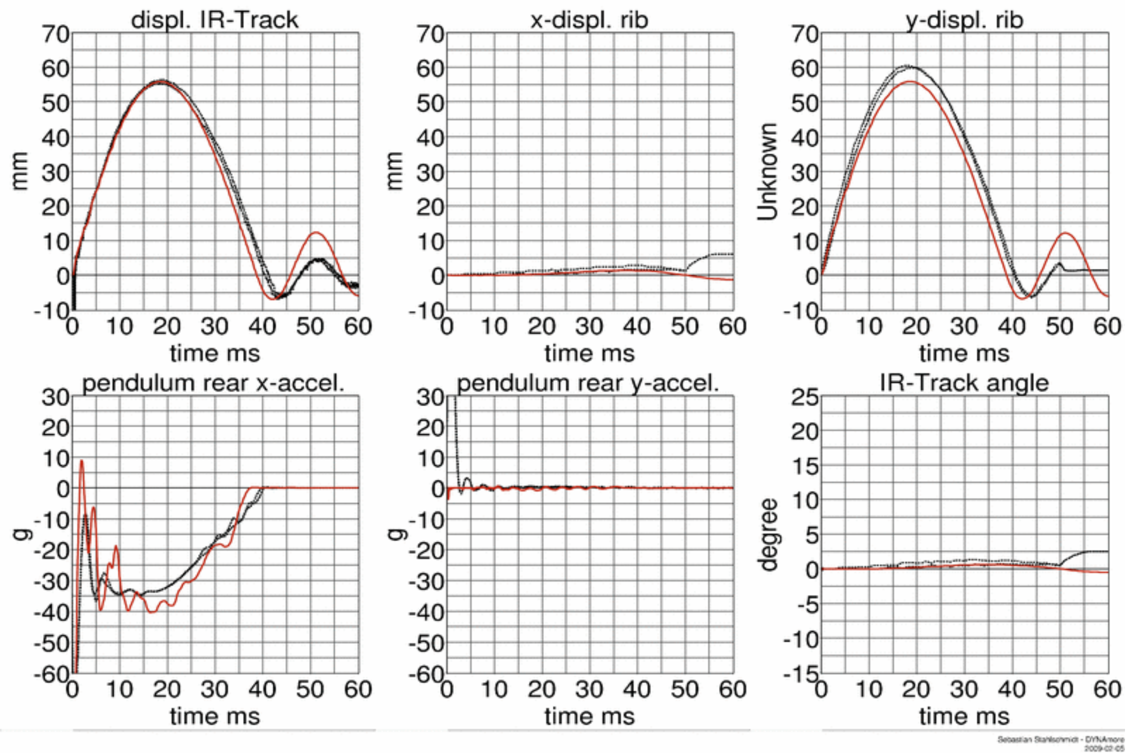


Figure 54: Shoulder rib test on inner band with damping material, high velocity

Second abdomen rib:

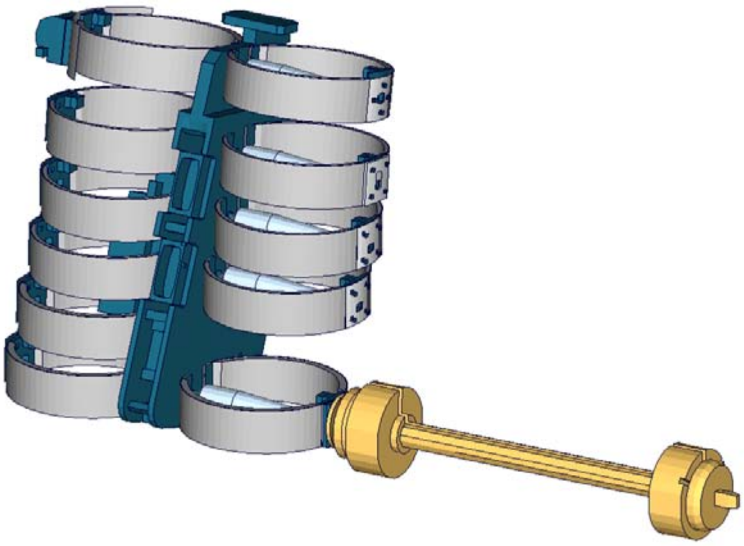


Figure 55: Second abdomen rib test on inner band with damping material.

Second abdomen rib inner band with damping material, low velocity

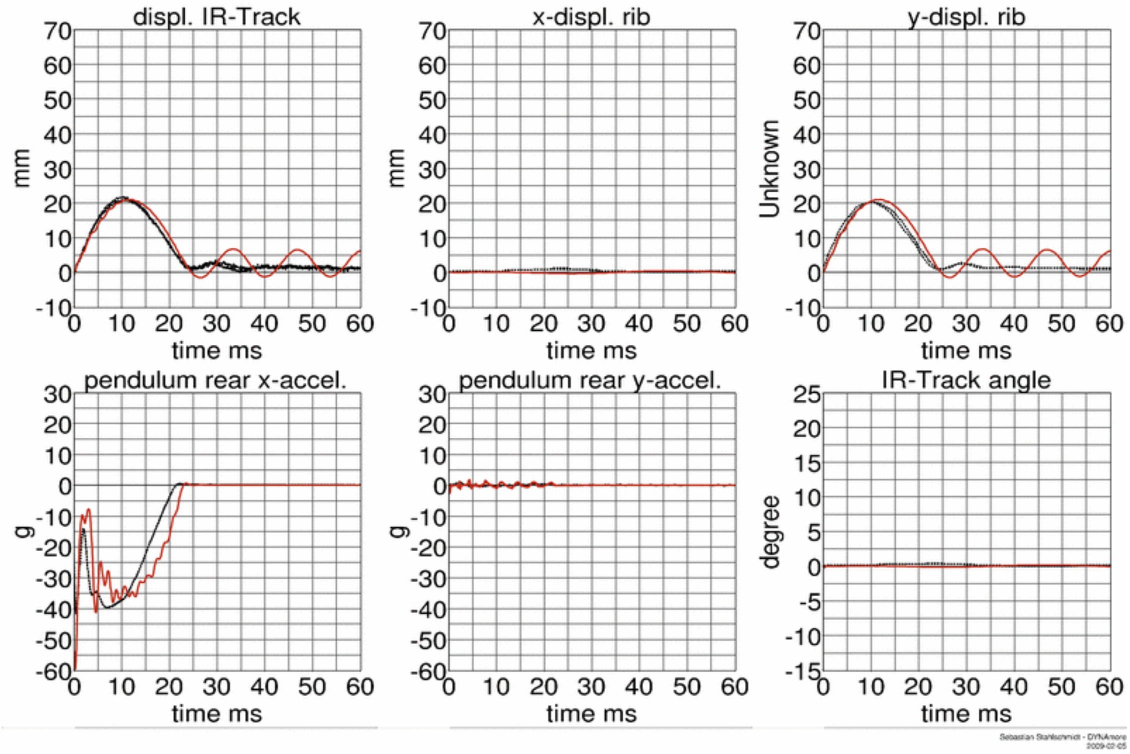


Figure 56: Second abdomen rib test on inner band with damping material, low velocity

Second abdomen rib inner band with damping material, high velocity

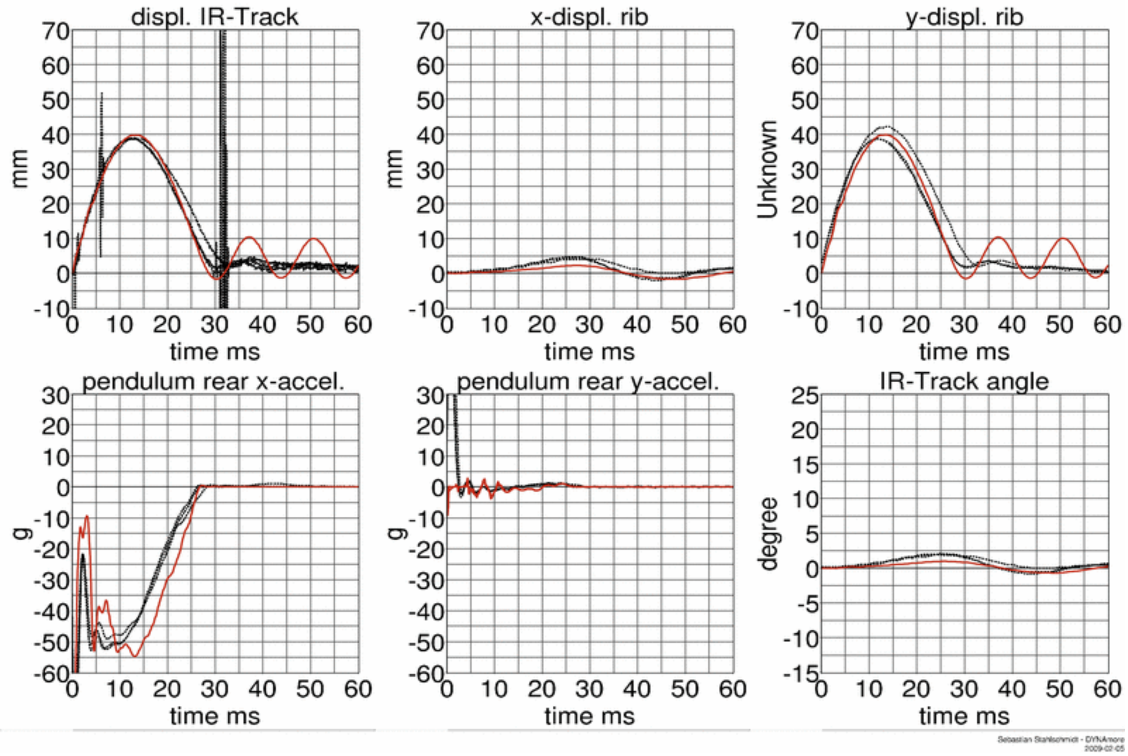


Figure 57: Second abdomen rib test on inner band with damping material, high velocity

8.1.3.3 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:

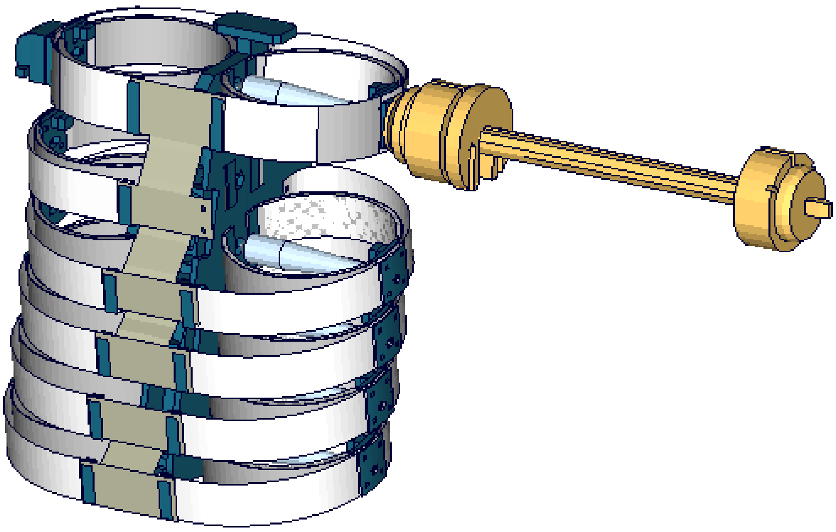


Figure 58: Shoulder rib outer band test

Shoulder rib outer band - low velocity, low mass

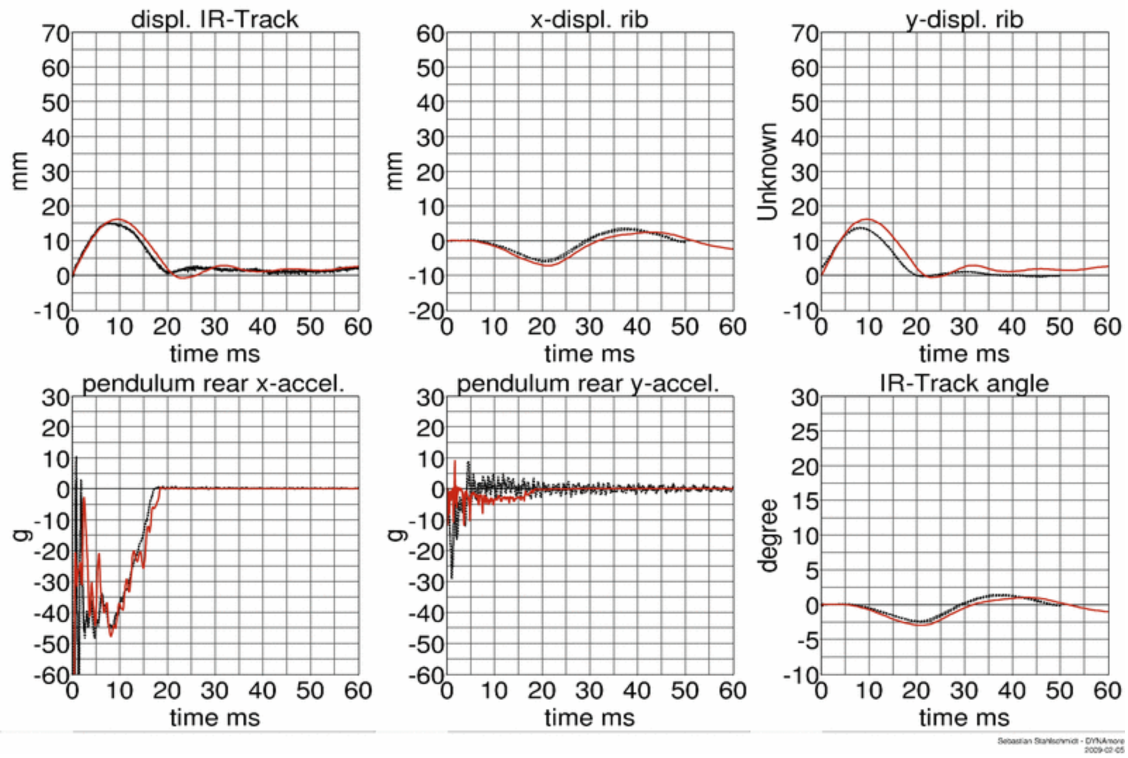


Figure 59: Shoulder rib test on outer band - low velocity and low mass

Shoulder rib outer band - low velocity, high mass

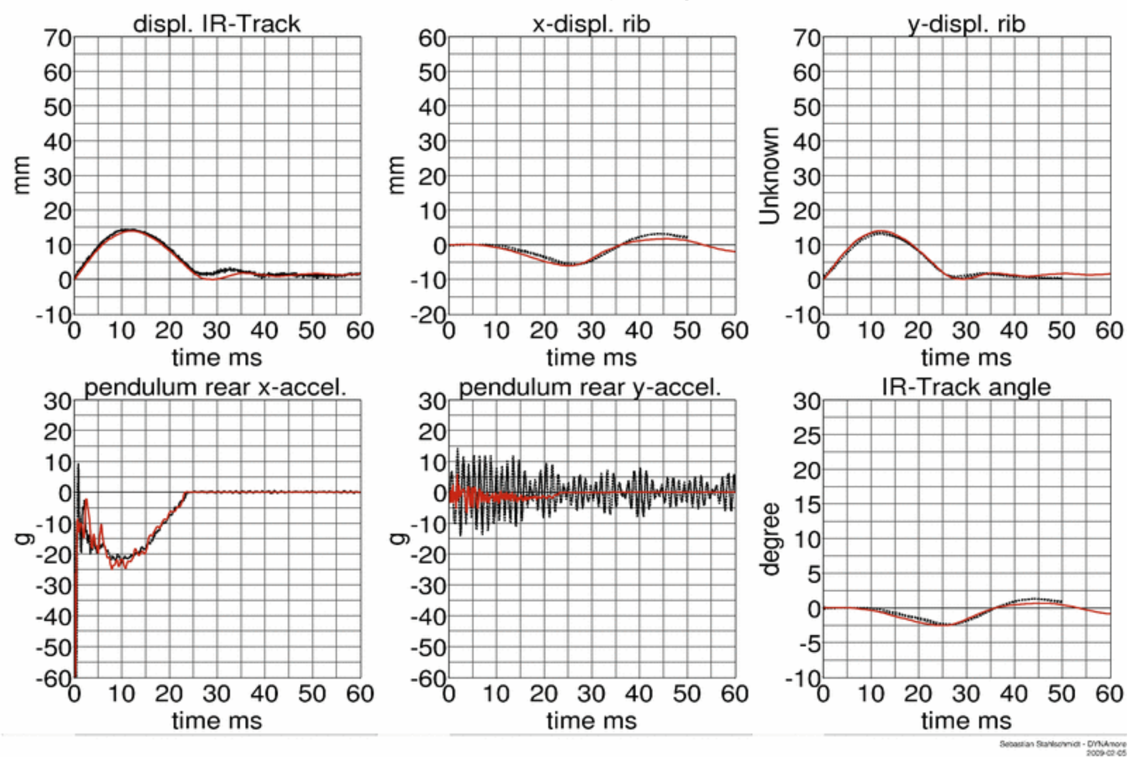


Figure 60: Shoulder rib test on outer band - low velocity and high mass

Shoulder rib outer band - high velocity, low mass

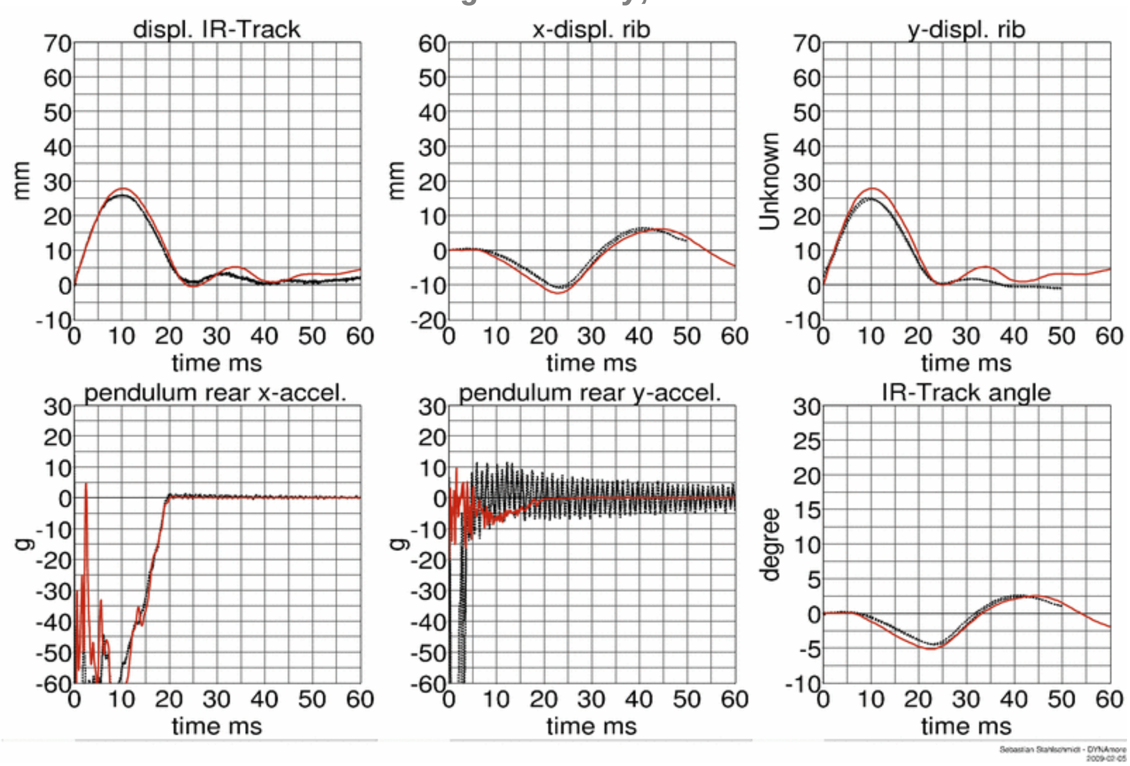


Figure 61: Shoulder rib test on outer band - high velocity and low mass

Shoulder rib outer band - high velocity, high mass

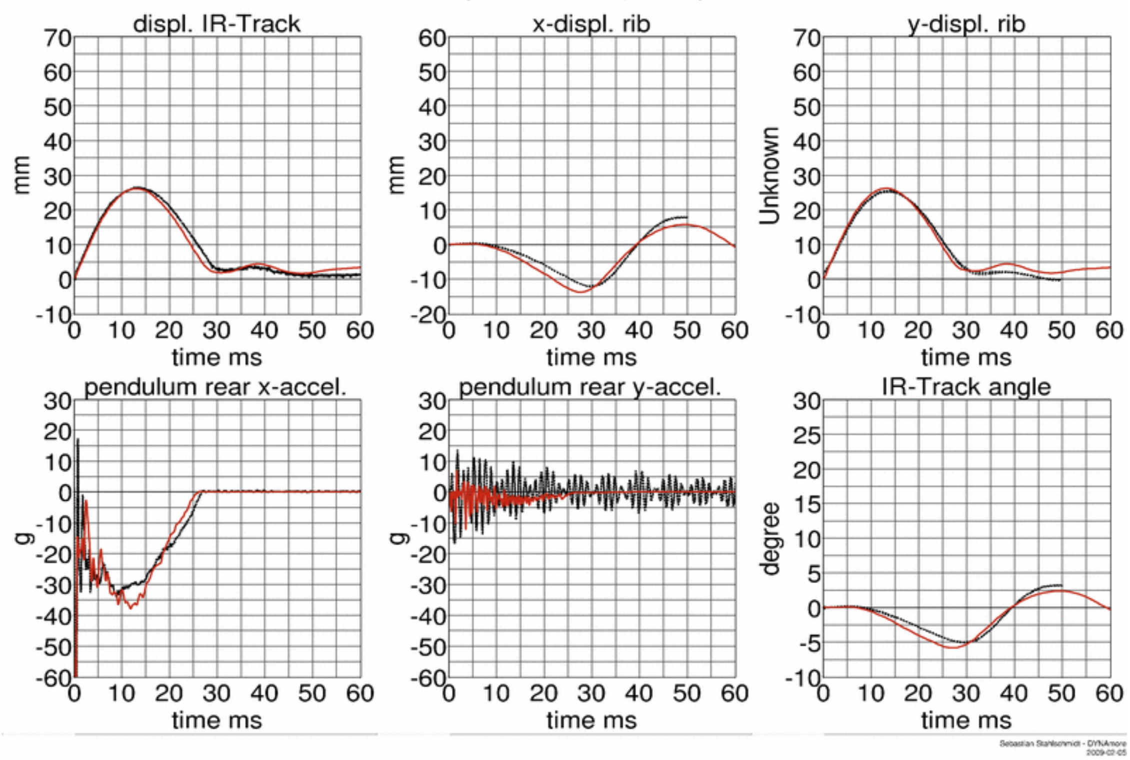


Figure 62: Shoulder rib test on outer band - high velocity and high mass

First thorax rib:

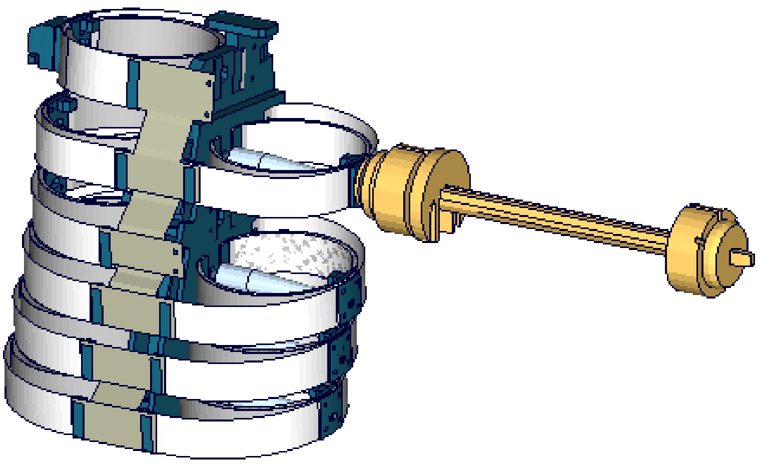


Figure 63: First thorax rib outer band test

First thorax rib outer band - low velocity, low mass

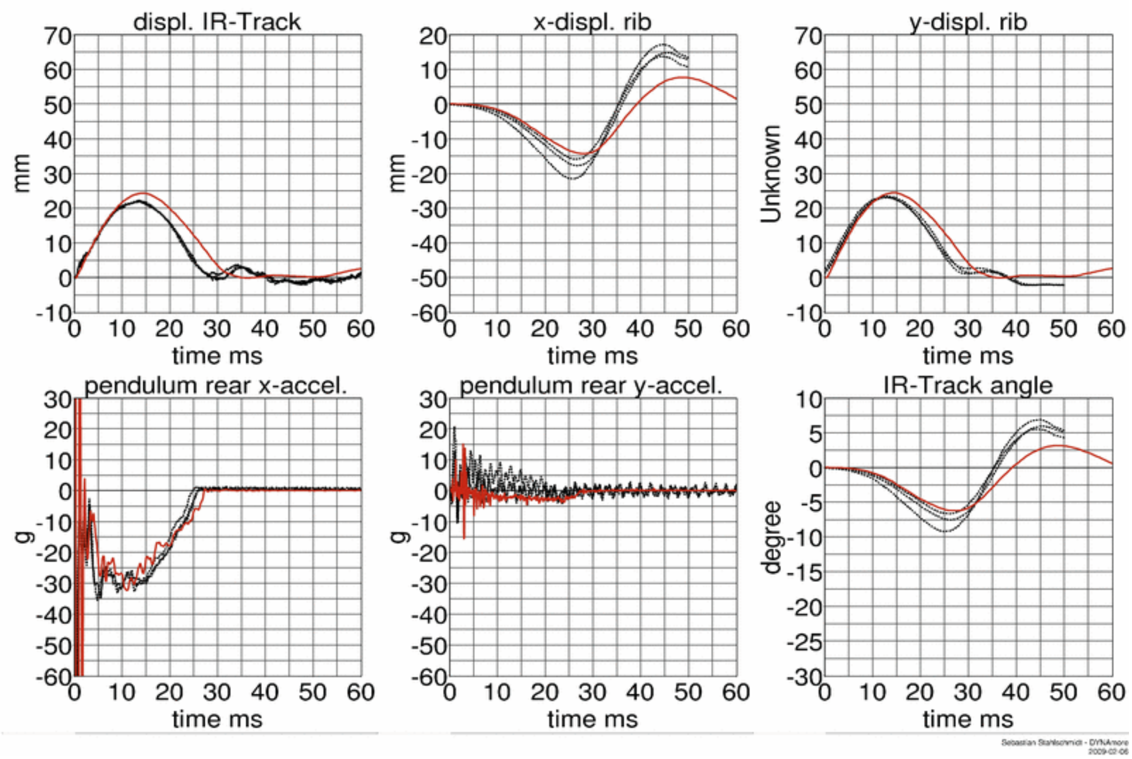


Figure 64: First thorax rib test on outer band - low velocity and low mass

First thorax rib outer band - low velocity, high mass

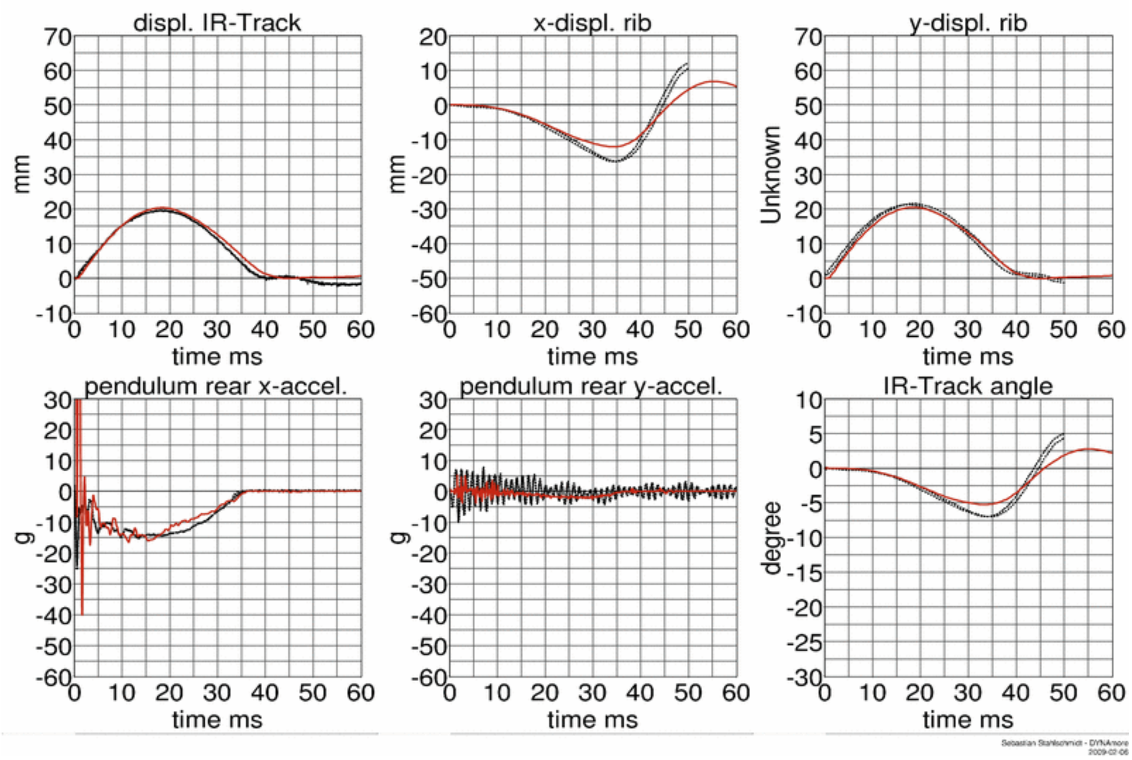


Figure 65: First thorax rib test on outer band - low velocity and high mass

First thorax rib outer band - middle velocity, low mass

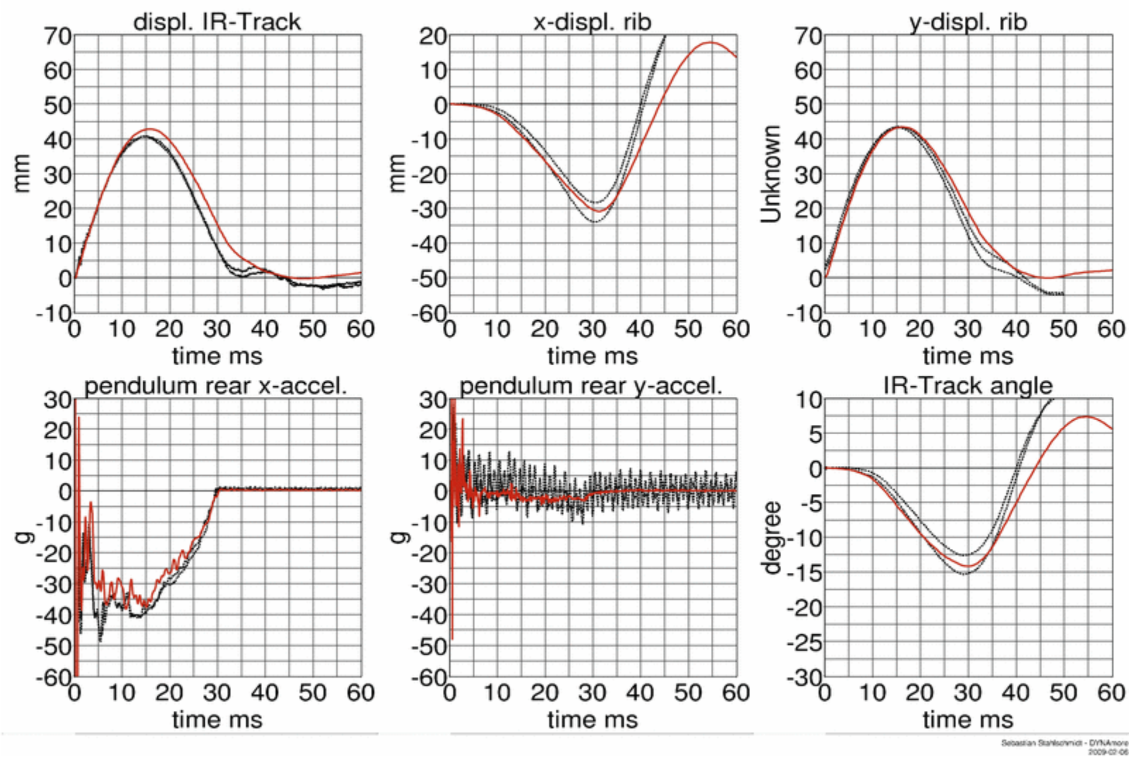


Figure 66: First thorax rib test on outer band - middle velocity and low mass

First thorax rib outer band - middle velocity, high mass

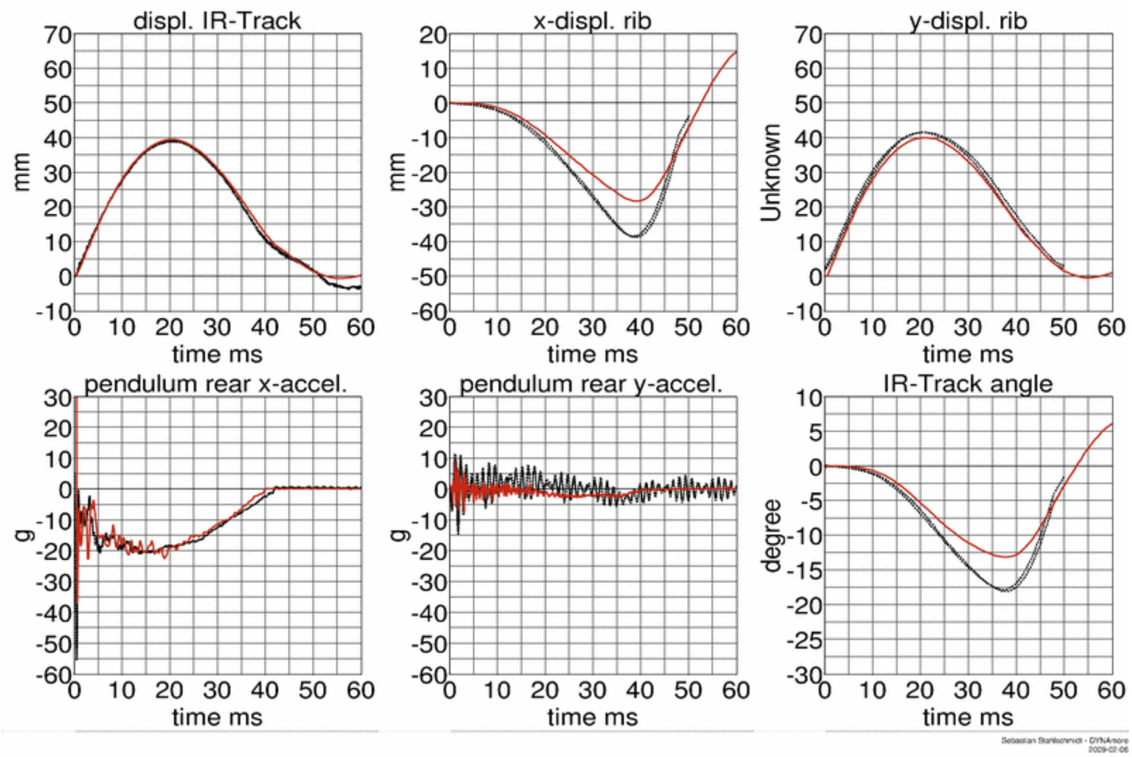


Figure 67: First thorax rib test on outer band - middle velocity and high mass

First thorax rib outer band - high velocity, low mass

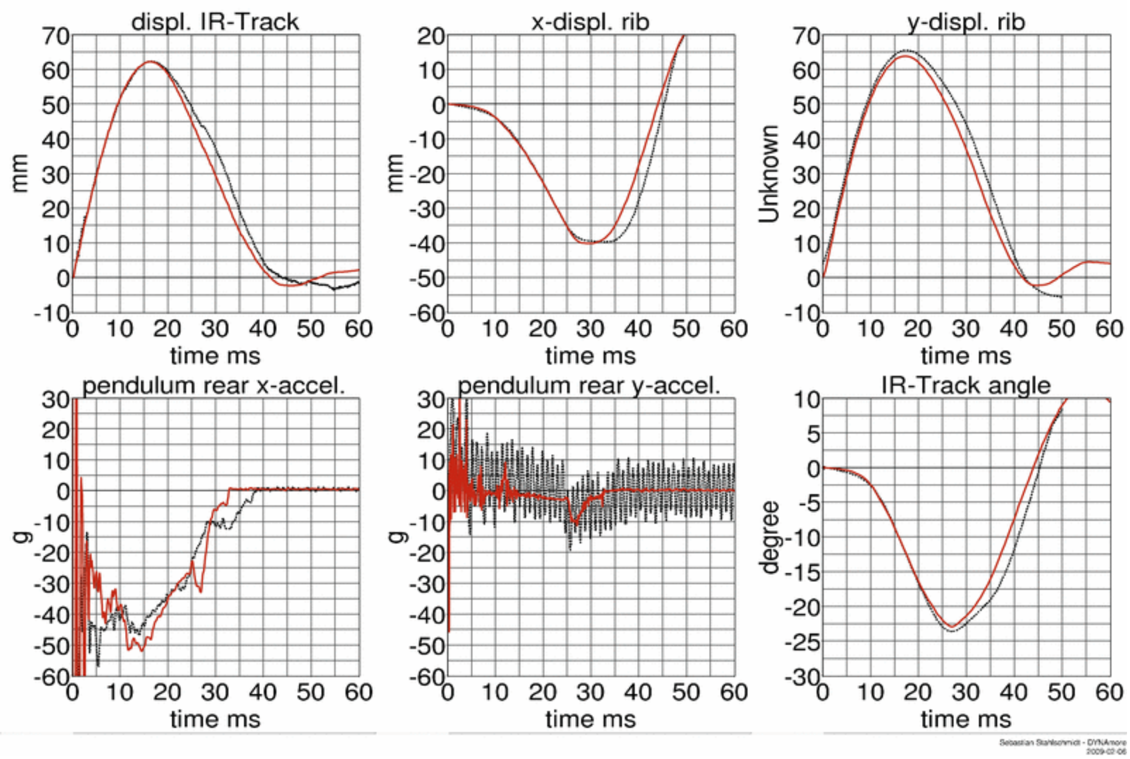


Figure 68: First thorax rib test on outer band - high velocity and low mass

First thorax rib outer band - high velocity, high mass

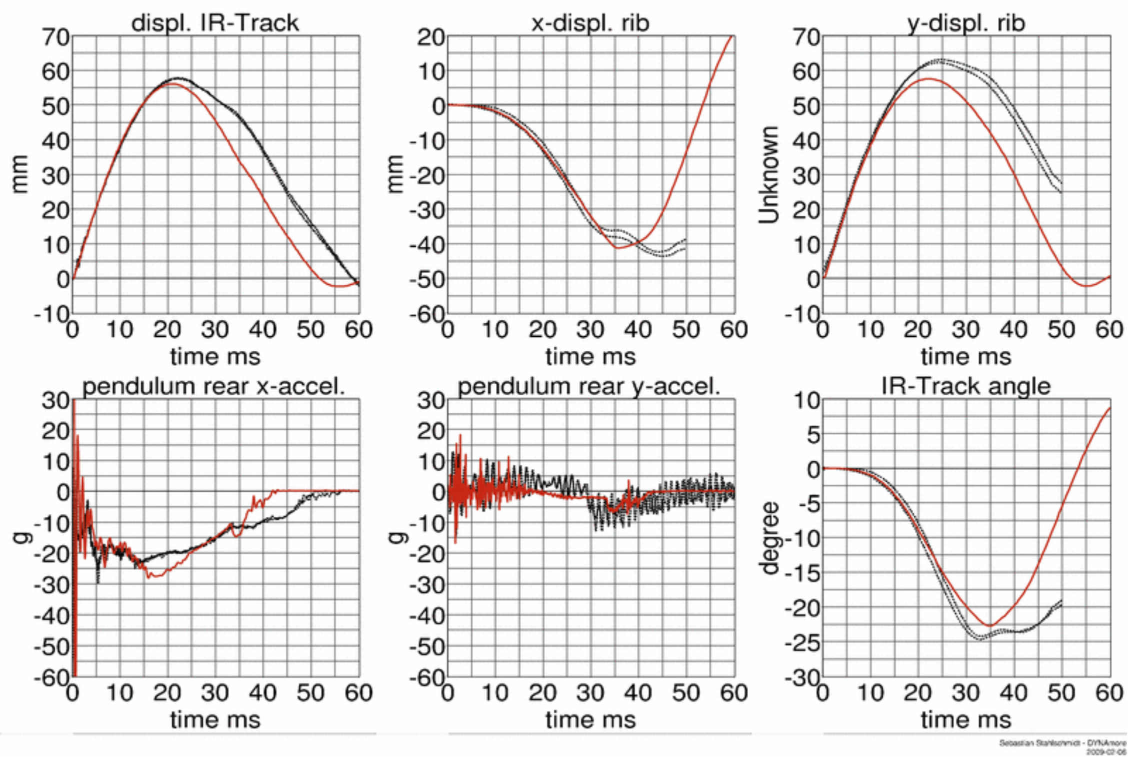


Figure 69: First thorax rib test on outer band - high velocity and high mass

Third thorax rib:

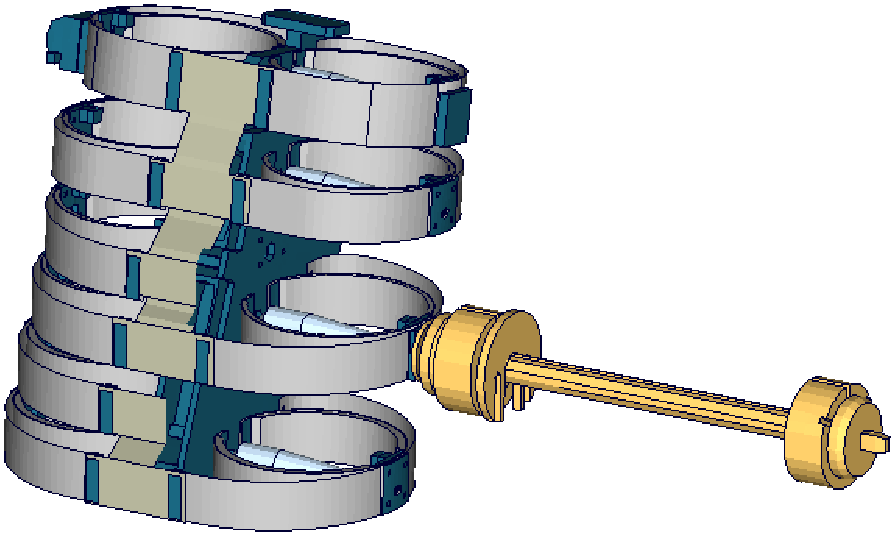


Figure 70: Third thorax rib outer band test

Third thorax rib outer band - low velocity, low mass

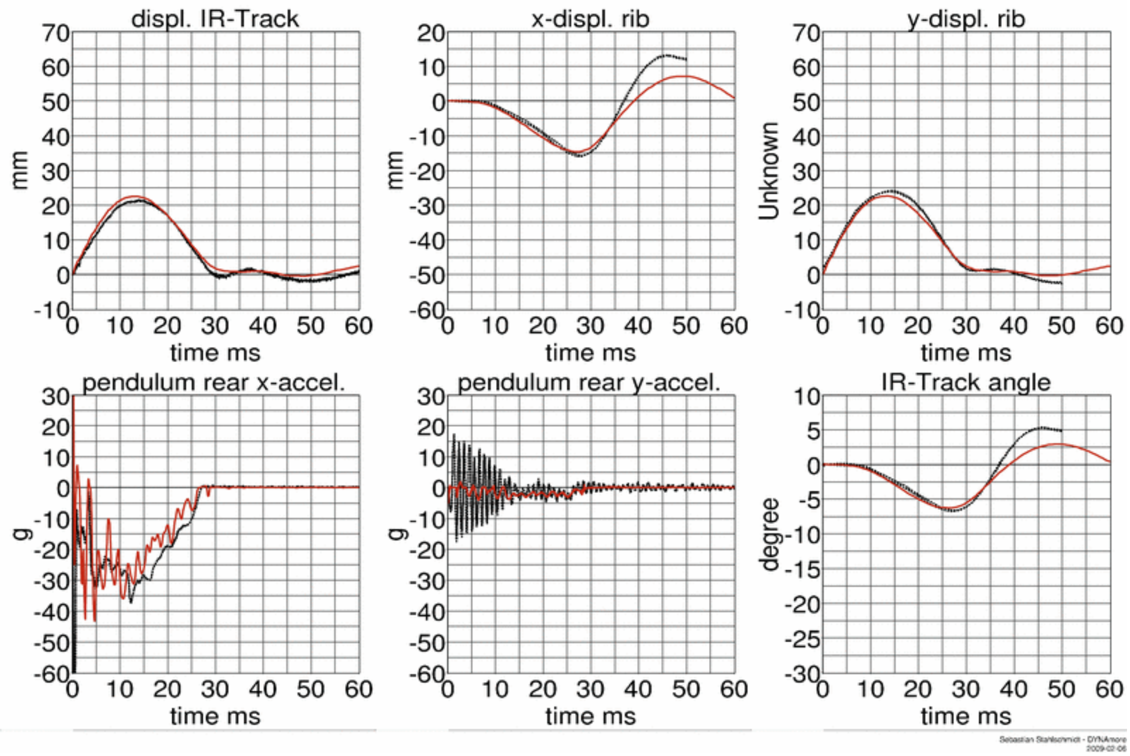


Figure 71: Third thorax rib test on outer band - low velocity and low mass

Third thorax rib outer band - low velocity, high mass

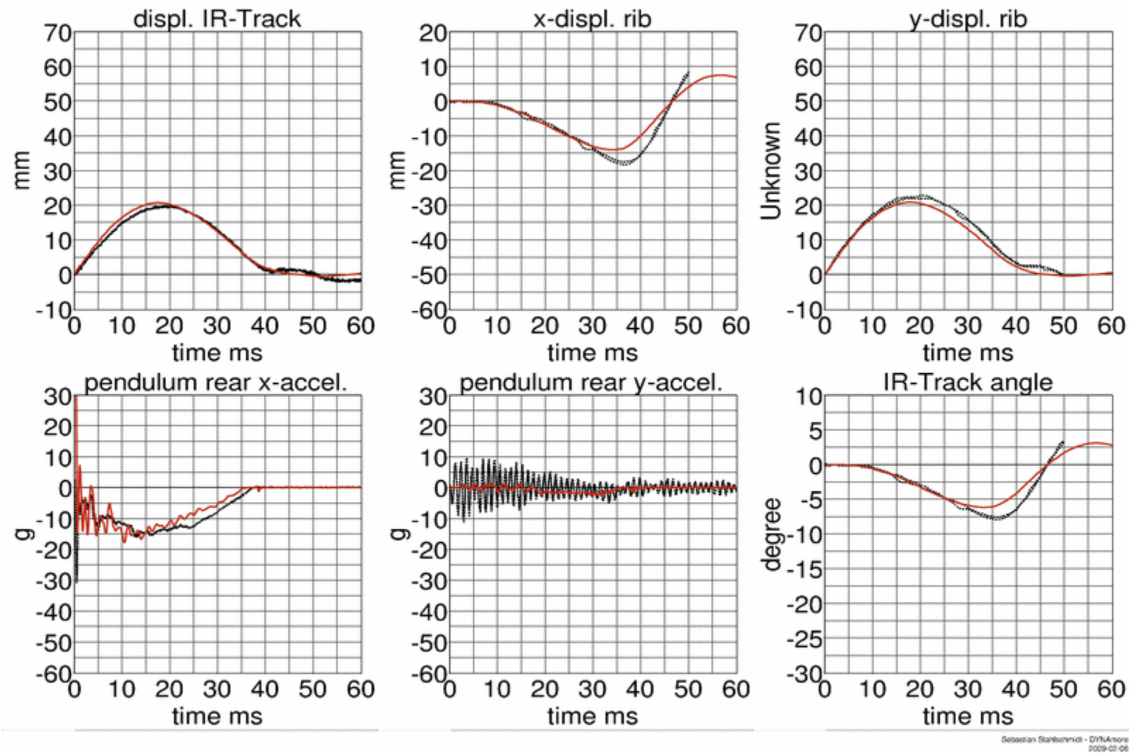


Figure 72: Third thorax rib test on outer band - low velocity and high mass

Third thorax rib outer band - high velocity, low mass

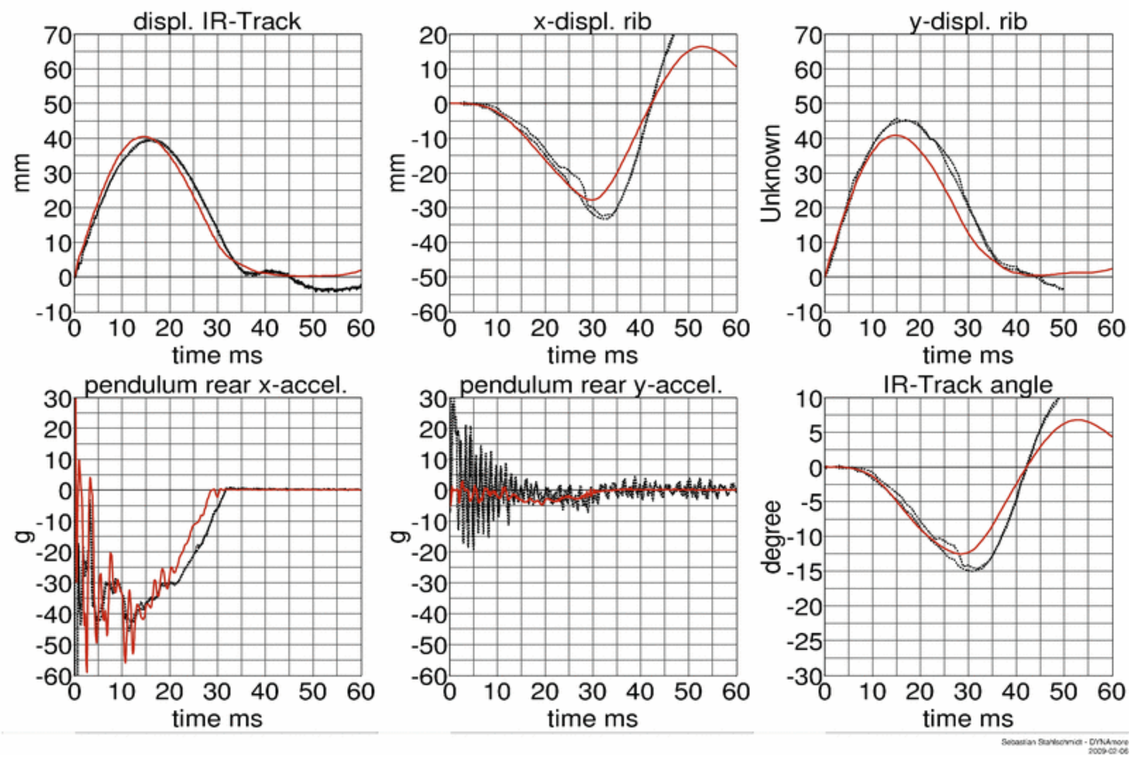


Figure 73: Third thorax rib test on outer band - high velocity and low mass

Third thorax rib outer band - high velocity, high mass

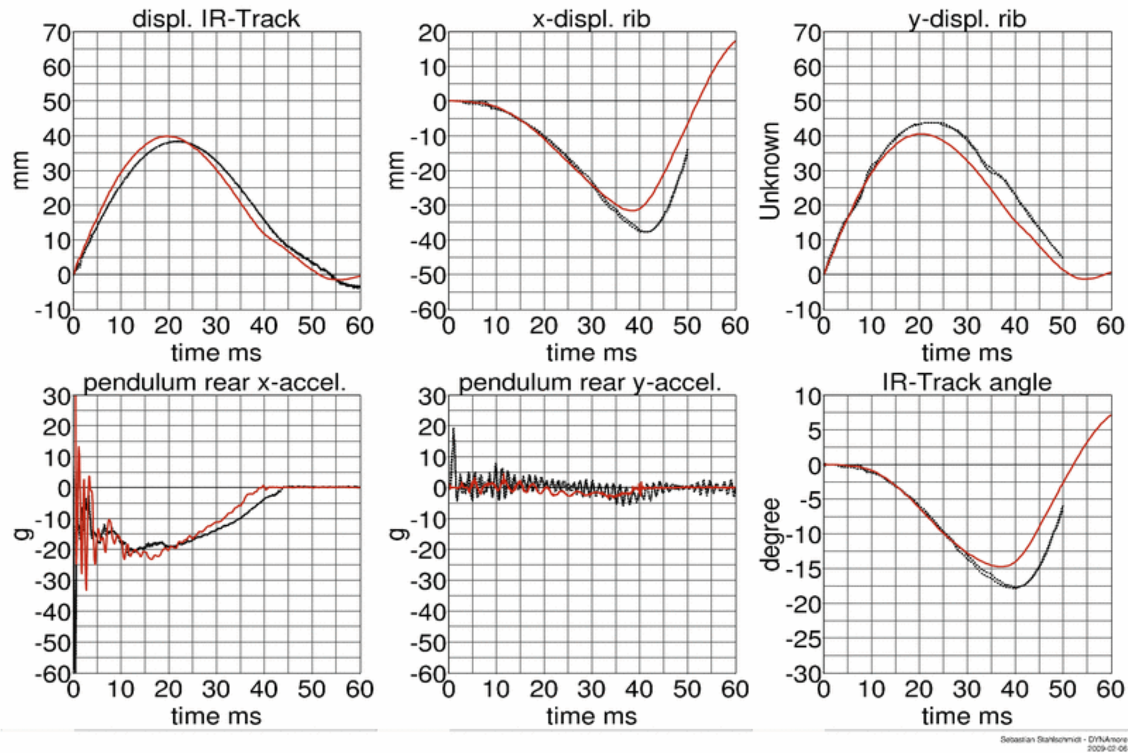


Figure 74: third thorax rib test on outer band - high velocity and high mass

Second abdomen rib:

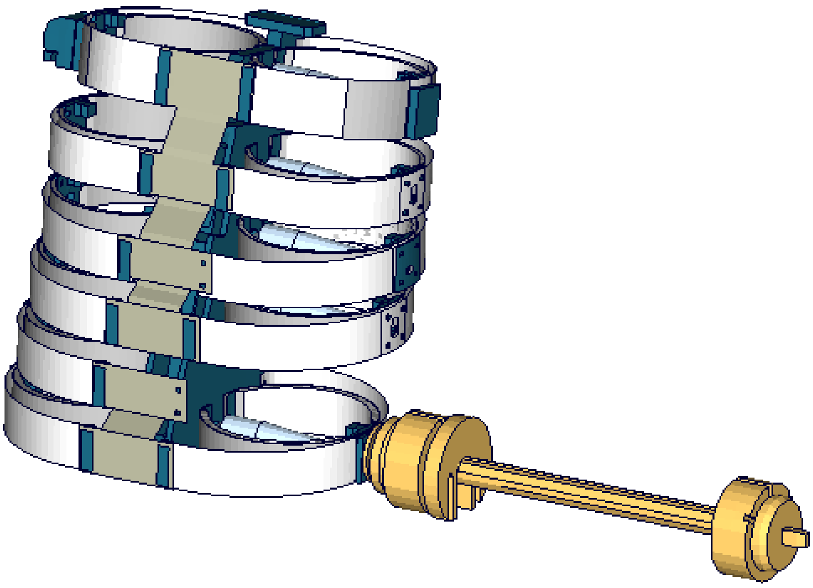


Figure 75: Second abdomen rib outer band test

Second abdomen rib outer band - low velocity, low mass

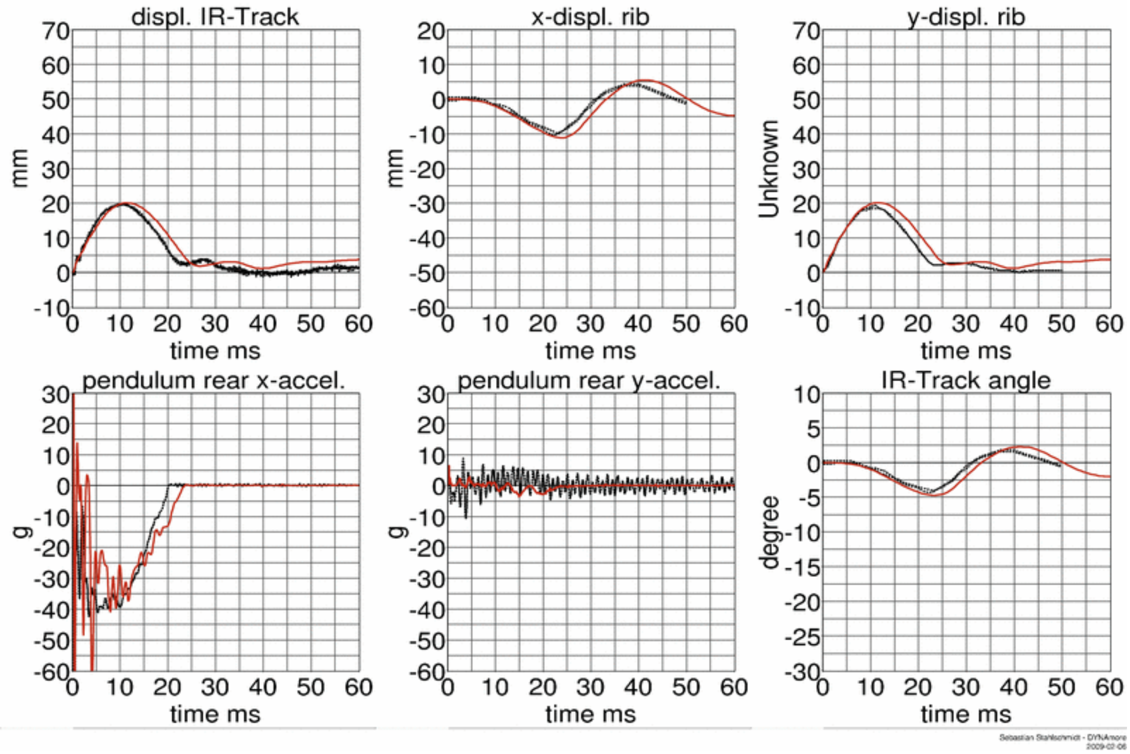


Figure 76: Second abdomen rib test on outer band - low velocity and low mass

Second abdomen rib outer band - low velocity, high mass

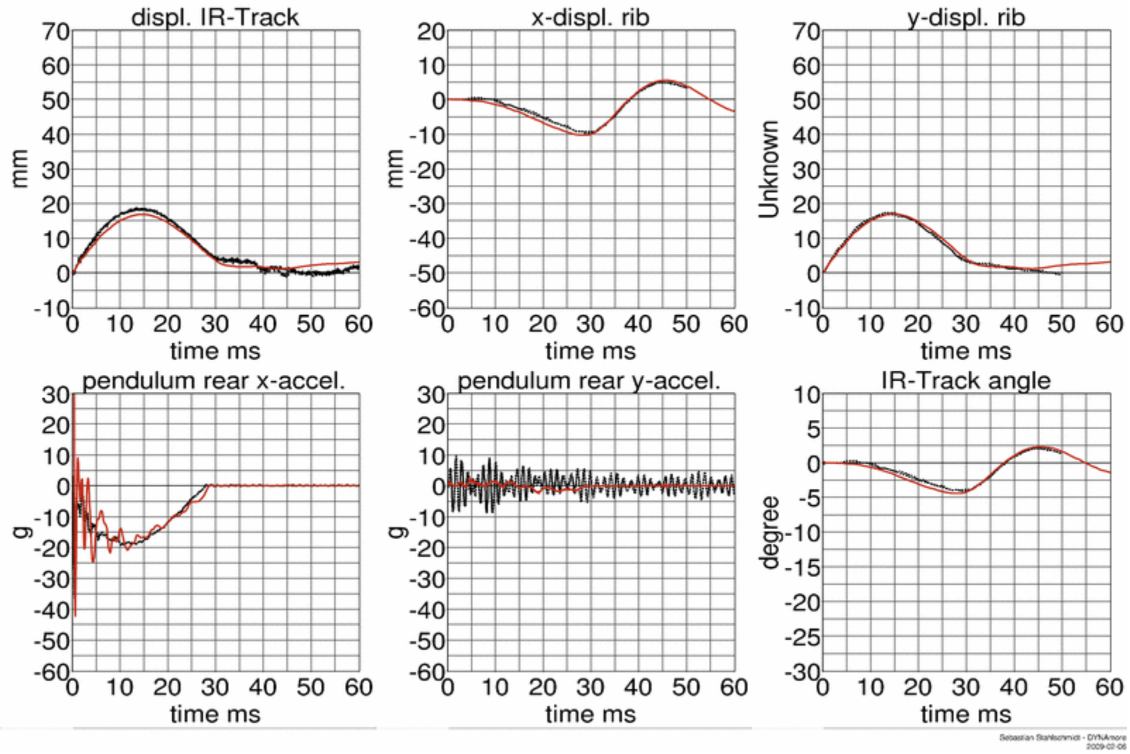


Figure 77: Second abdomen rib test on outer band - low velocity and high mass

Second abdomen rib outer band - high velocity, low mass

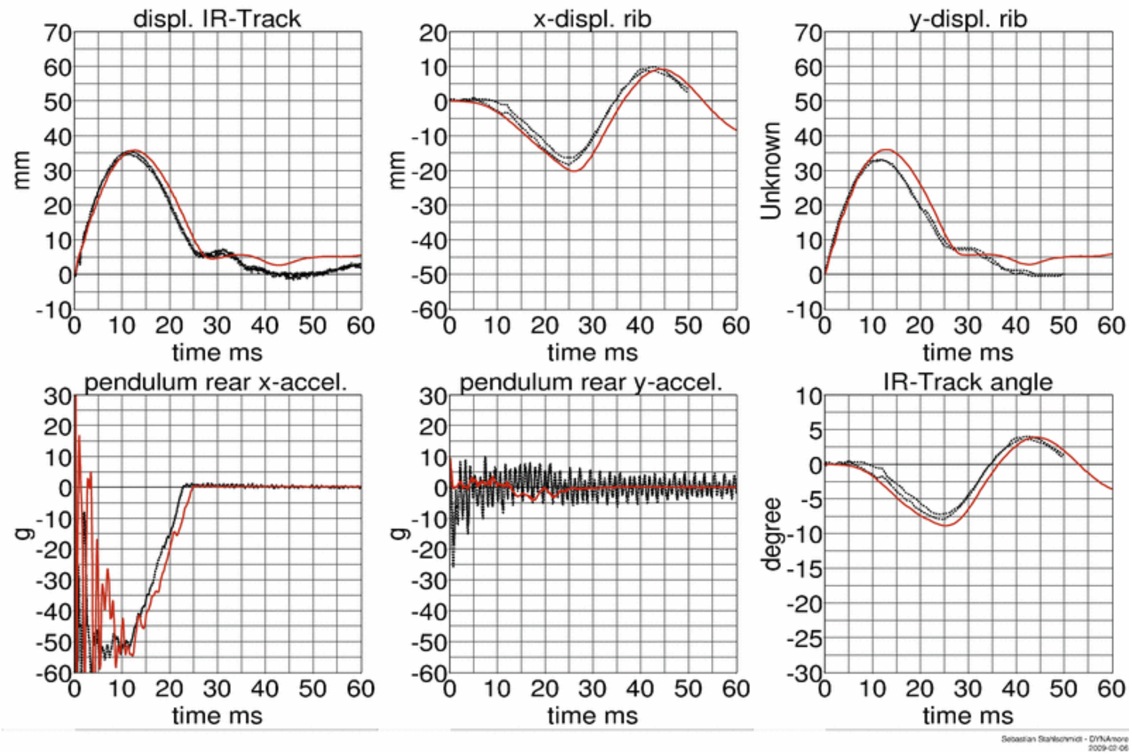


Figure 78: Second abdomen rib test on outer band - high velocity and low mass

Second abdomen rib outer band - high velocity, high mass

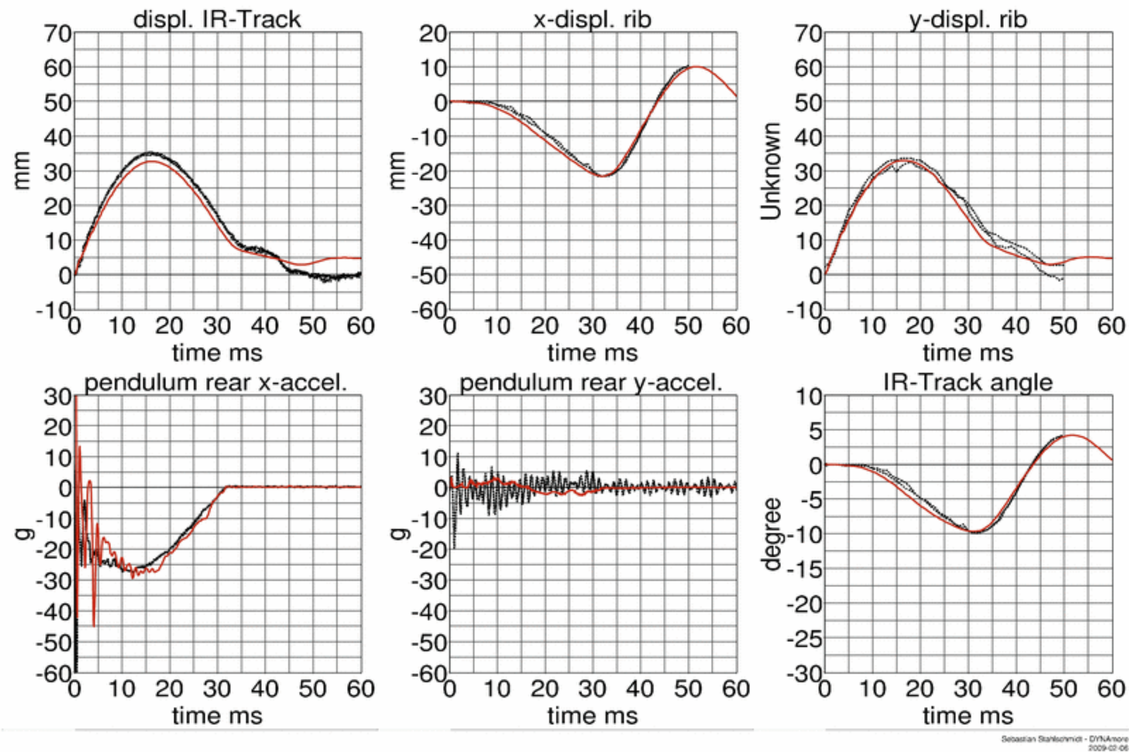


Figure 79: Second abdomen rib test on outer band - high velocity and high mass

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.

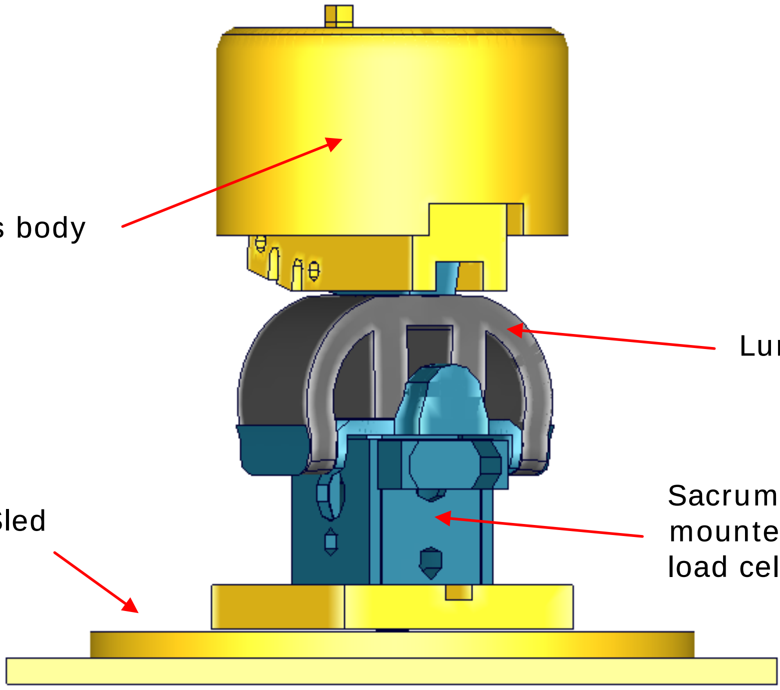


Figure 80: Lumbar spine component test setup

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 29.

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 29: Test configurations for lumbar spine test

Results of 90 degree, 20g configuration:

Mass body accelerations

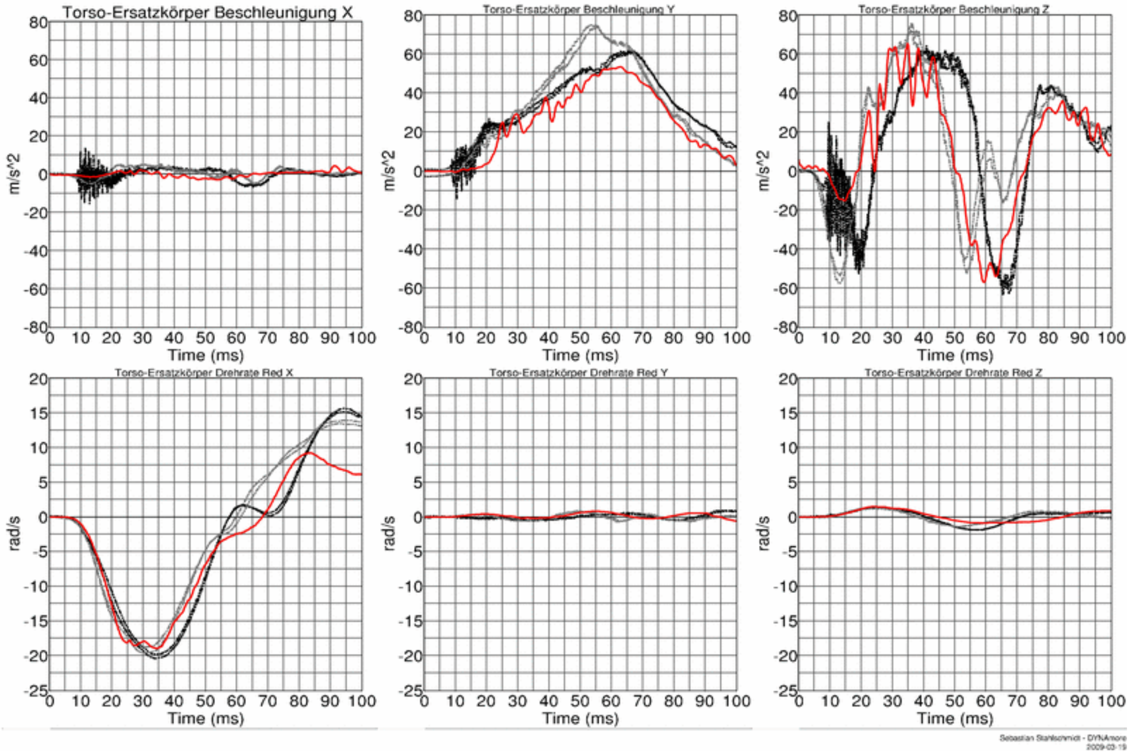


Figure 81: Result of lumbar spine test -- 20g, 90 degree (Mass body accelerations)

Lumbar load cell forces and moments

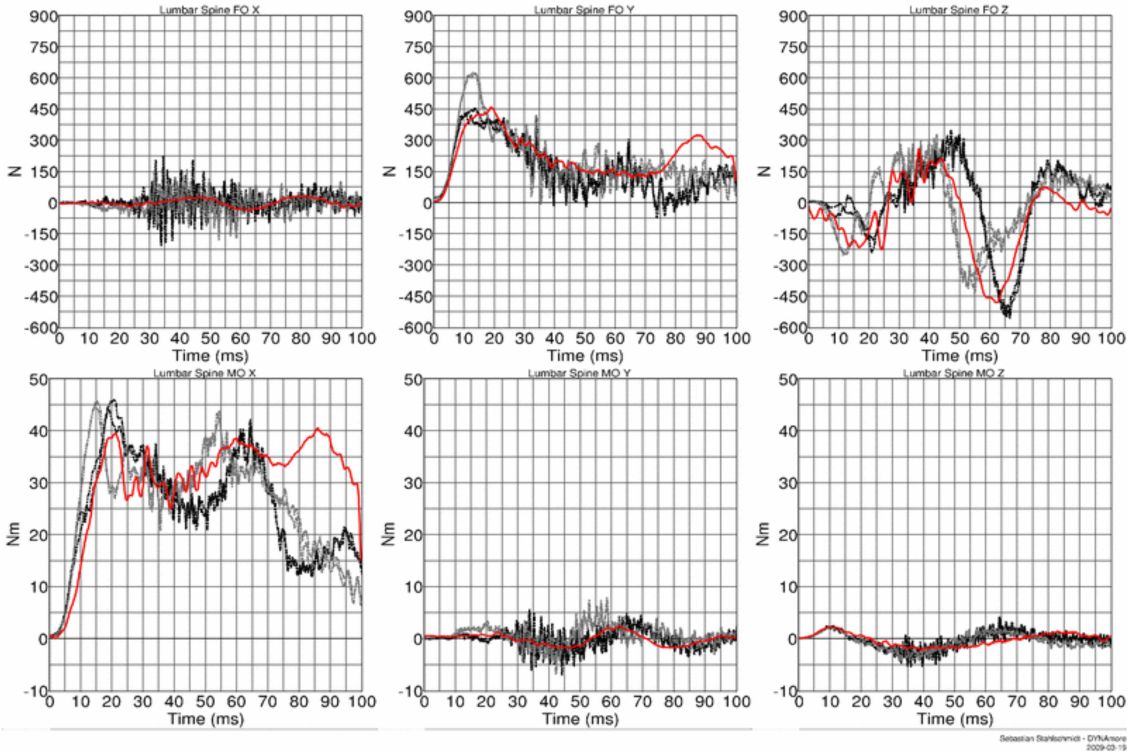


Figure 82: Result of lumbar spine test -- 20g, 90 degree (Lumbar load cell forces and moments)

Mass body rotations

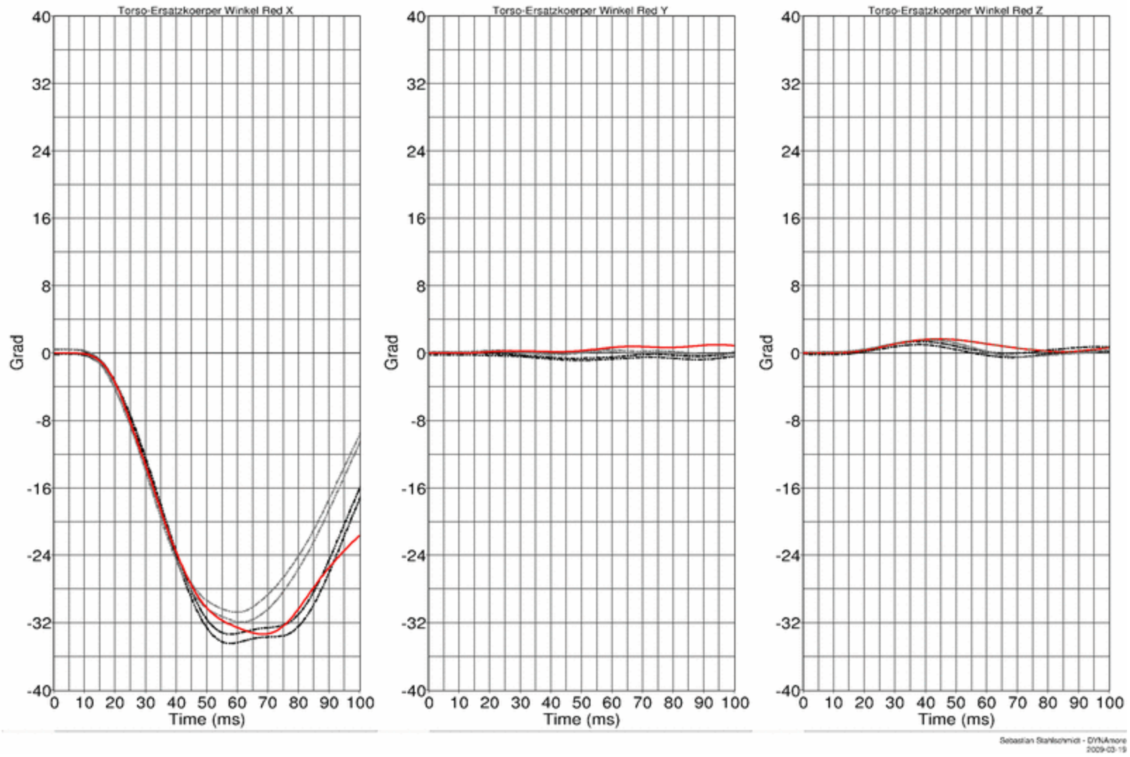


Figure 83: Result of lumbar spine test -- 20g, 90 degree (Mass body rotations)

Results of 90 degree, 35g configuration:

Mass body accelerations

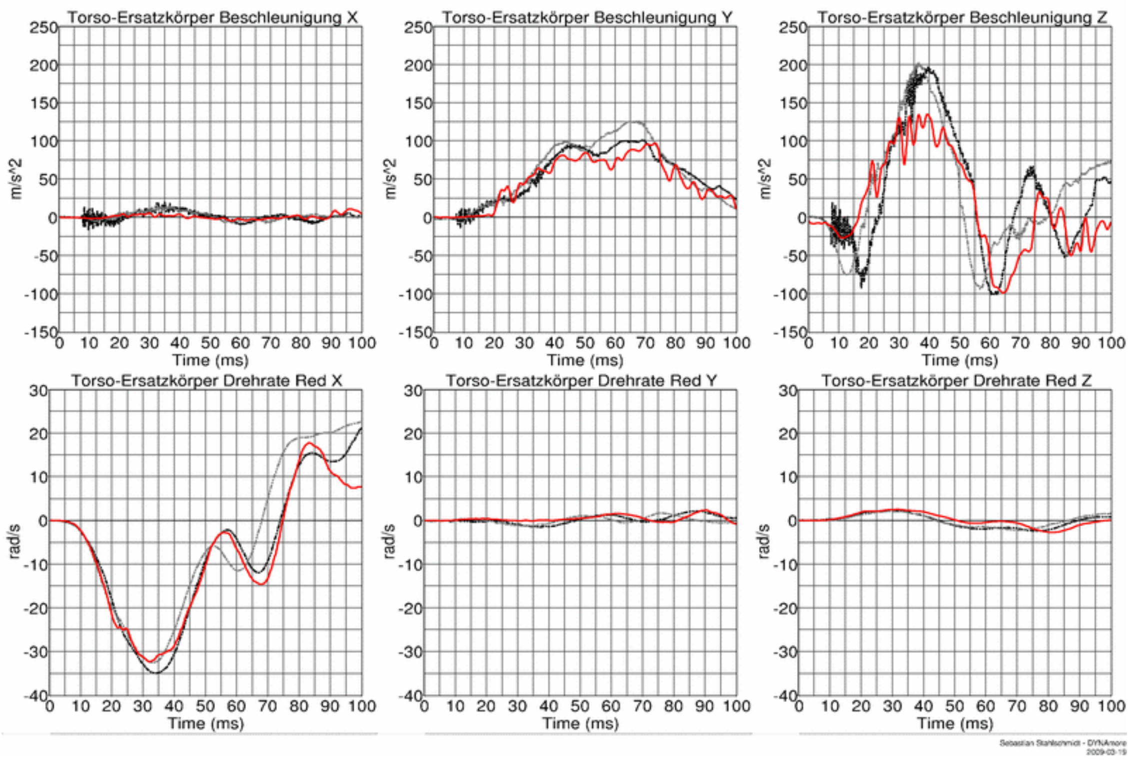


Figure 84: Result of lumbar spine test -- 35g, 90 degree (Mass body accelerations)

Lumbar load cell forces and moments

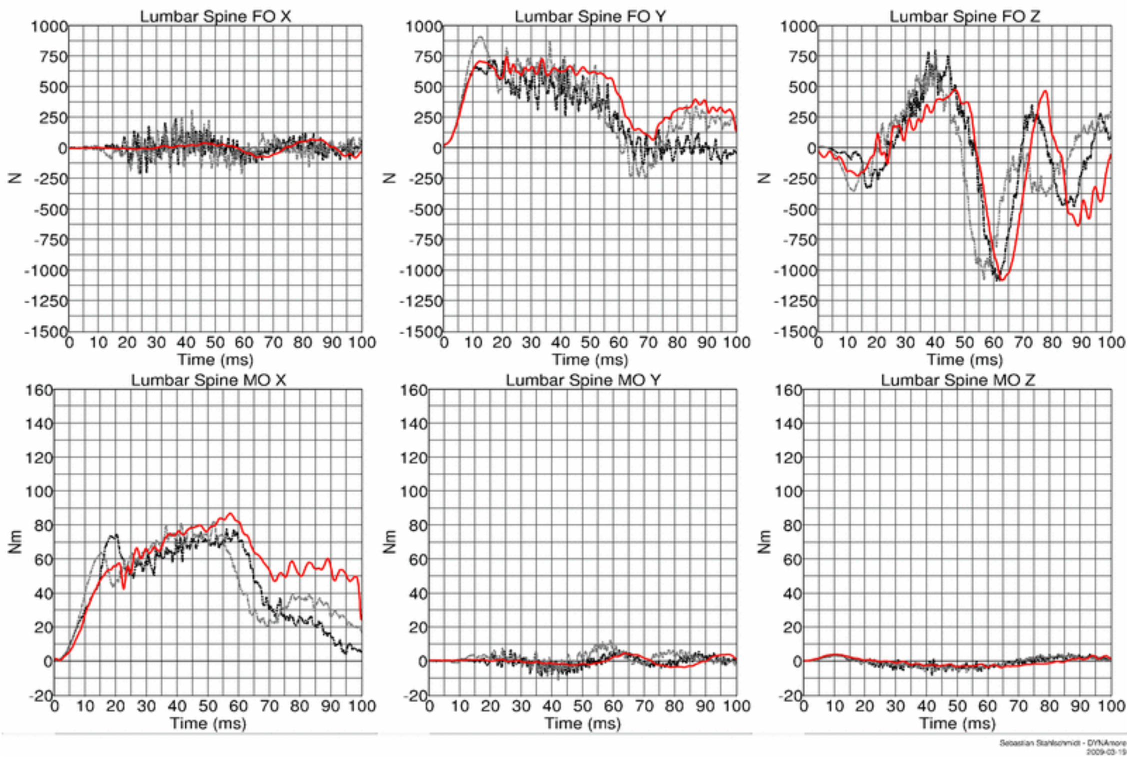


Figure 85: Result of lumbar spine test -- 35g, 90 degree (Lumbar load cell forces and moments)

Mass body rotations

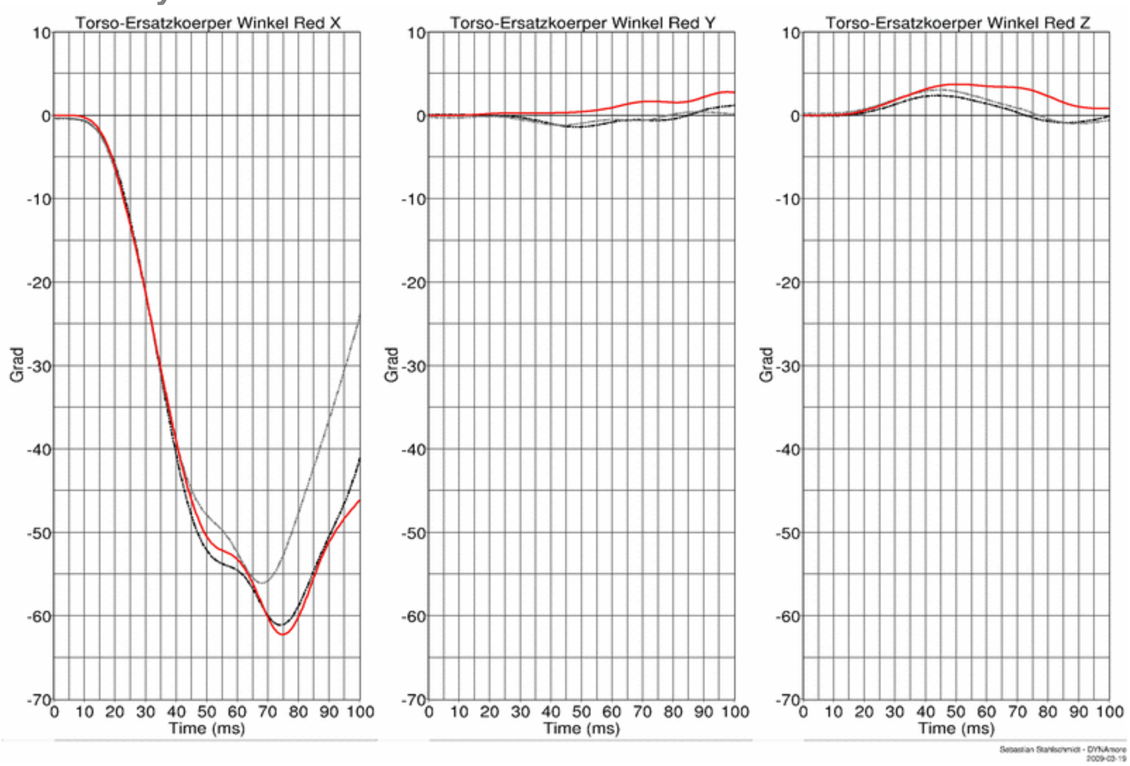


Figure 86: Result of lumbar spine test -- 35g, 90 degree (Mass body rotations)

Results of 60 degree, 20g configuration:

Mass body accelerations

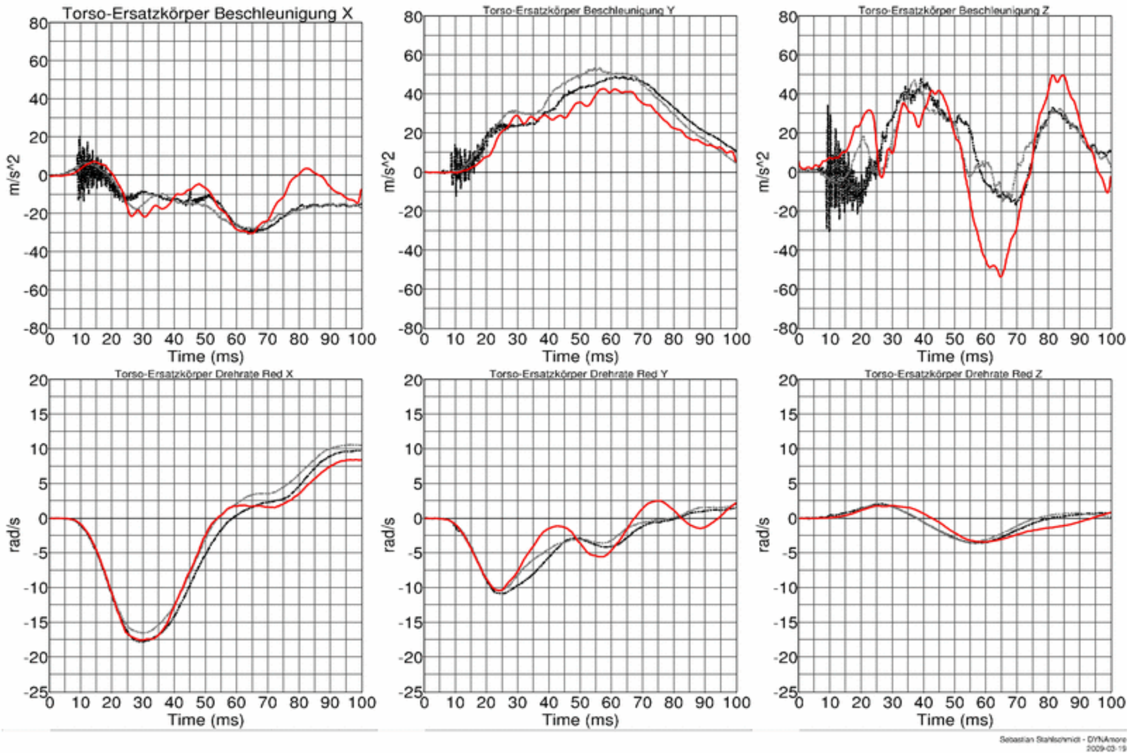


Figure 87: Result of lumbar spine test -- 20g, 60 degree (Mass body accelerations)

Lumbar load cell forces and moments

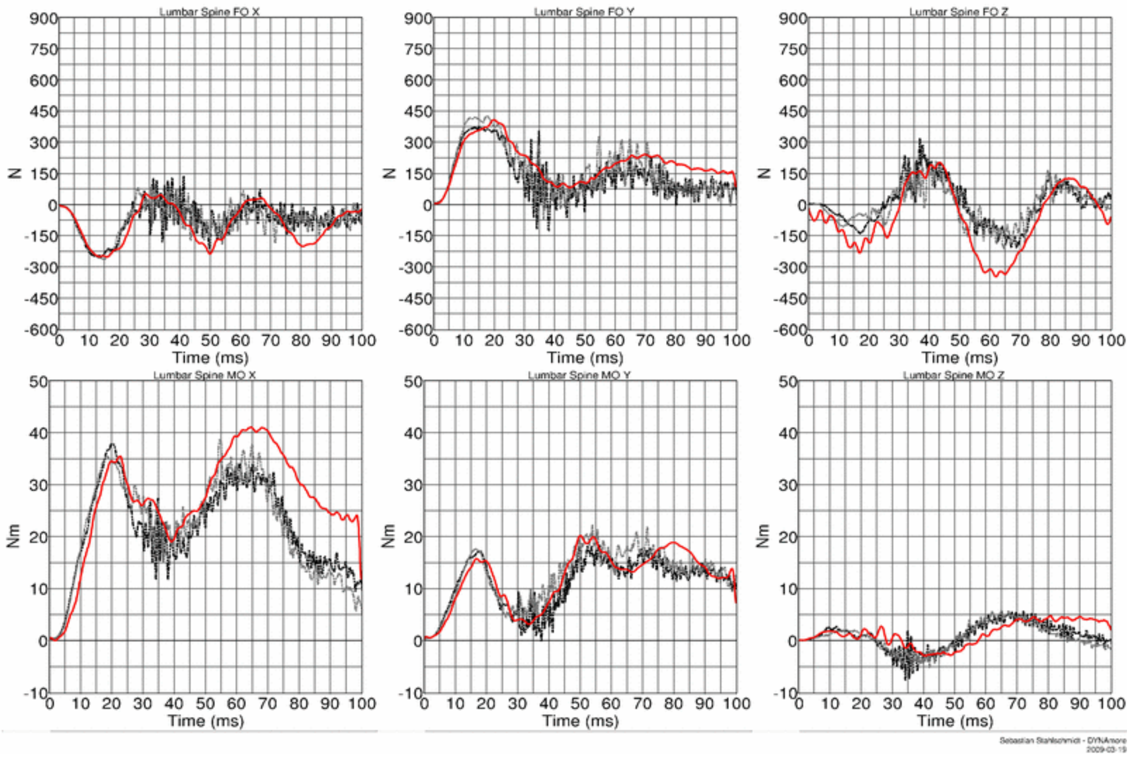


Figure 88: Result of lumbar spine test -- 20g, 60 degree (Lumbar load cell forces and moments)

Mass body rotations

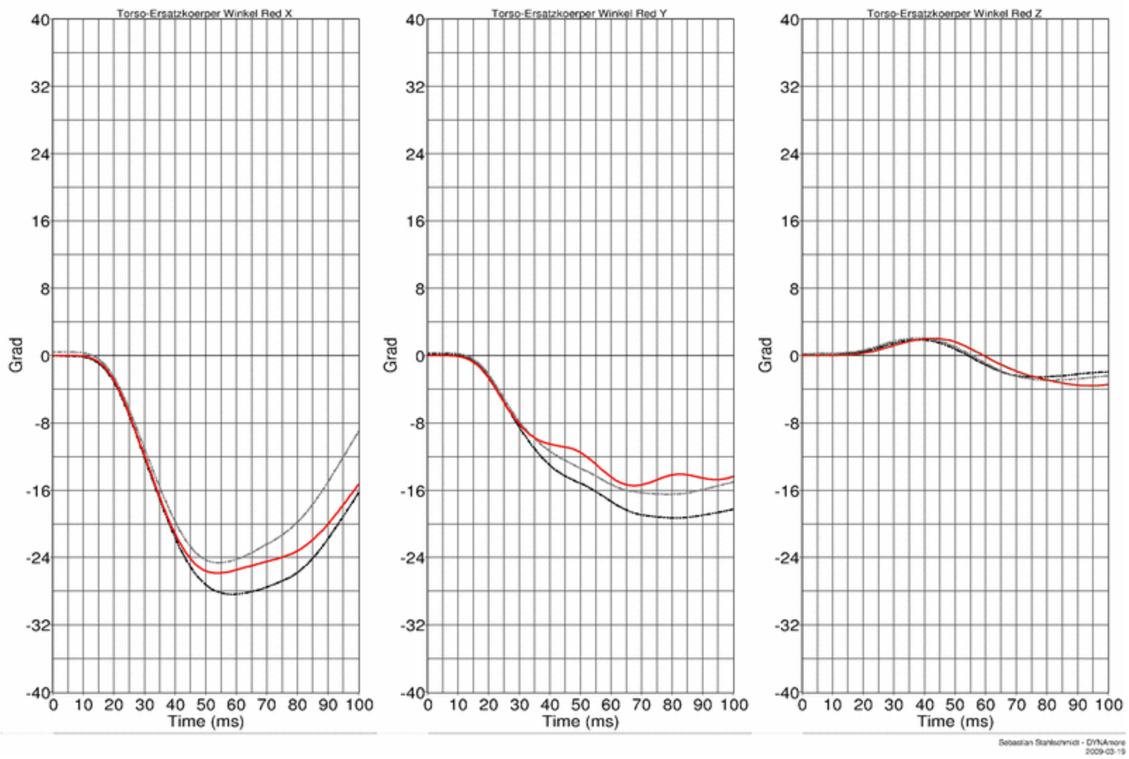


Figure 89: Result of lumbar spine test -- 20g, 60 degree (Mass body rotations)

Results of 60 degree, 35g configuration:

Mass body accelerations

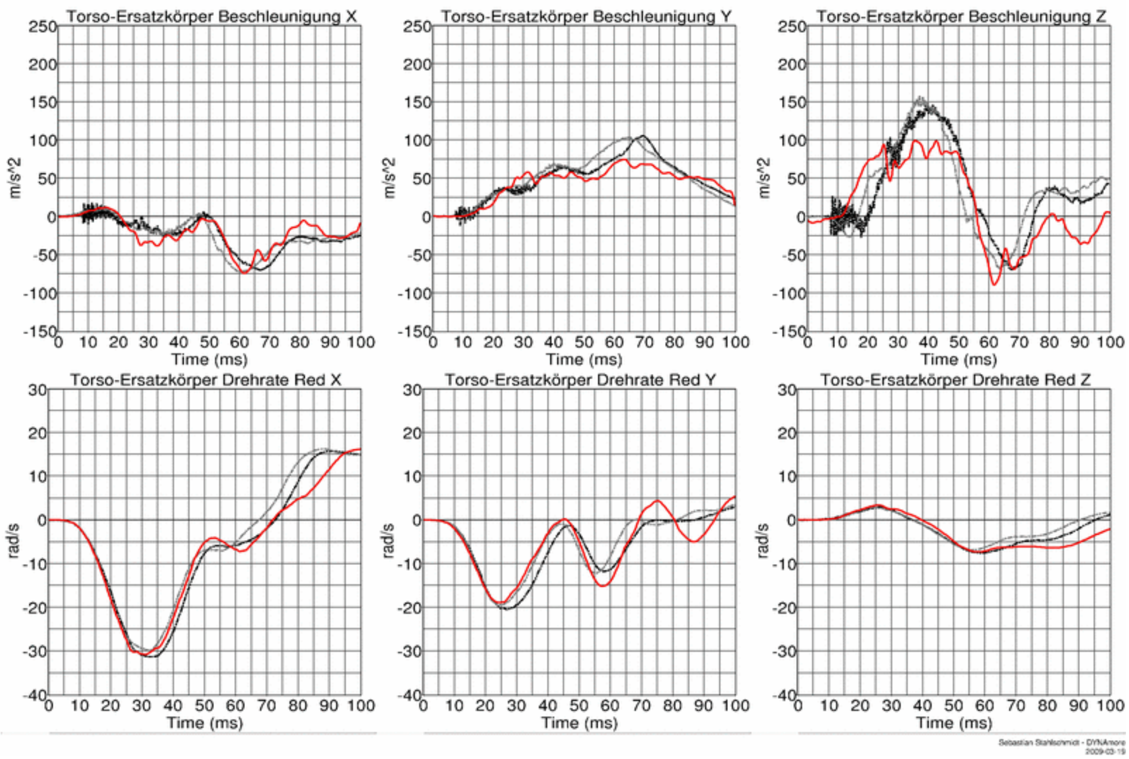


Figure 90: Result of lumbar spine test -- 35g, 60 degree (Mass body accelerations)

Lumbar load cell forces and moments

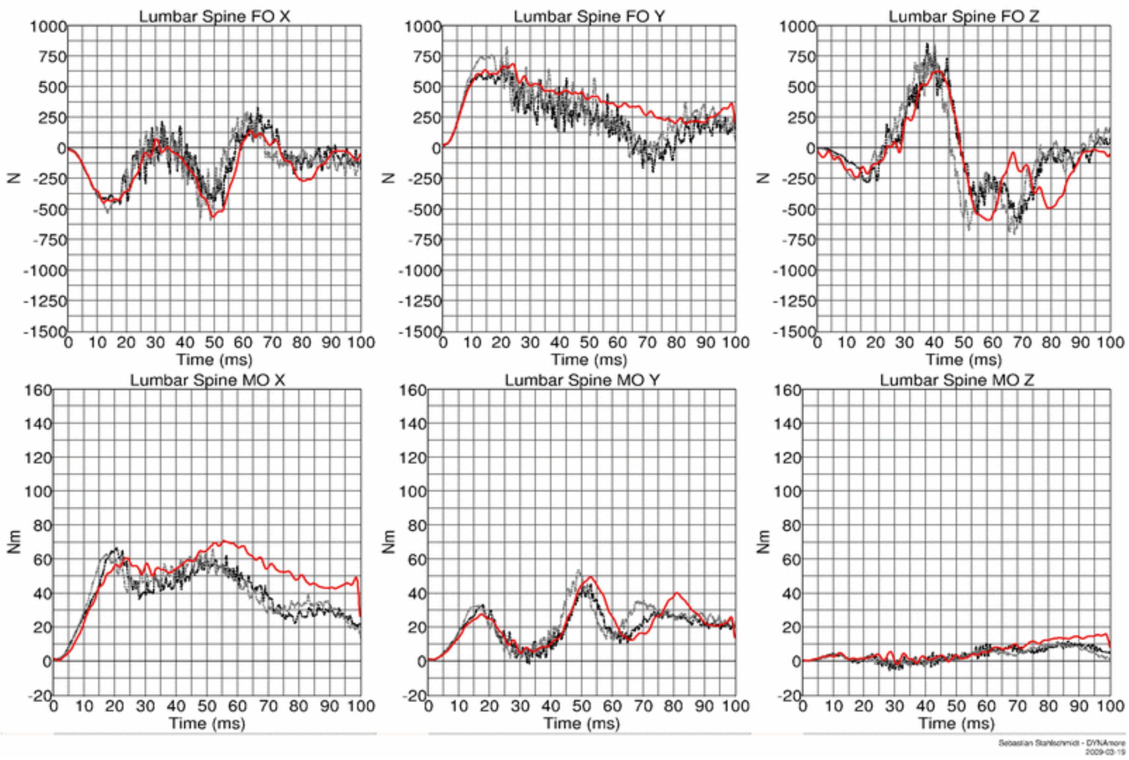


Figure 91: Result of lumbar spine test -- 35g, 60 degree (Lumbar load cell forces and moments)

Mass body rotations

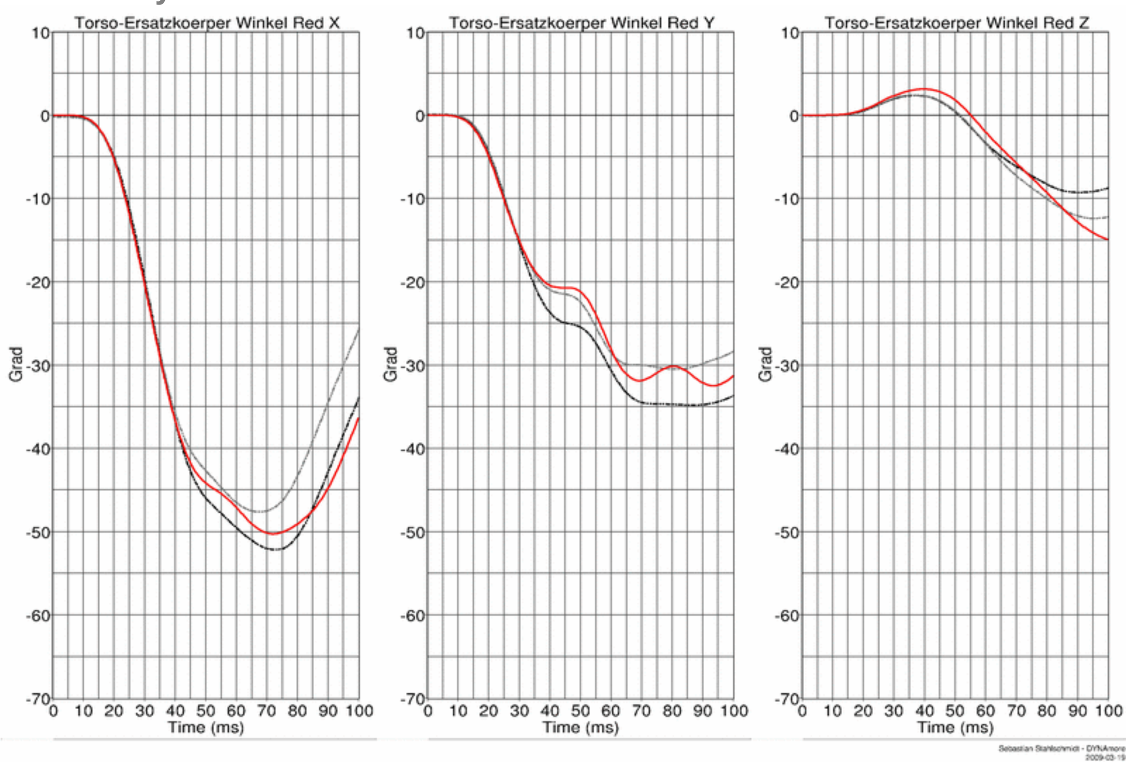


Figure 92: Result of lumbar spine test -- 35g, 60 degree (Mass body rotations)

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.

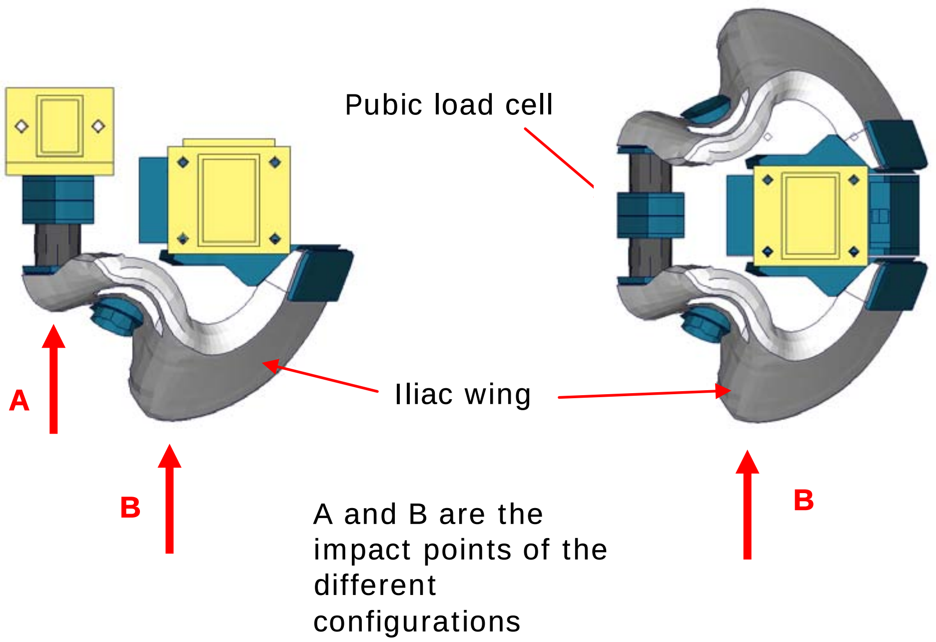


Figure 93: Iliac wing component test configurations

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 30: Test configurations for iliac wing test

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

Pendulum accelerations

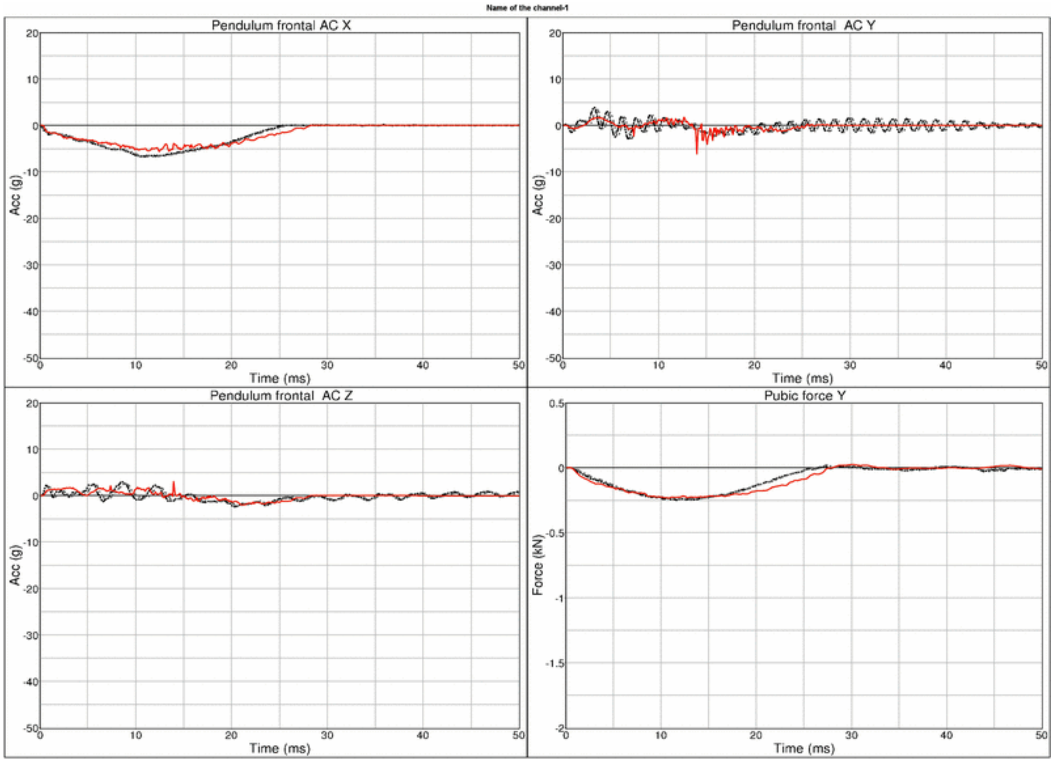


Figure 94: Result of iliac wing test -- Target point A, low velocity, half pelvis (Pendulum accelerations)

Sacro-iliac load cell

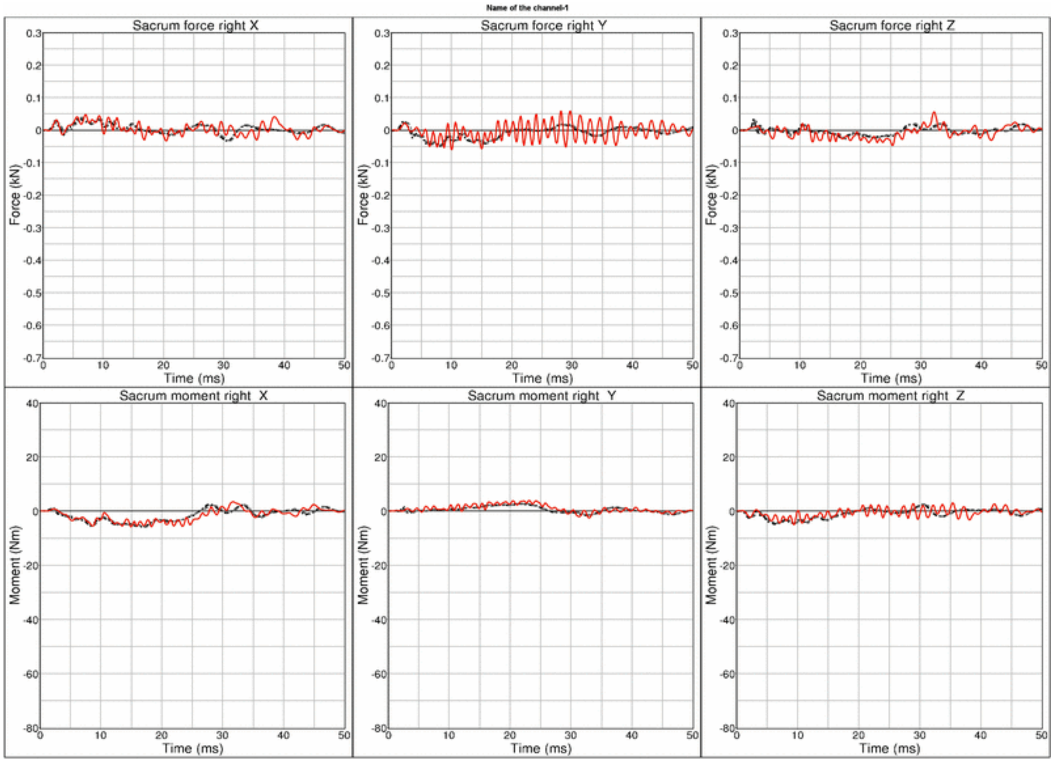


Figure 95: Result of iliac wing test -- Target point A, low velocity, half pelvis (Sacro-iliac load cell)

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

Pendulum accelerations

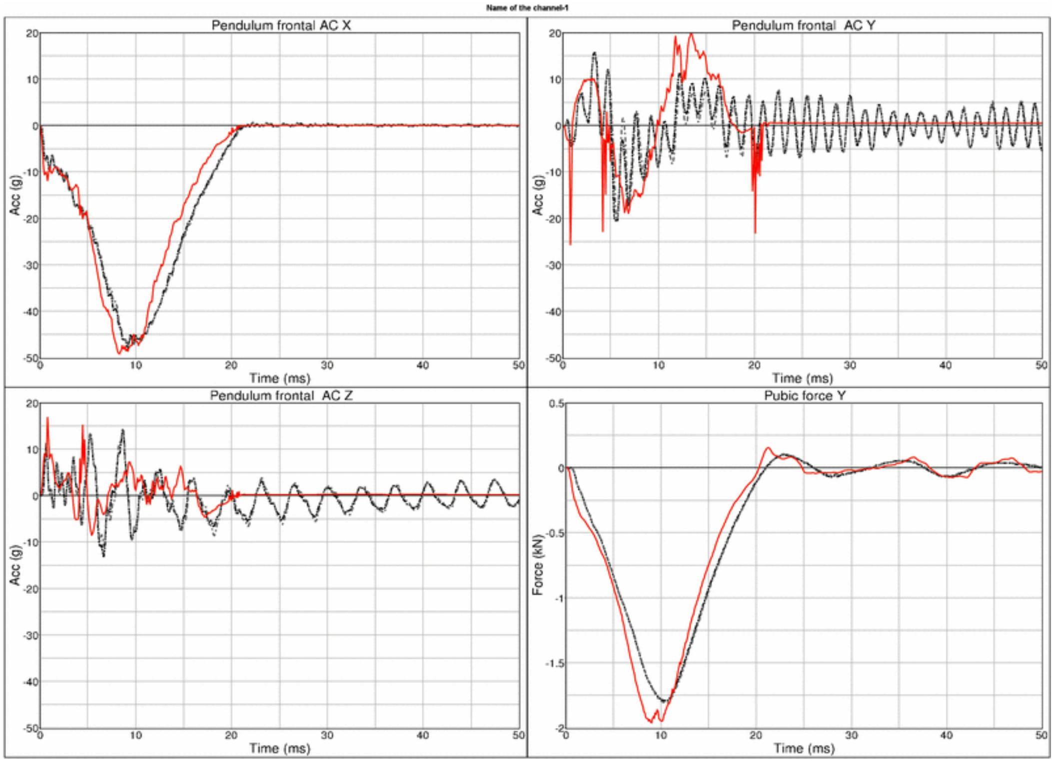


Figure 96: Result of iliac wing test -- Target point A, high velocity, half pelvis (Pendulum accelerations)

Sacro-iliac load cell

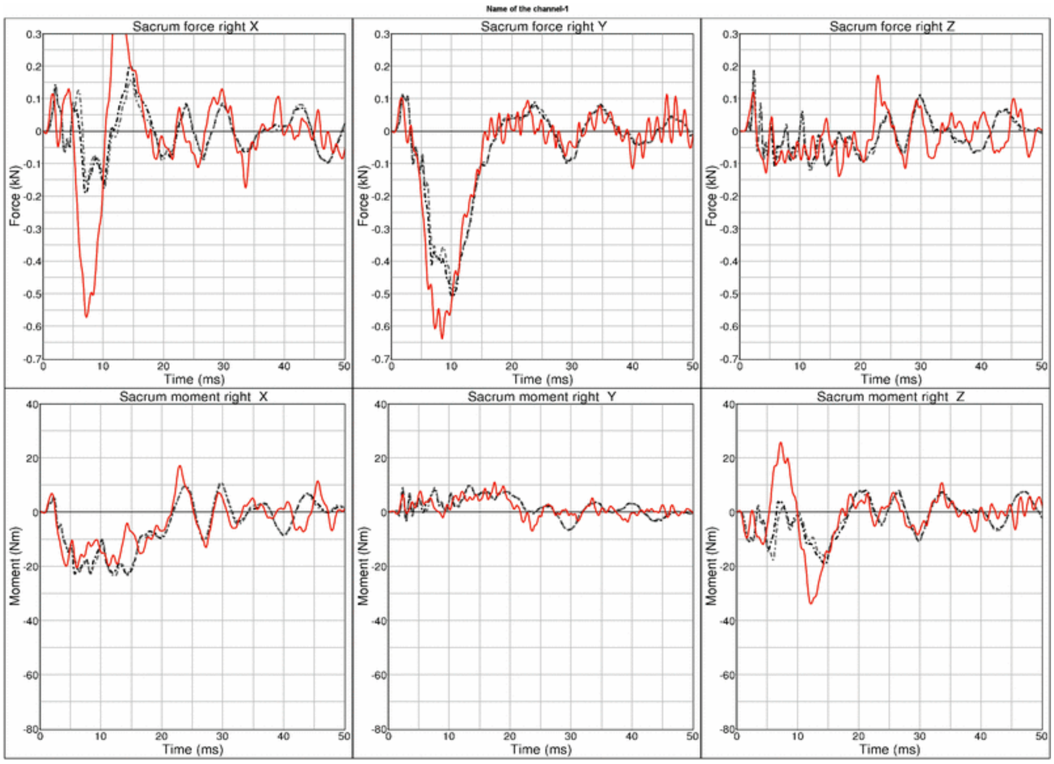


Figure 97: Result of iliac wing test -- Target point A, high velocity, half pelvis (Sacro-iliac load cell)

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

Pendulum accelerations

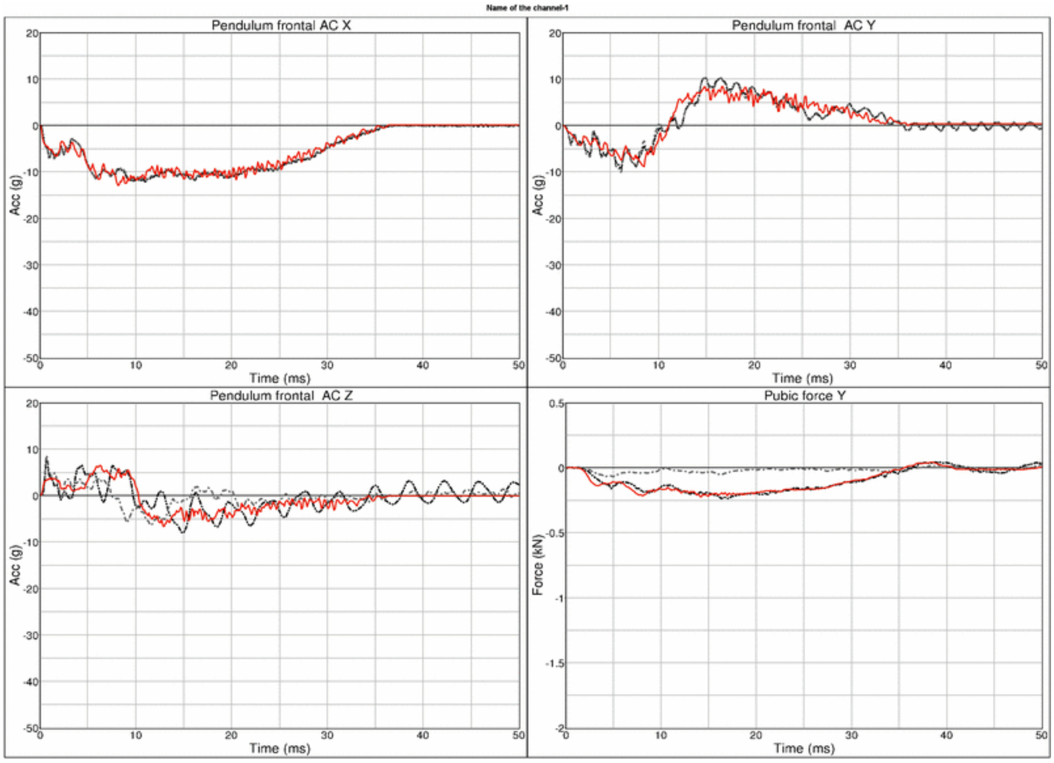


Figure 98: Result of iliac wing test -- Target point B, low velocity, half pelvis (Pendulum accelerations)

Sacro-iliac load cell

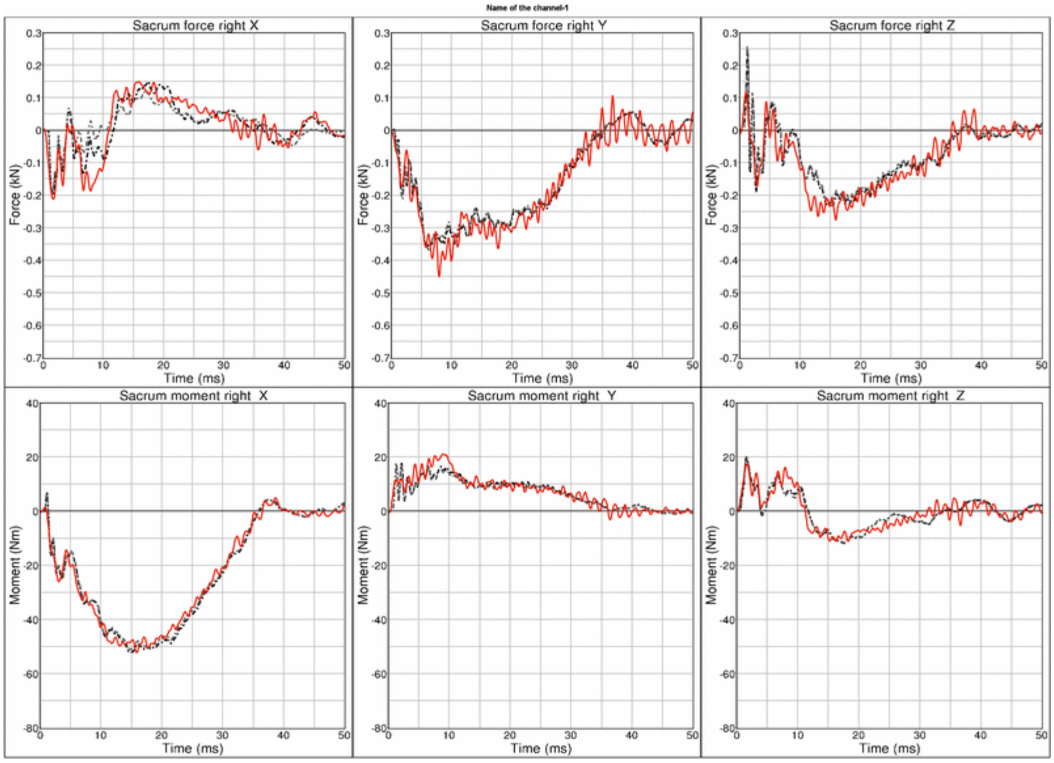


Figure 99: Result of iliac wing test -- Target point B, low velocity, half pelvis (Sacro-iliac load cell)

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

Pendulum accelerations

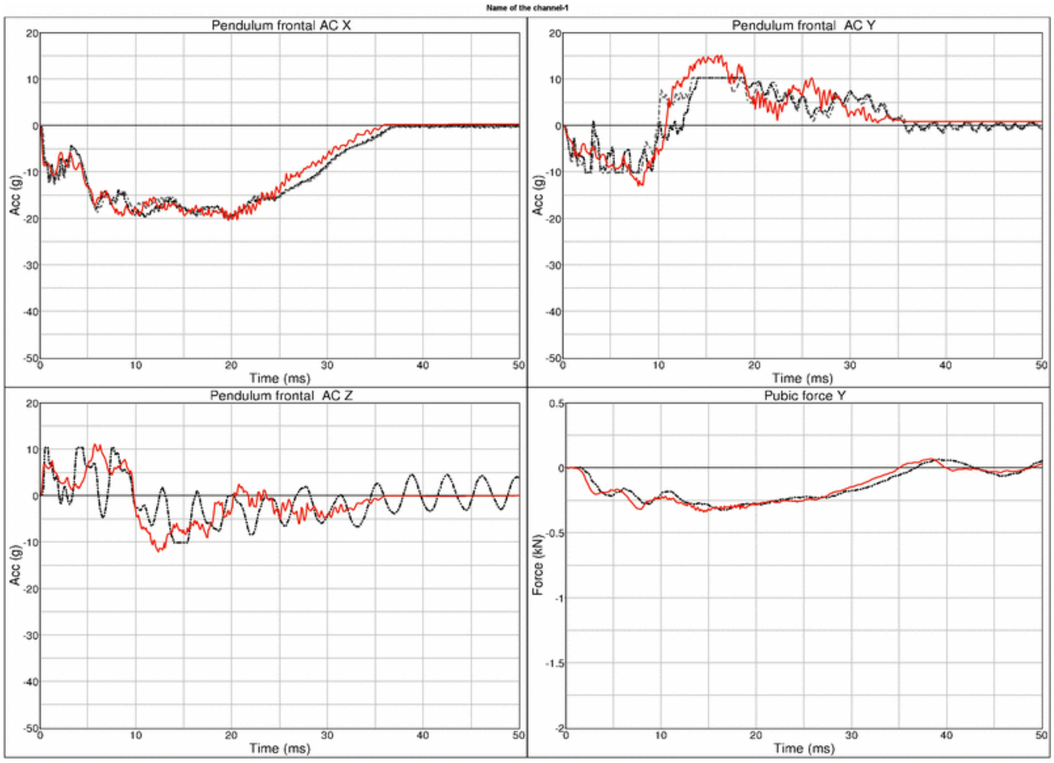


Figure 100: Result of iliac wing test -- Target point B, high velocity, half pelvis (Pendulum accelerations)

Sacro-iliac load cell

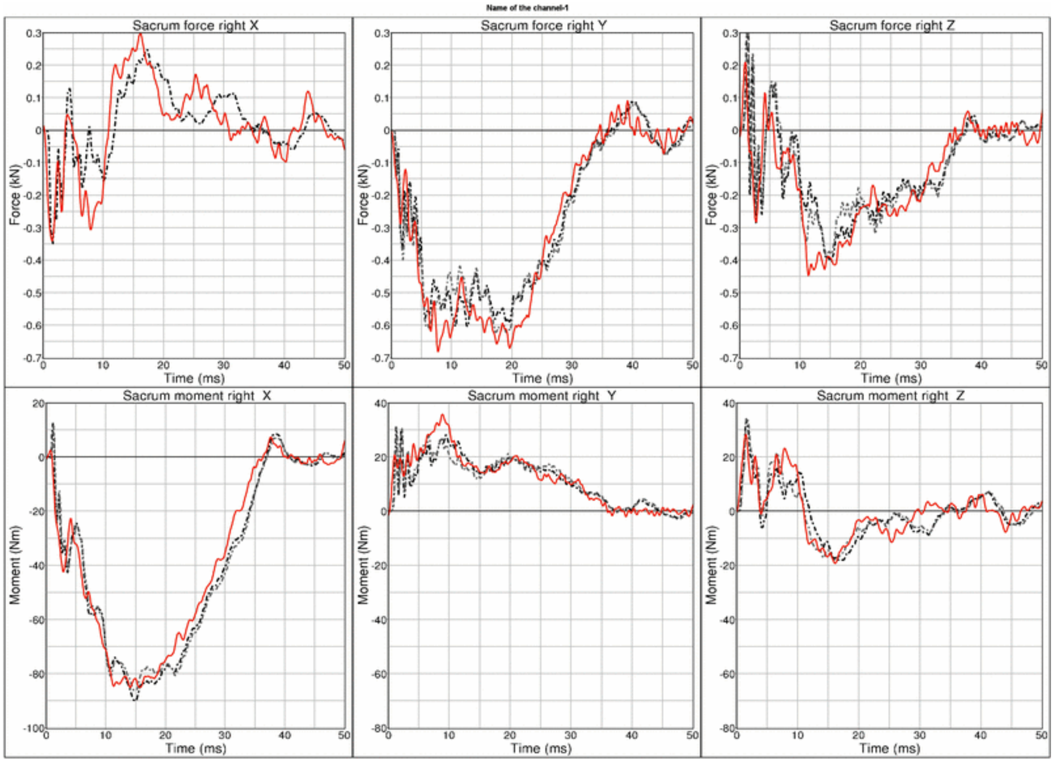


Figure 101: Result of iliac wing test -- Target point B, high velocity, half pelvis (Sacro-iliac load cell)

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

Pendulum accelerations

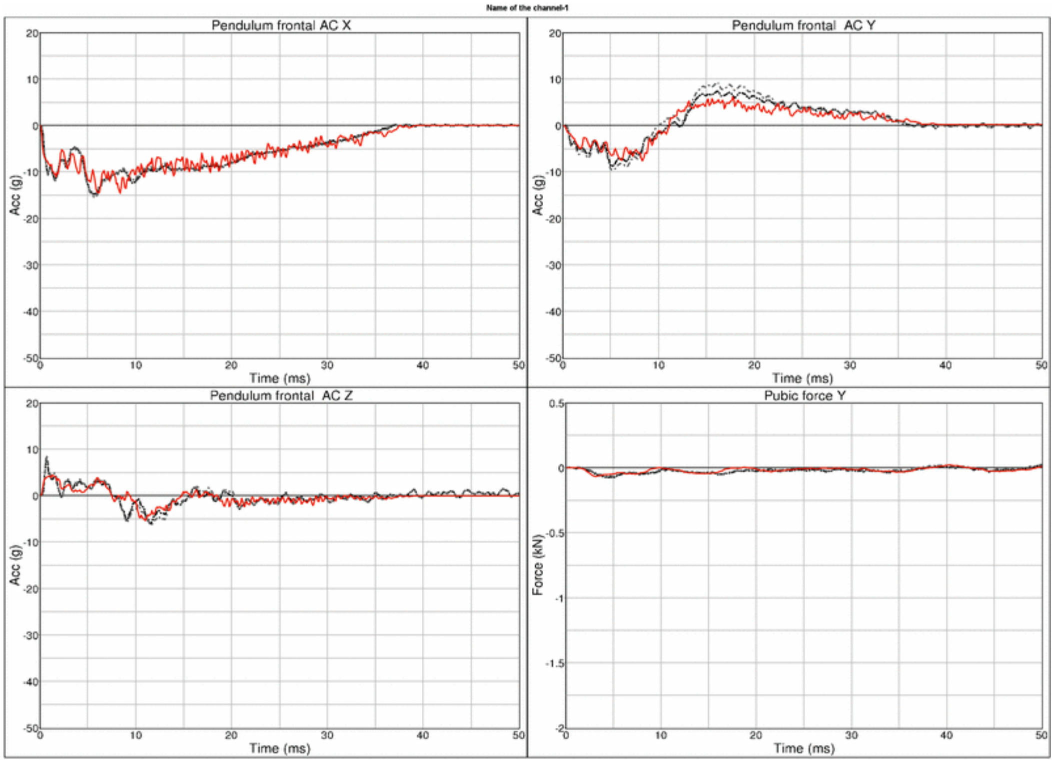


Figure 102: Result of iliac wing test -- Target point B, low velocity, full pelvis (Pendulum accelerations)

Sacro-iliac load cell

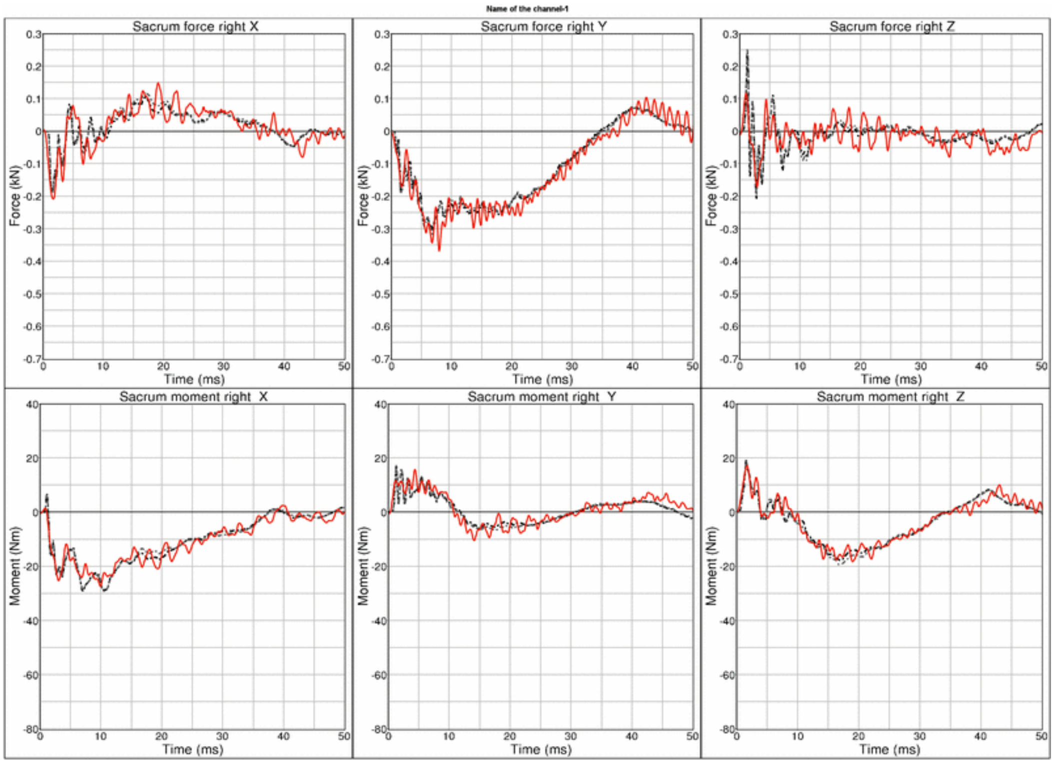


Figure 103: Result of iliac wing test -- Target point B, low velocity, full pelvis (Sacro-iliac load cell)

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

Pendulum accelerations

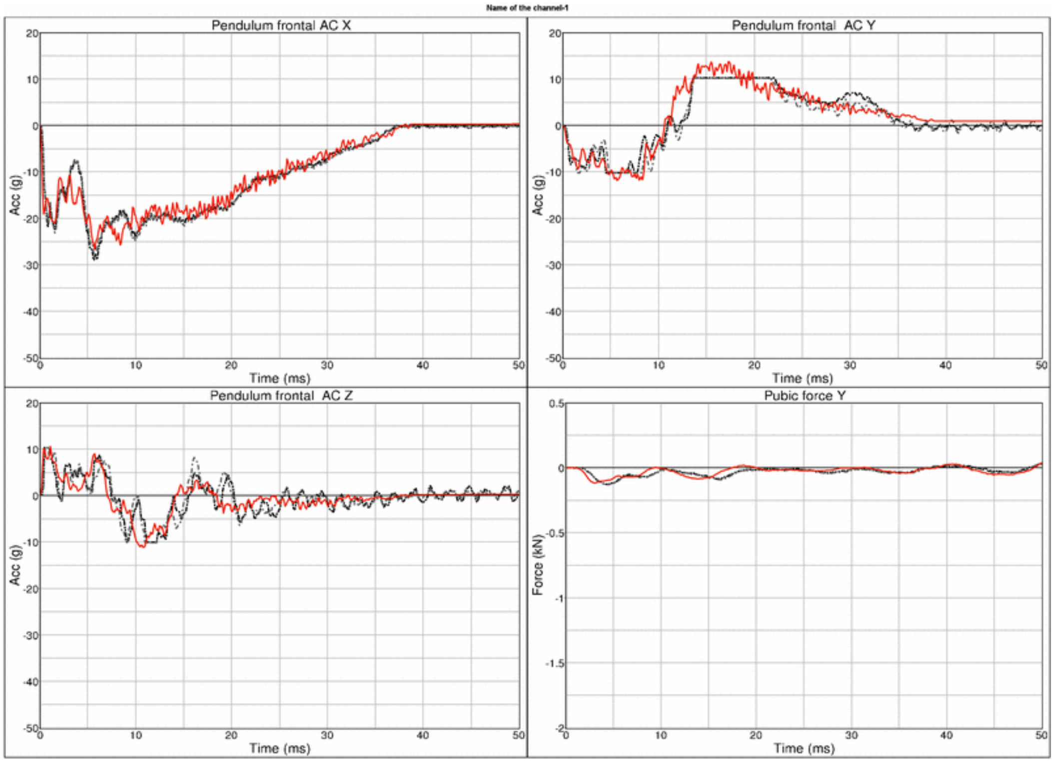


Figure 104: Result of iliac wing test -- Target point B, high velocity, full pelvis (Pendulum accelerations)

Sacro-iliac load cell

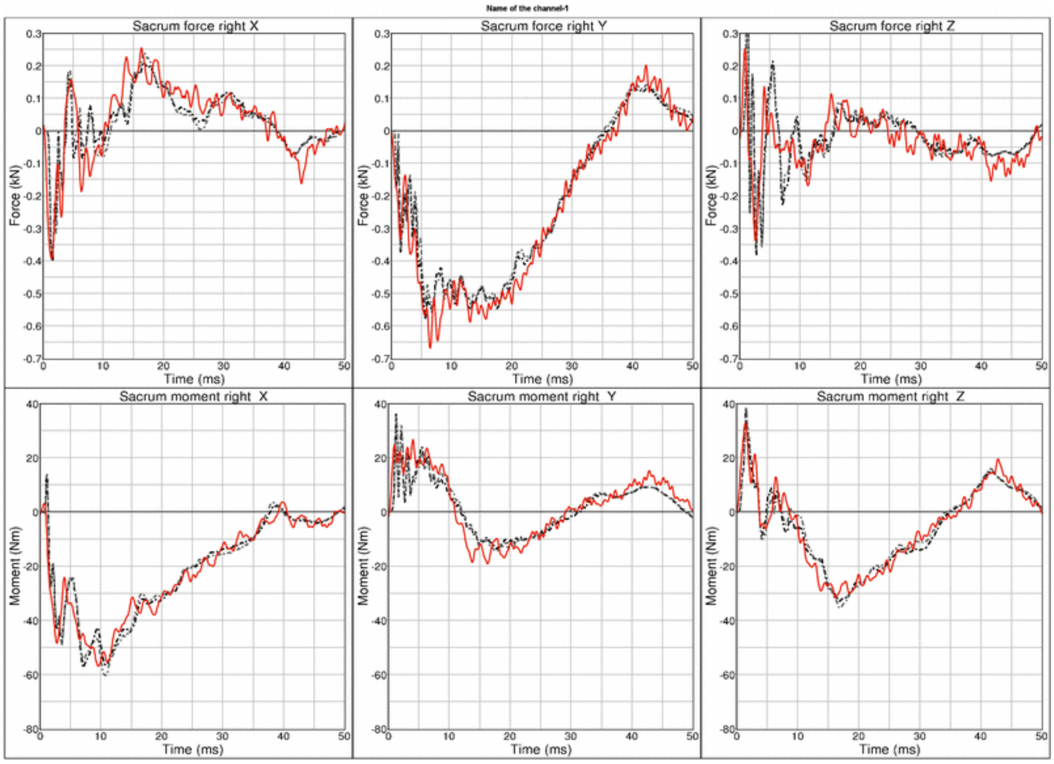


Figure 105: Result of iliac wing test -- Target point B, high velocity, full pelvis (Sacro-iliac load cell)

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.

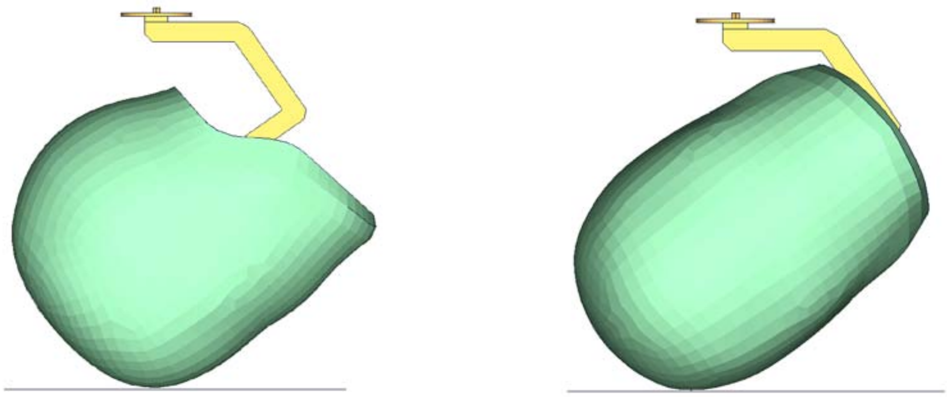


Figure 106: Head drop test, Left: Frontal test, Right: Lateral test

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

Results of frontal head drop test

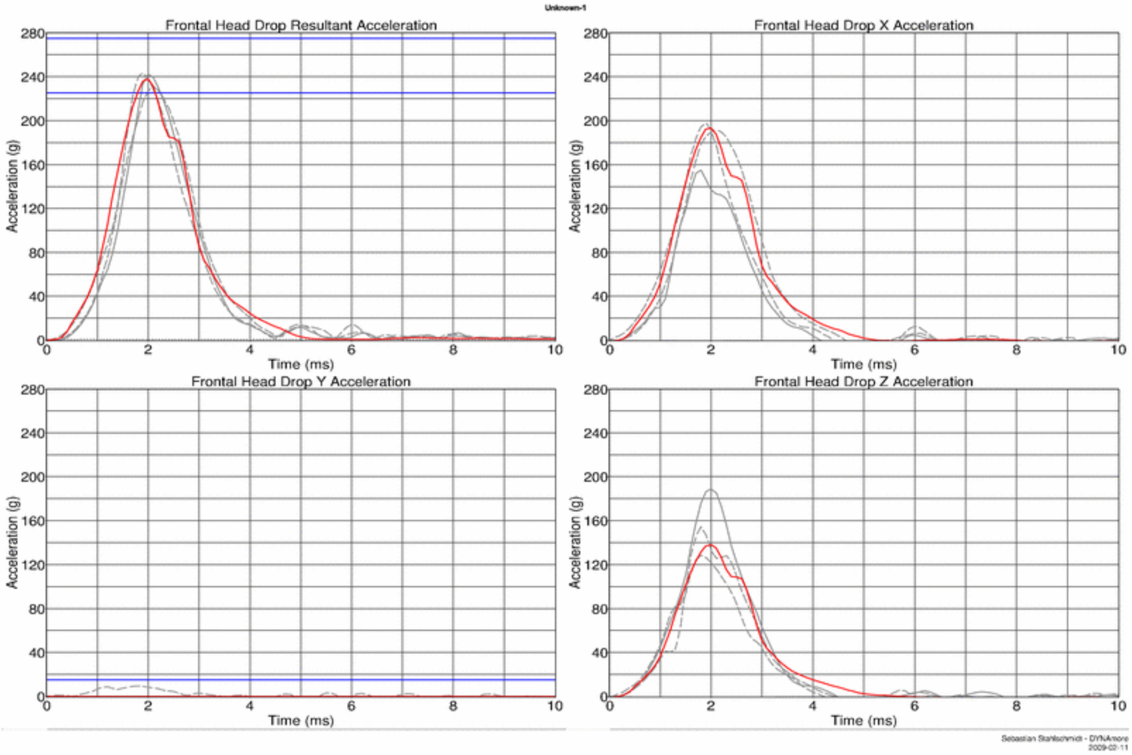


Figure 107: Results of frontal head drop test

Results of lateral head drop test

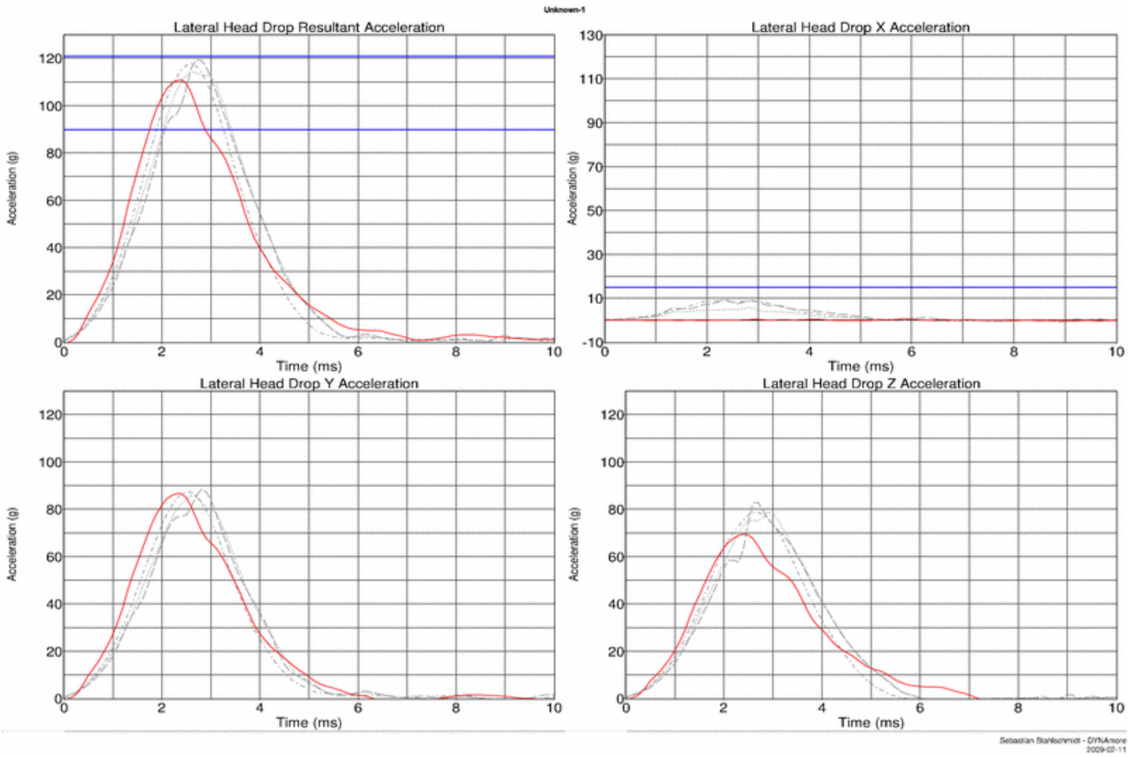


Figure 108: Results of lateral head drop test

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.

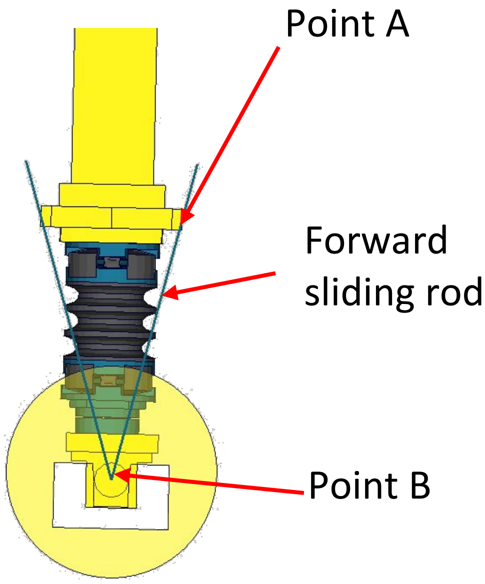


Figure 109: Neck pendulum calibration test setup

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.

Upper neck load cell results

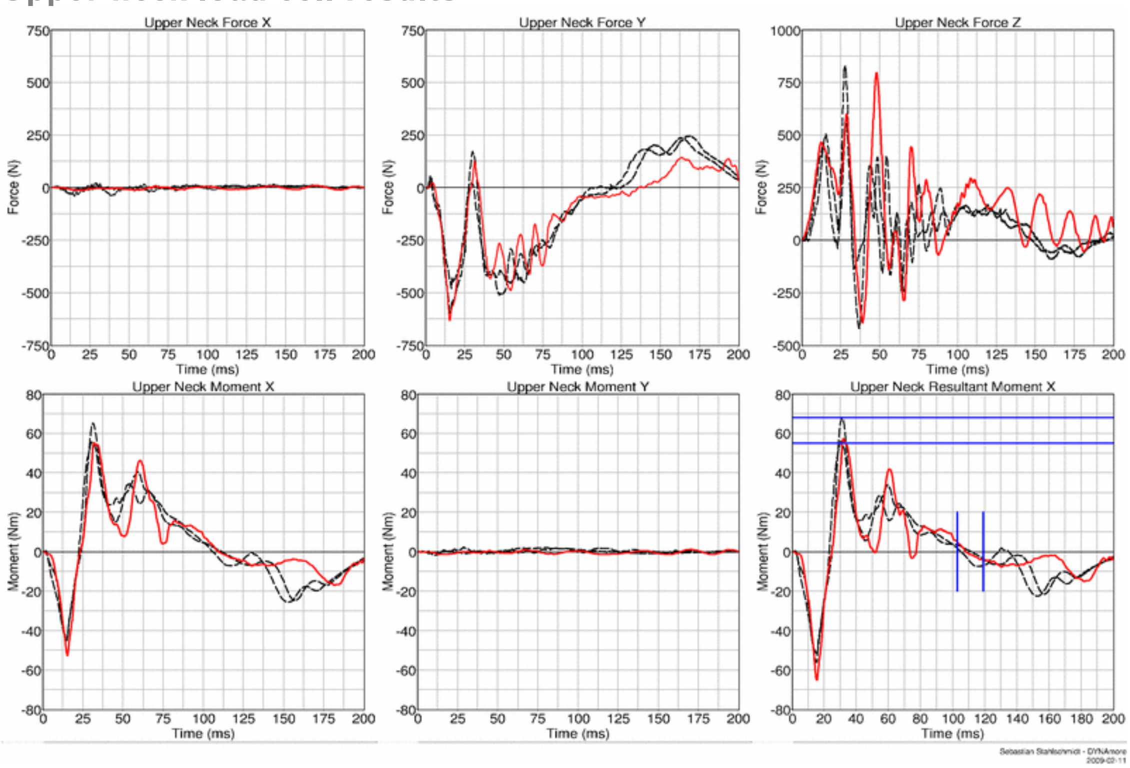


Figure 110: Result of neck calibration test upper neck load cell

Head form rotation results

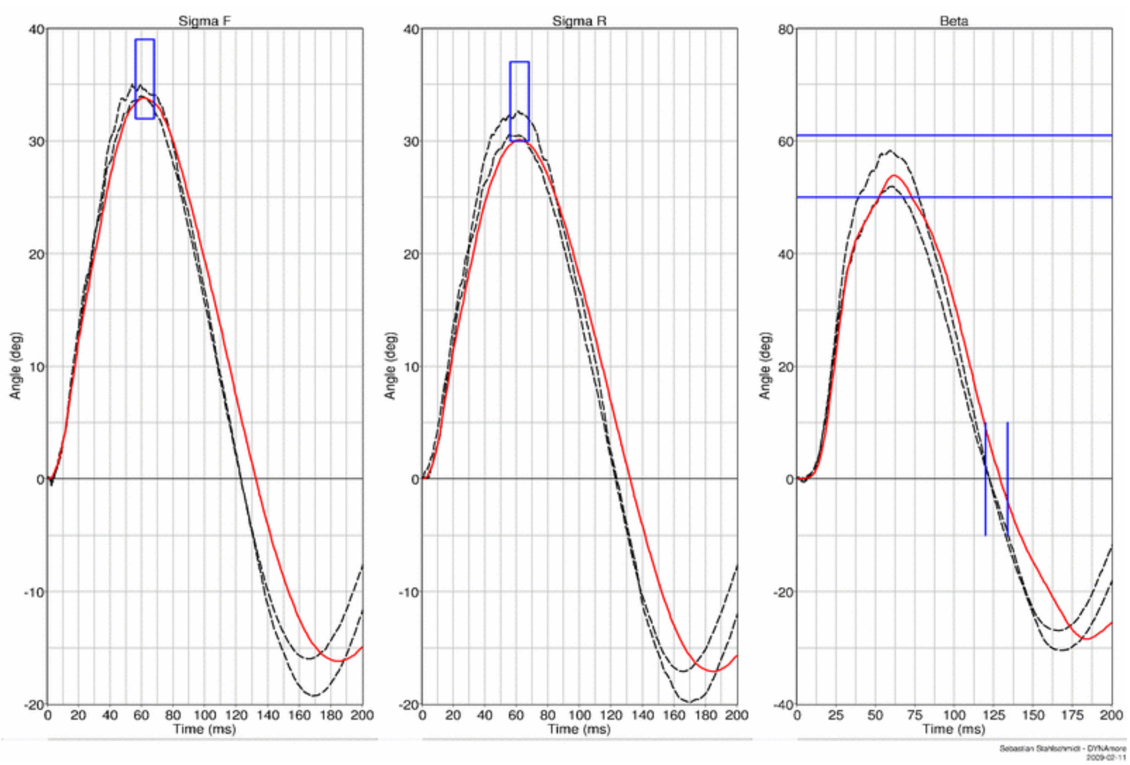


Figure 111: Result of neck calibration test head form rotations

8.2.3 Shoulder pendulum test

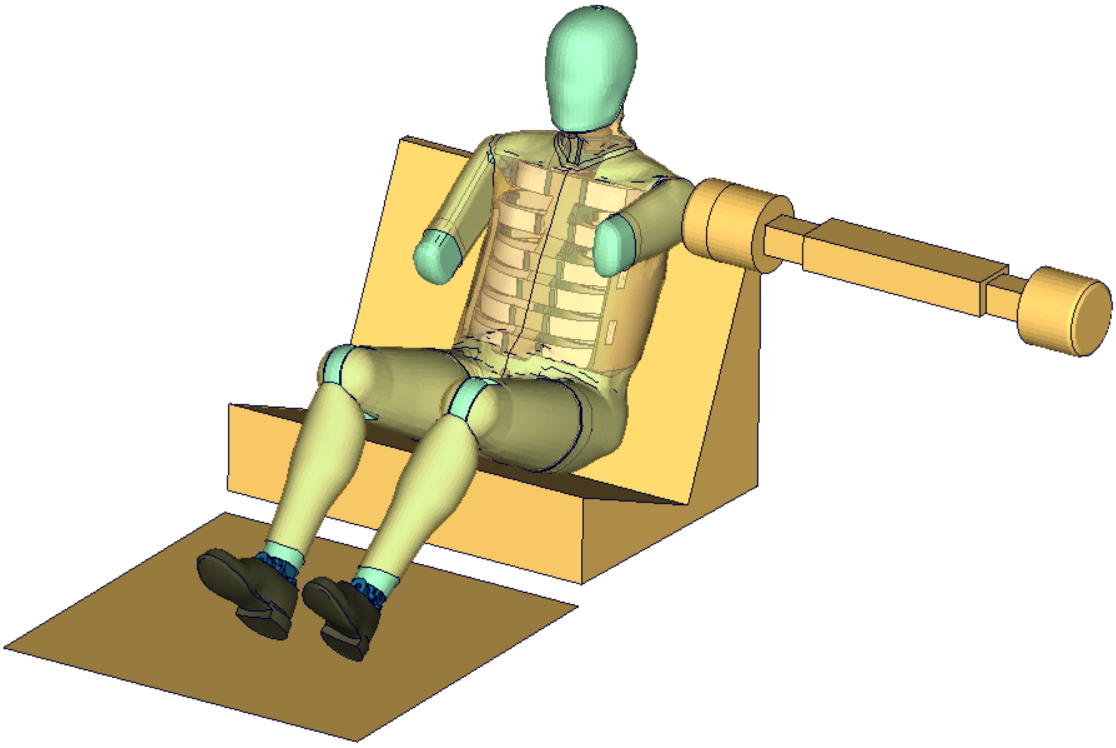


Figure 112: Shoulder calibration test setup

Results of shoulder calibration test with arm (Page 1)

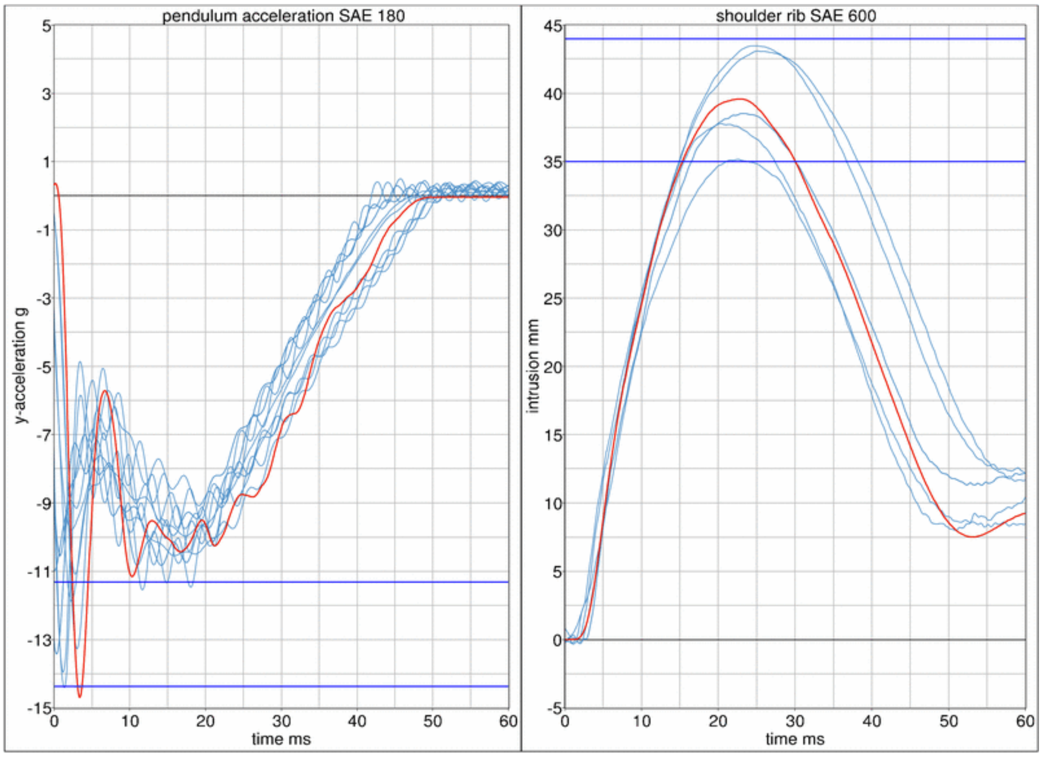


Figure 113: Shoulder calibration test results with arm (Page 1)

8.2.4 Thorax pendulum test without arm

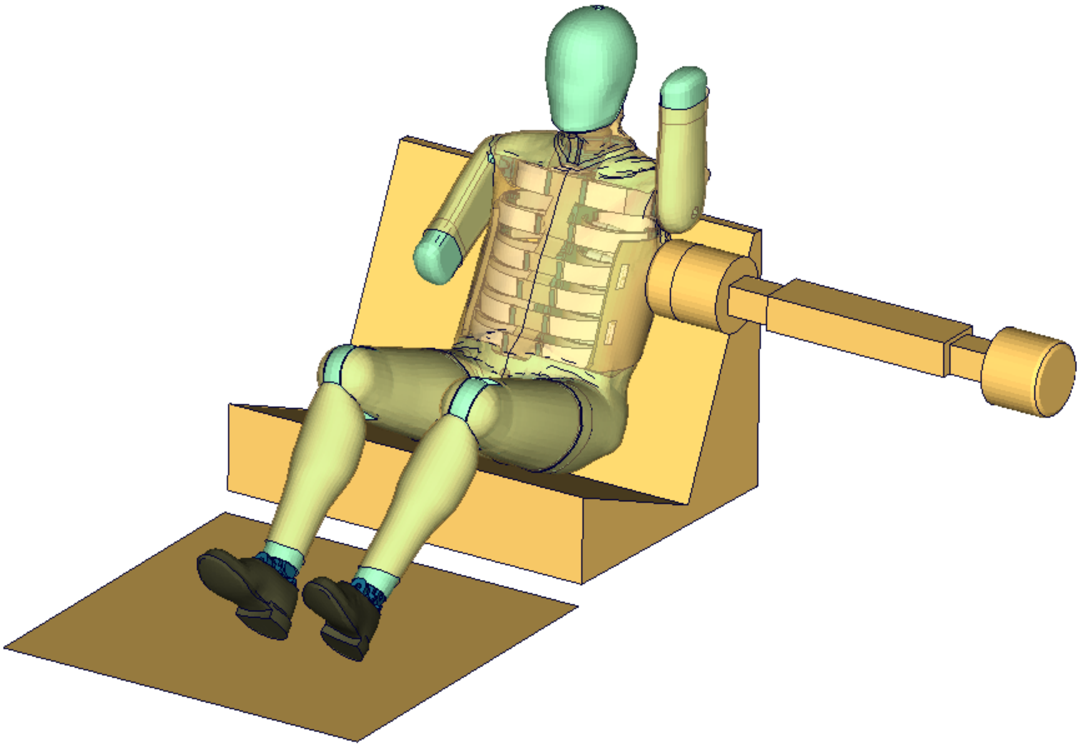


Figure 114: Thorax calibration test setup without arm

Results of thorax calibration test without arm (Page 1)

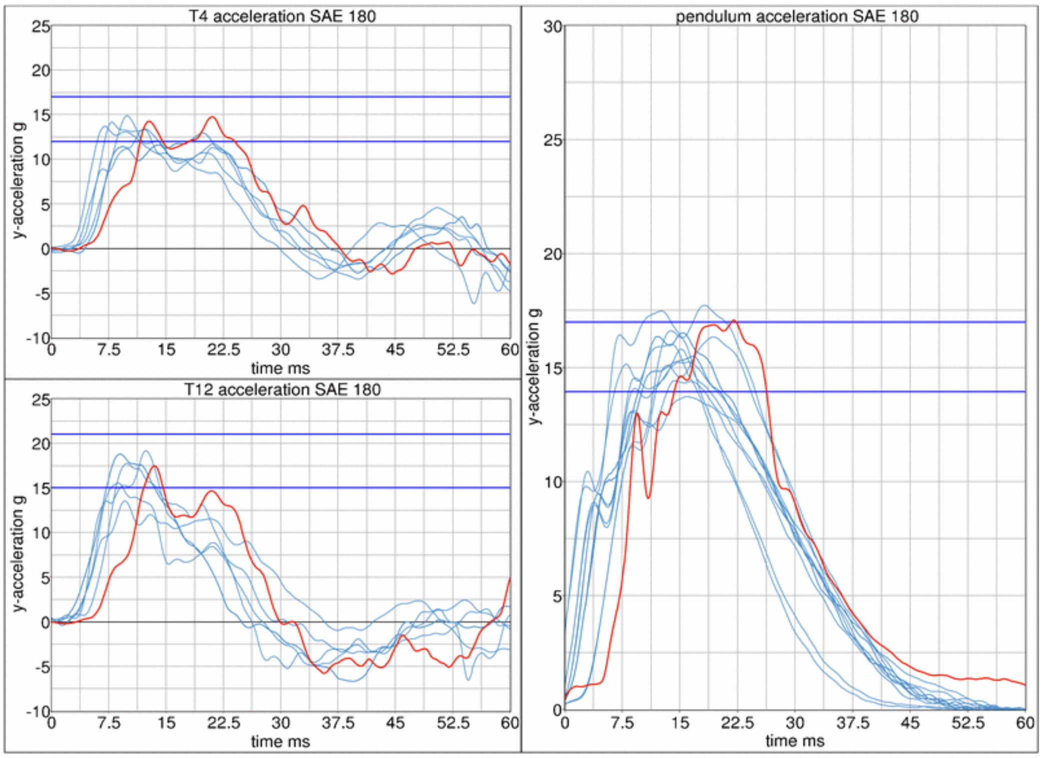


Figure 115: Thorax calibration test results without arm (Page 1)

Results of thorax calibration test without arm (Page 2)

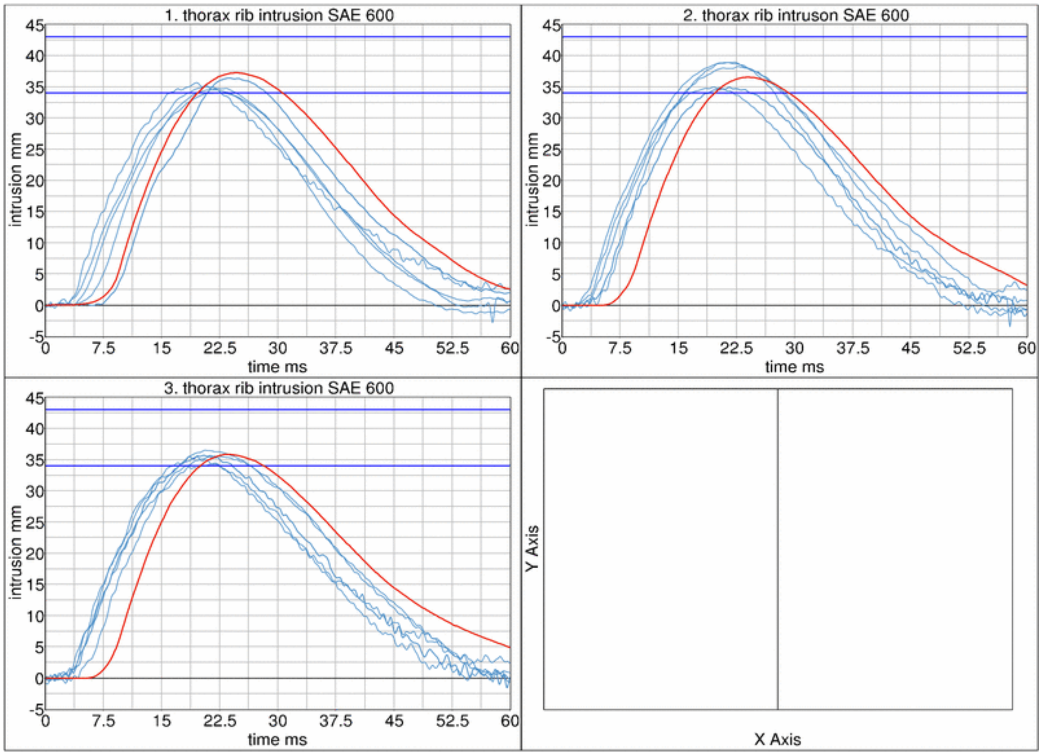


Figure 116: Thorax calibration test results without arm (Page 2)

8.2.5 Thorax pendulum test with arm

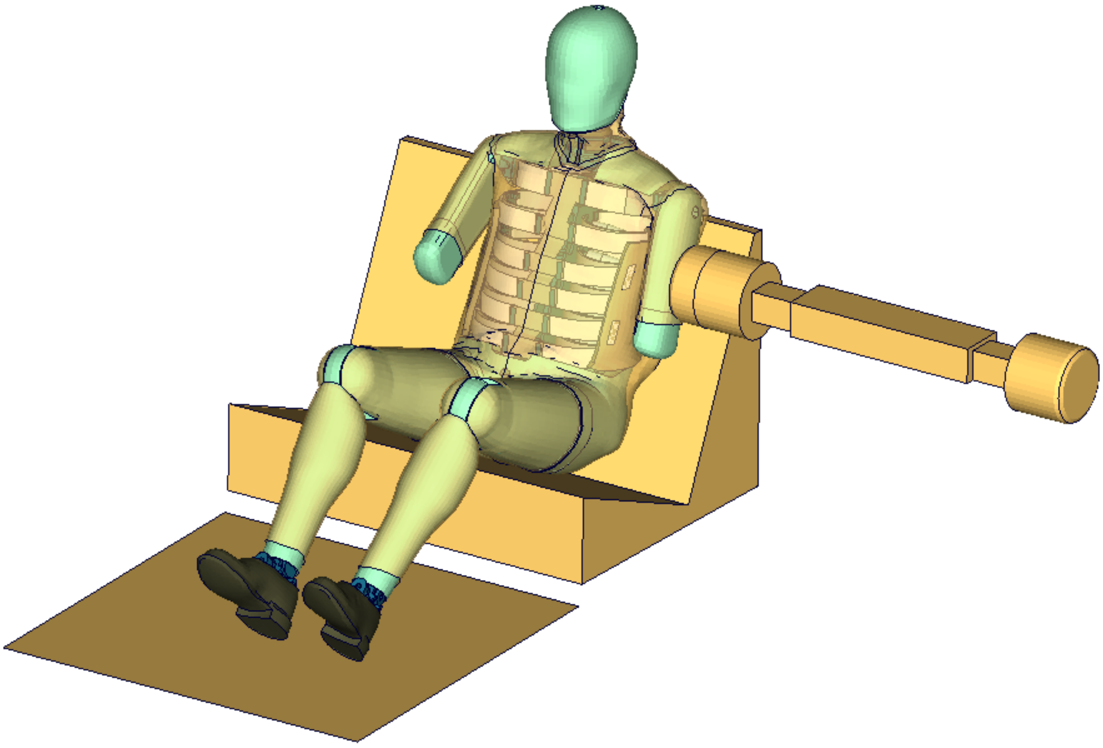


Figure 117: Thorax calibration test setup with arm

Results of thorax calibration test with arm (Page 1)

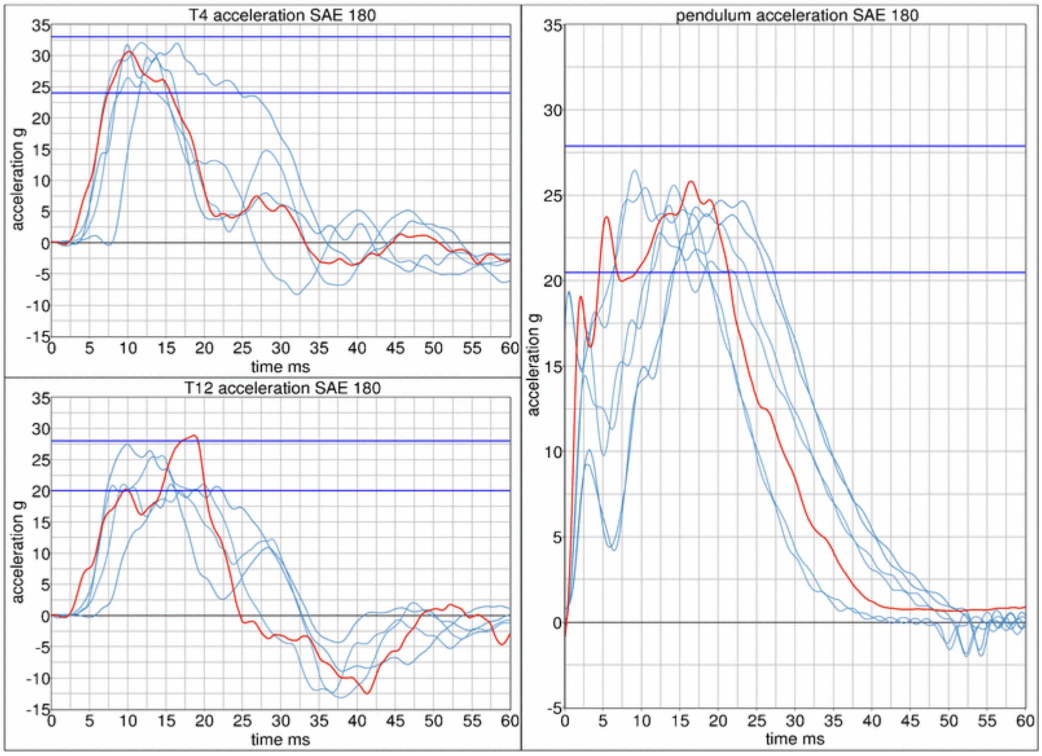


Figure 118: Thorax calibration test results with arm (Page 1)

Results of thorax calibration test with arm (Page 2)

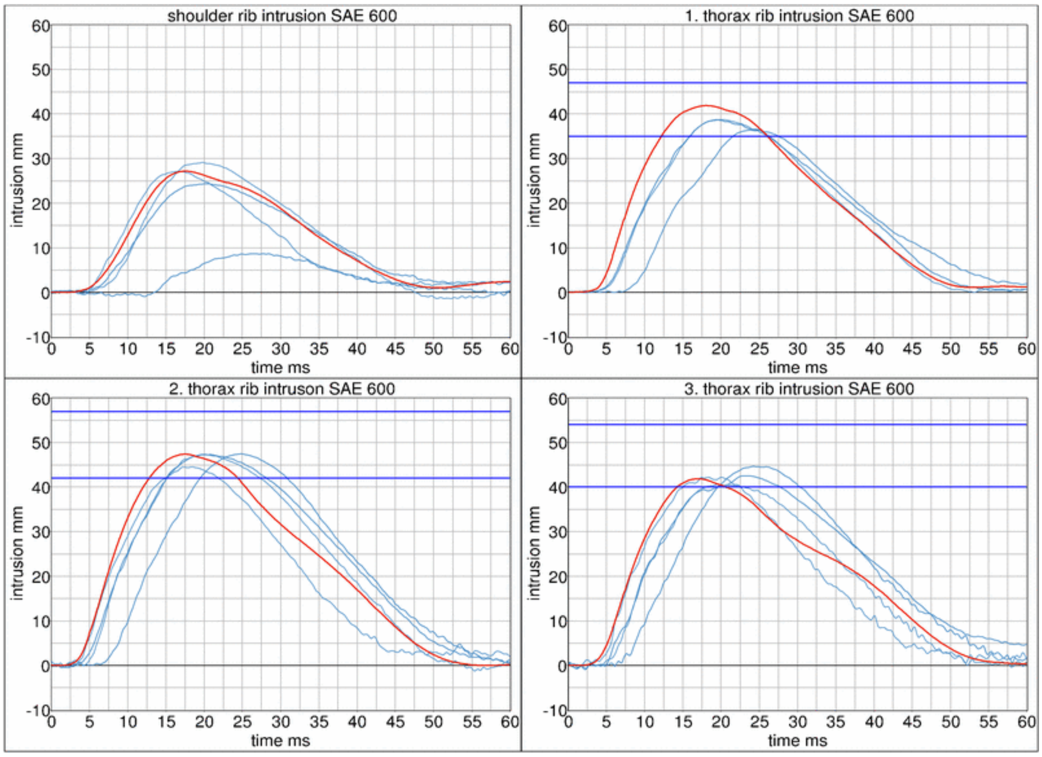


Figure 119: Thorax calibration test results with arm (Page 2)

8.2.6 Abdomen pendulum test

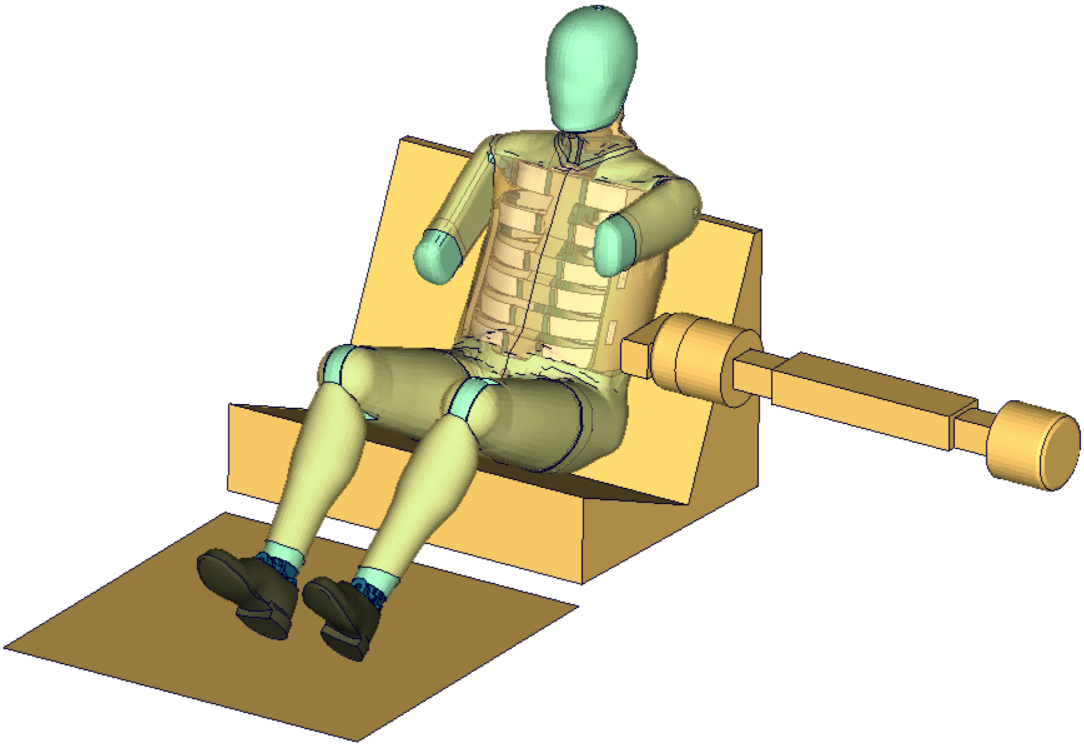


Figure 120: Abdomen calibration test setup

Results of abdomen calibration test with arm (Page 1)

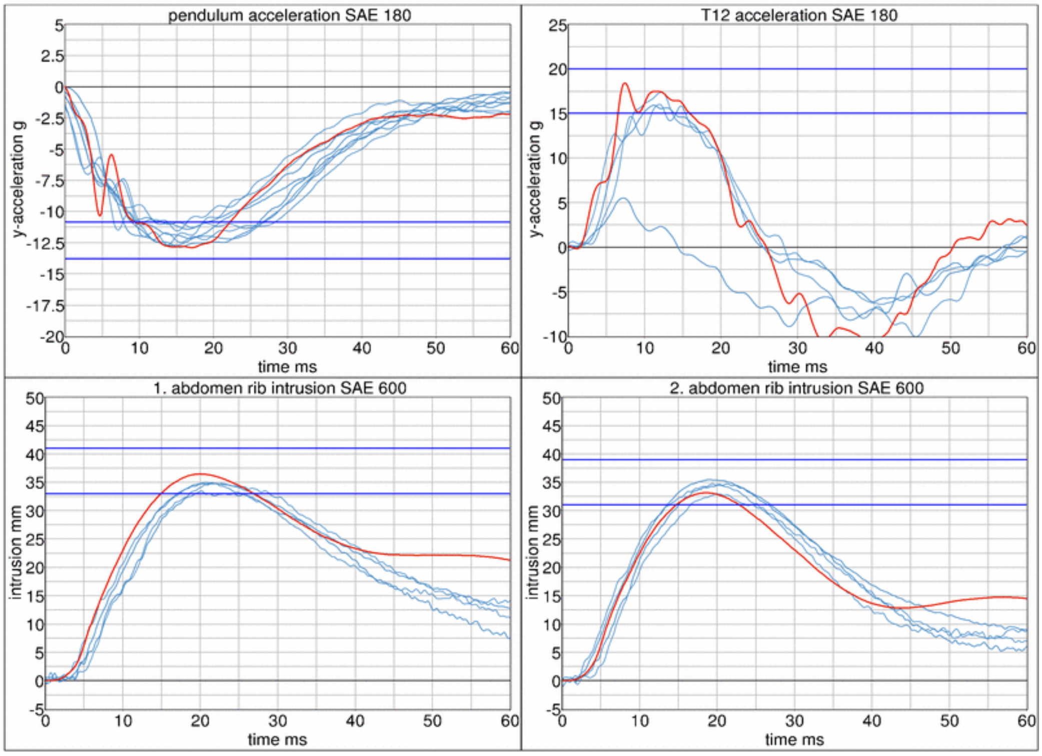


Figure 121: Abdomen calibration test results with arm (Page 1)

8.2.7 Pelvis pendulum test

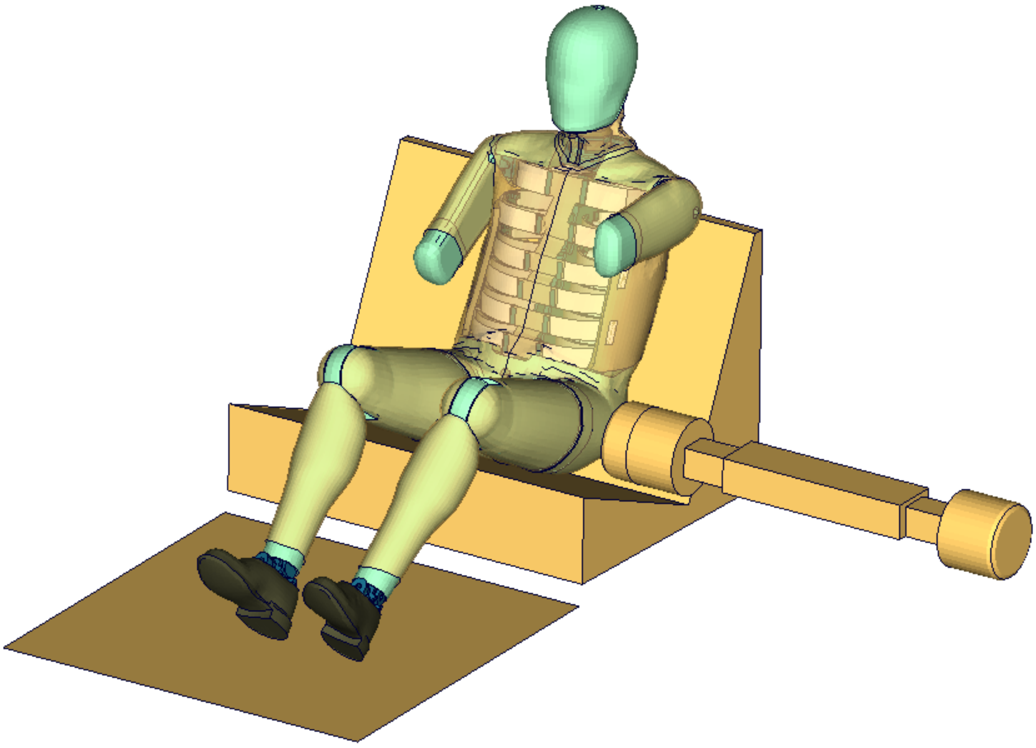


Figure 122: Pelvis calibration test setup

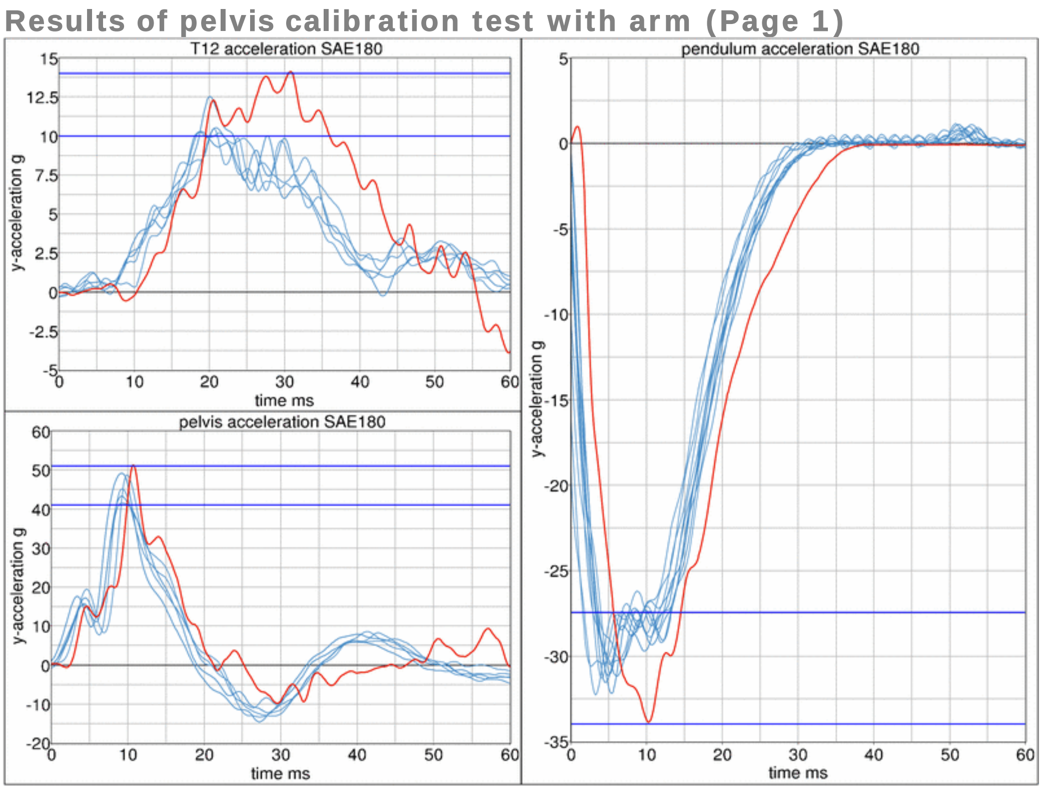


Figure 123: Pelvis calibration test results with arm (Page 1)

8.3 Sled Tests

The current release of the WorldSID is now validated by using material, component, dummy certification and sled tests. The validation of the interactions of all components is now done.

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 tests is done without the jacket and one without the Arm.

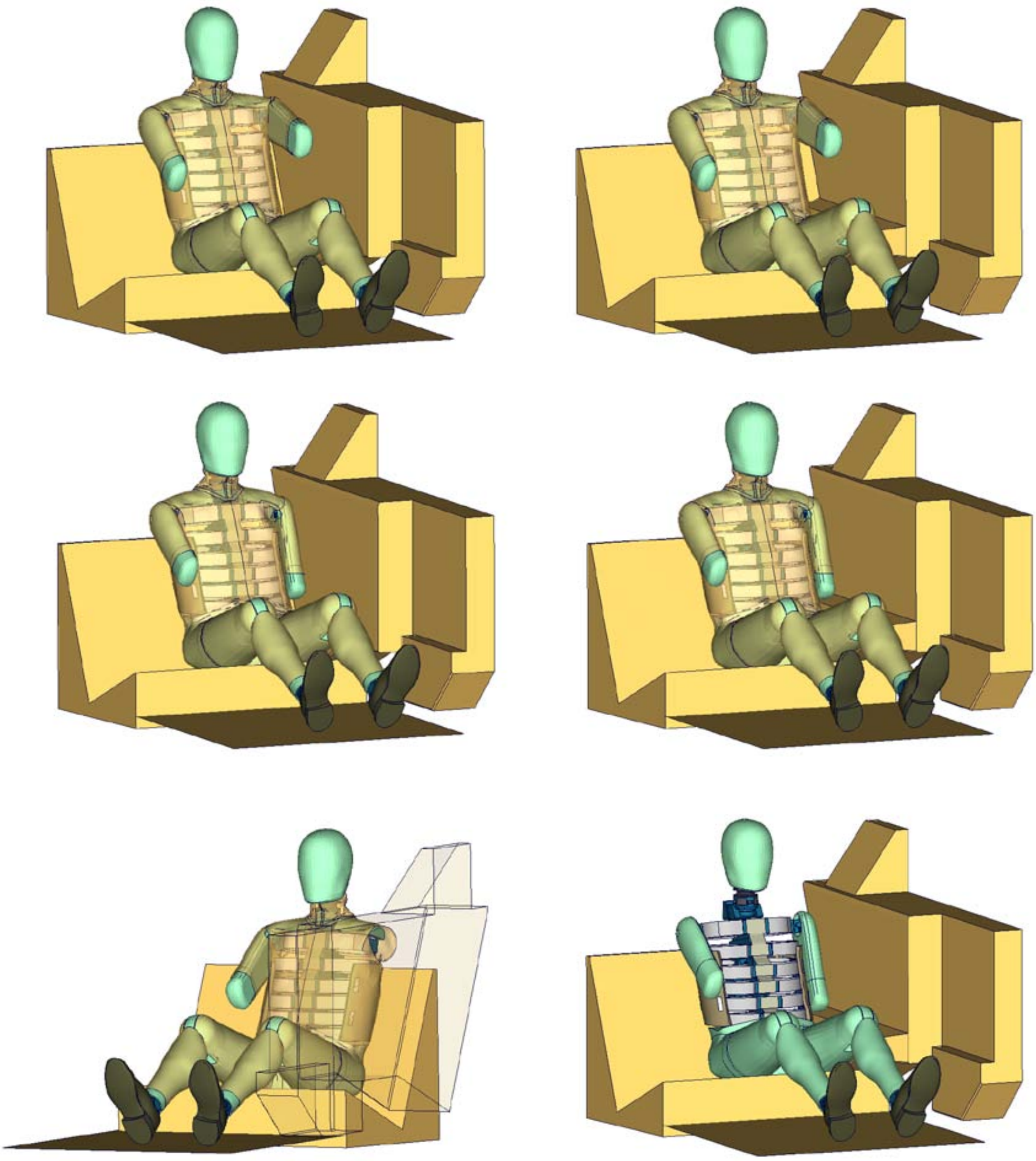


Figure 124: Sled tests for next WorldSID release. Left hand side: Plane sled. Right hand side: Plane sled with pelvis pusher

8.3.1 Flat barrier

8.3.1.1 Arm position second notch

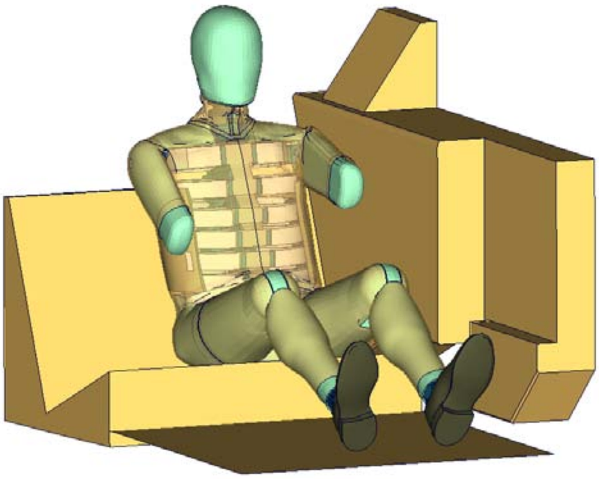
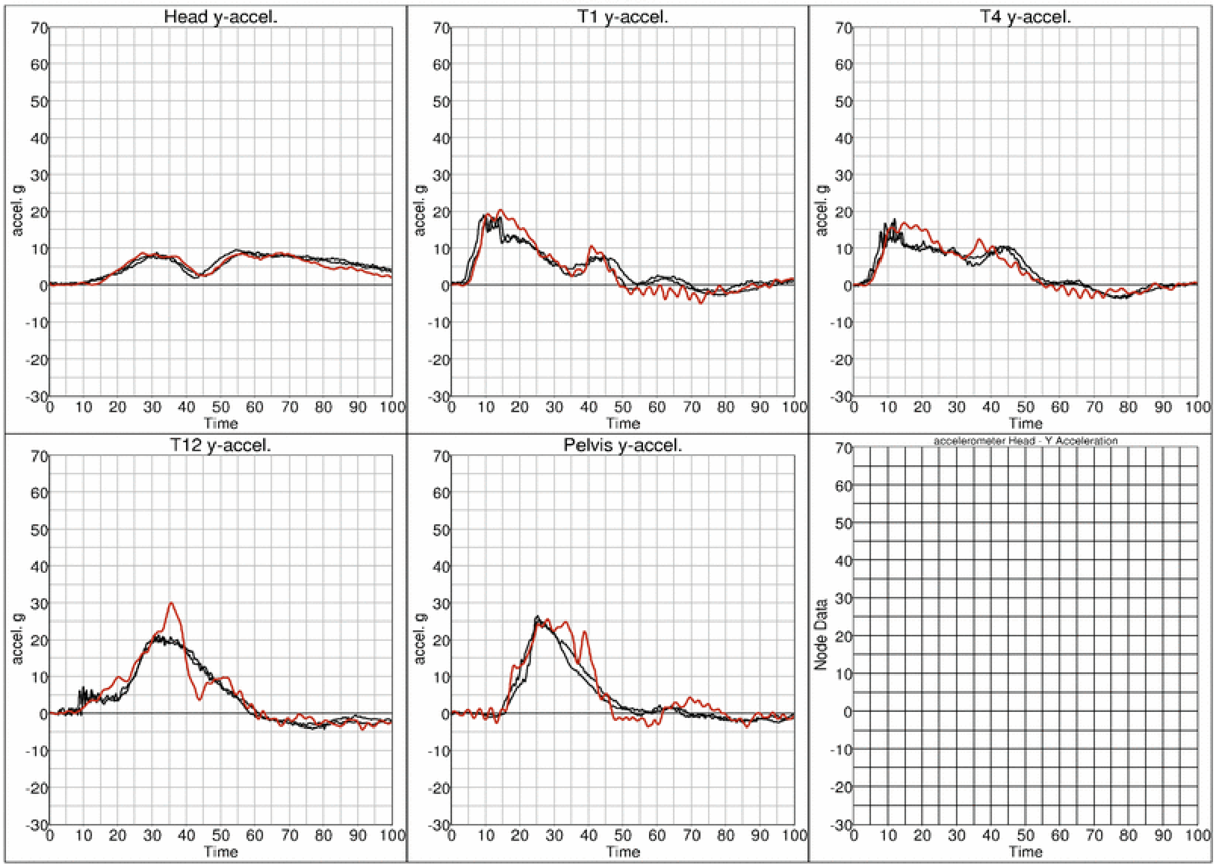
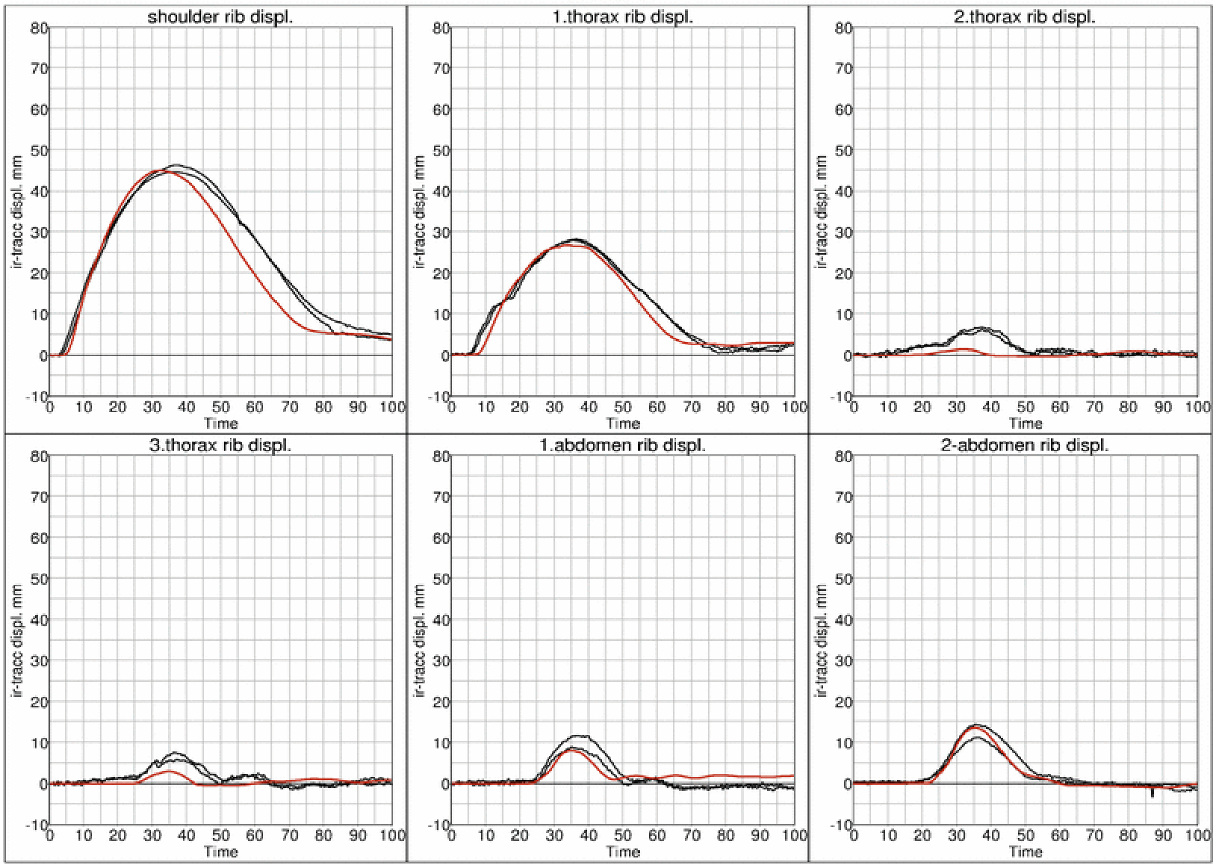
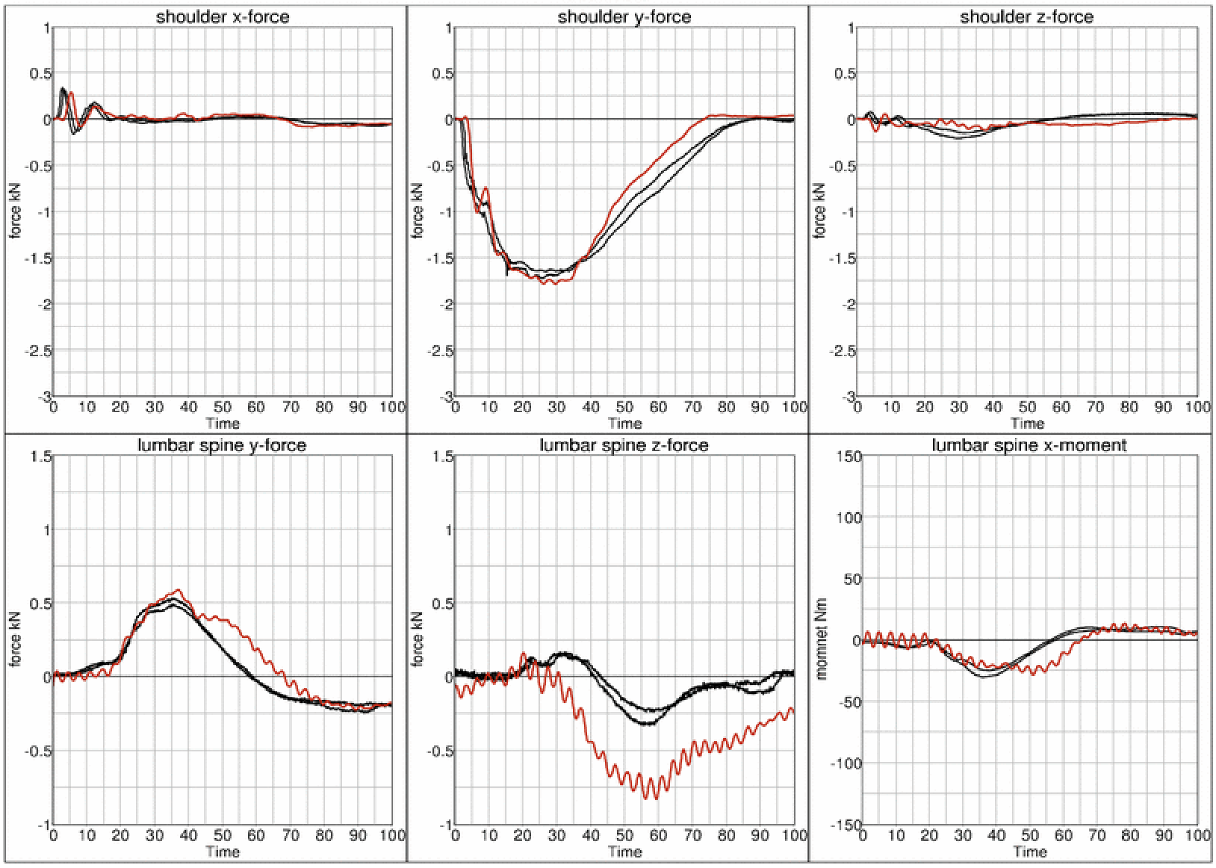


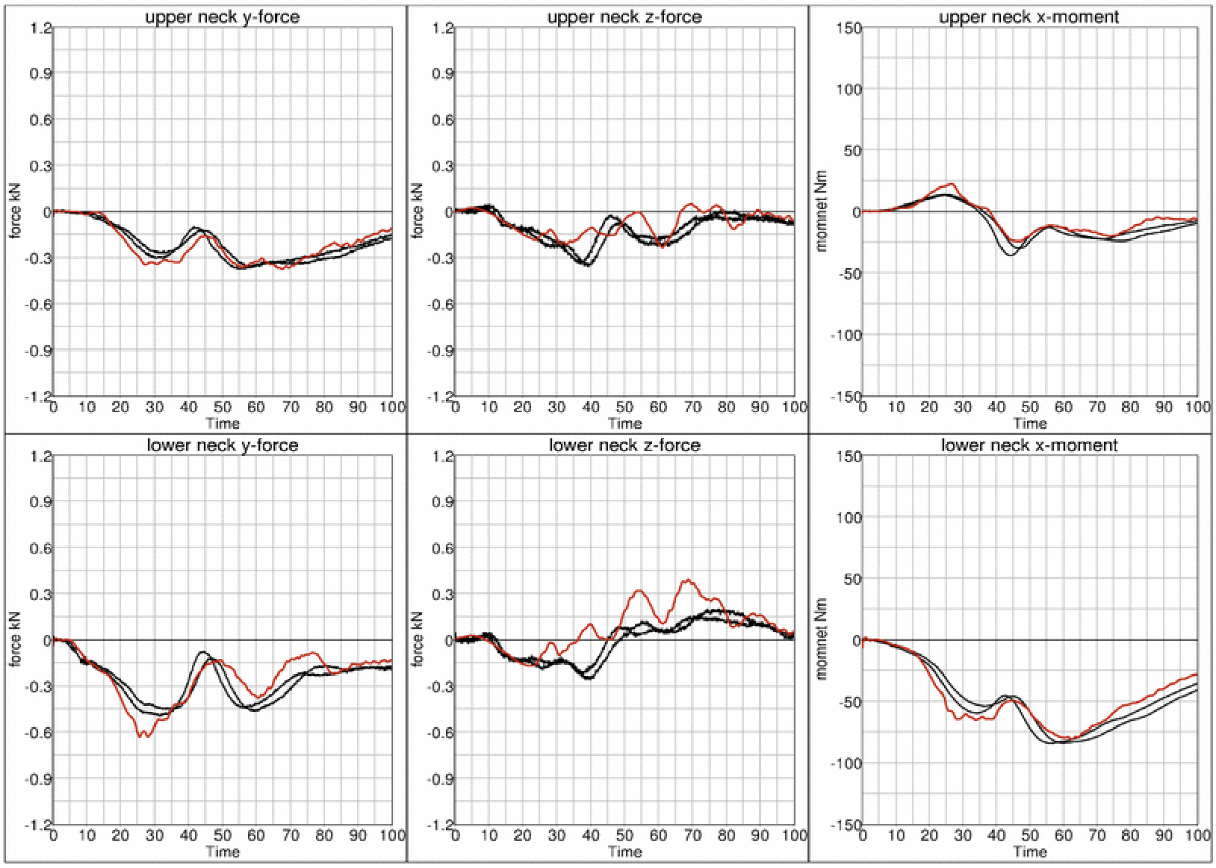
Figure 125: Flat barrier and arm second notch.

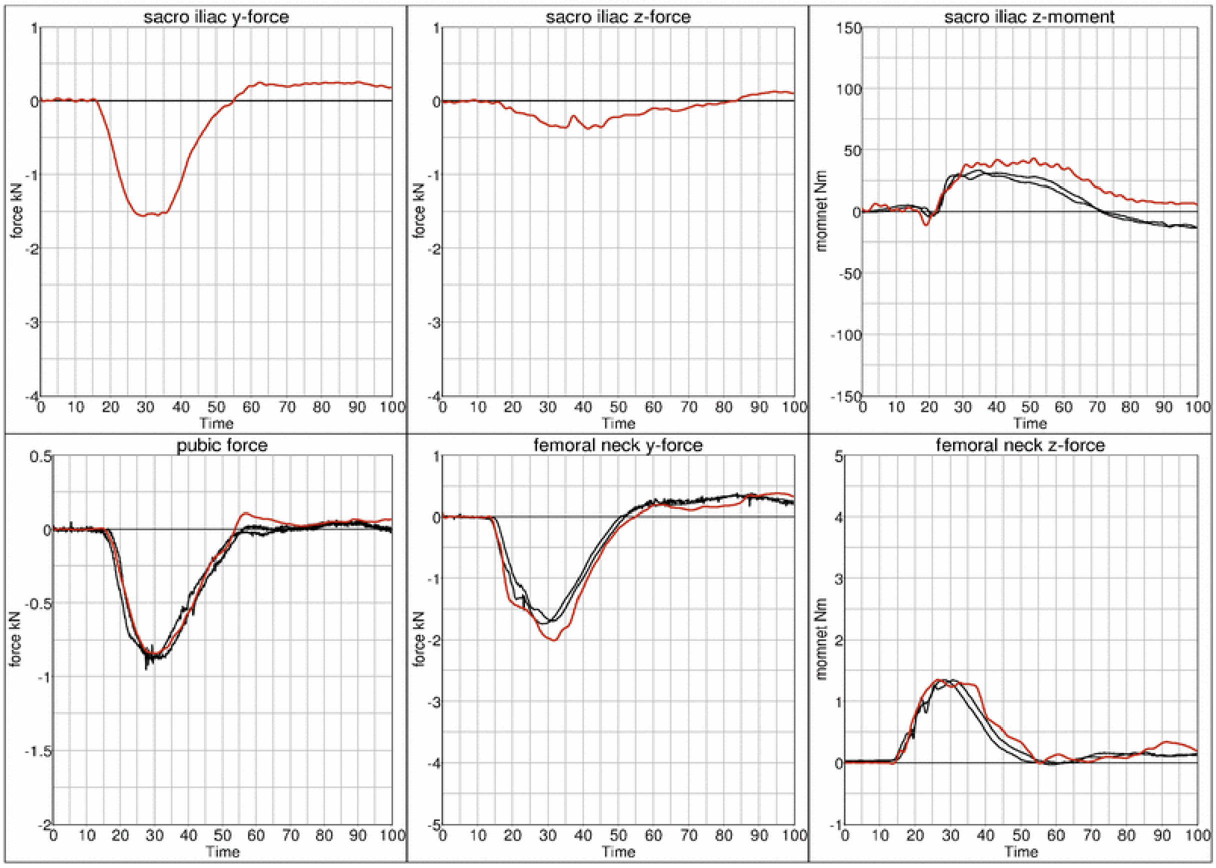
Low velocity:

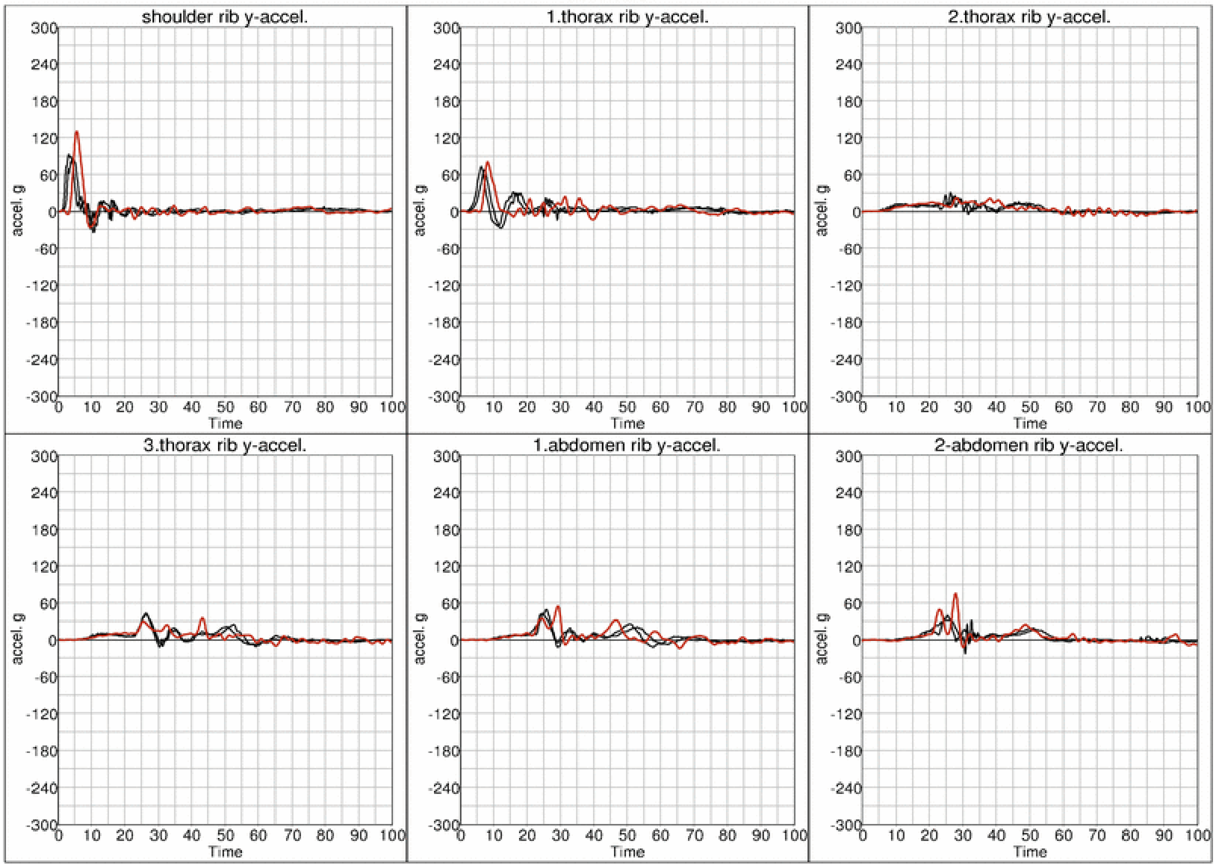



shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
ir-tracc displ. mm
Time

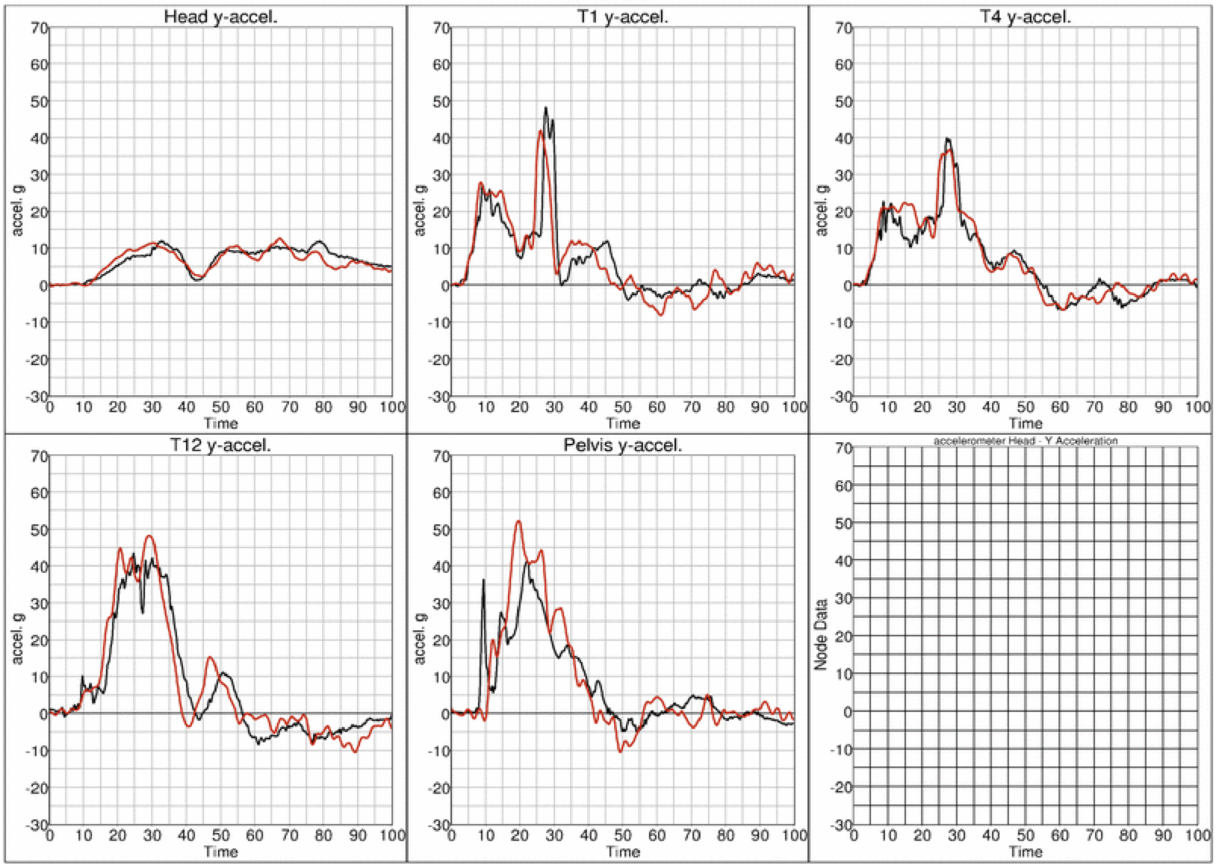

shoulder x-force
shoulder y-force
shoulder z-force
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
force kN
momnet Nm
Time

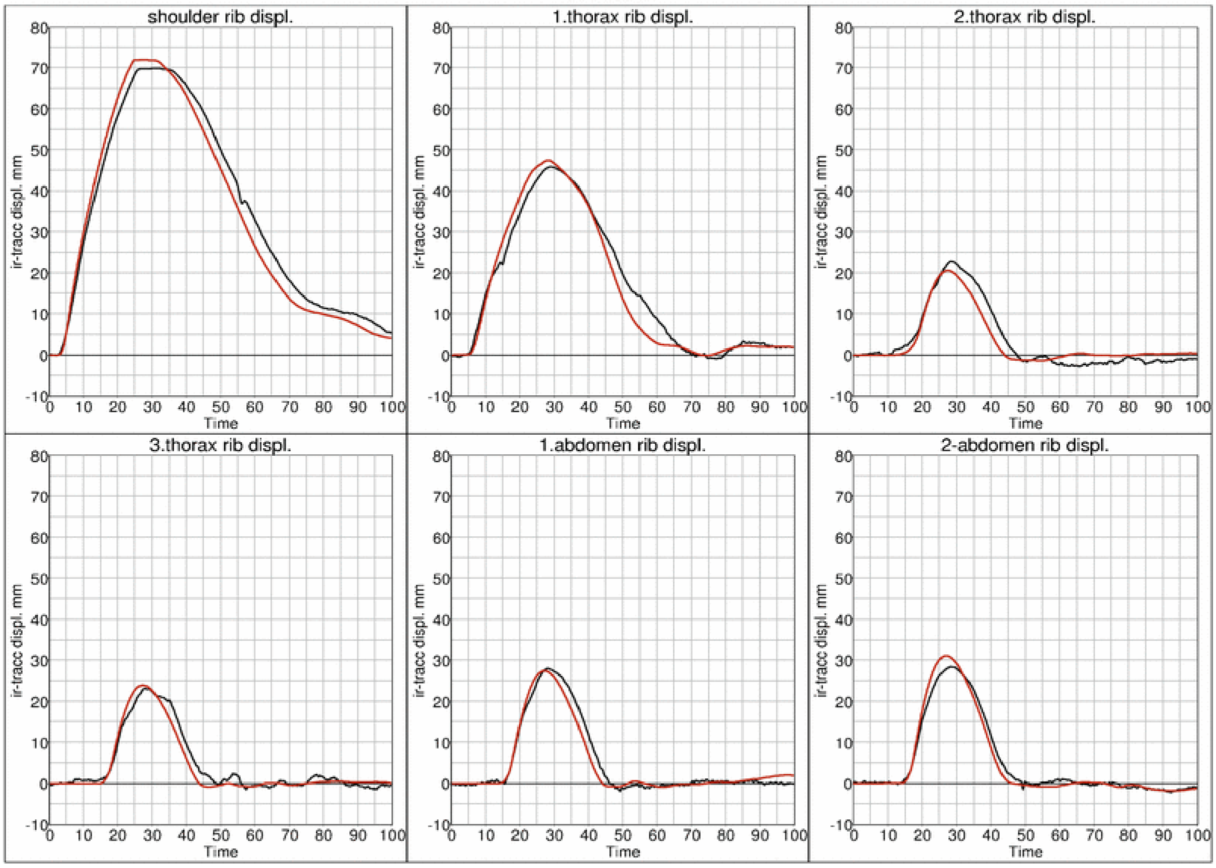

upper neck y-force
upper neck z-force
upper neck x-moment
lower neck y-force
lower neck z-force
lower neck x-moment
force kN
momnet Nm
Time

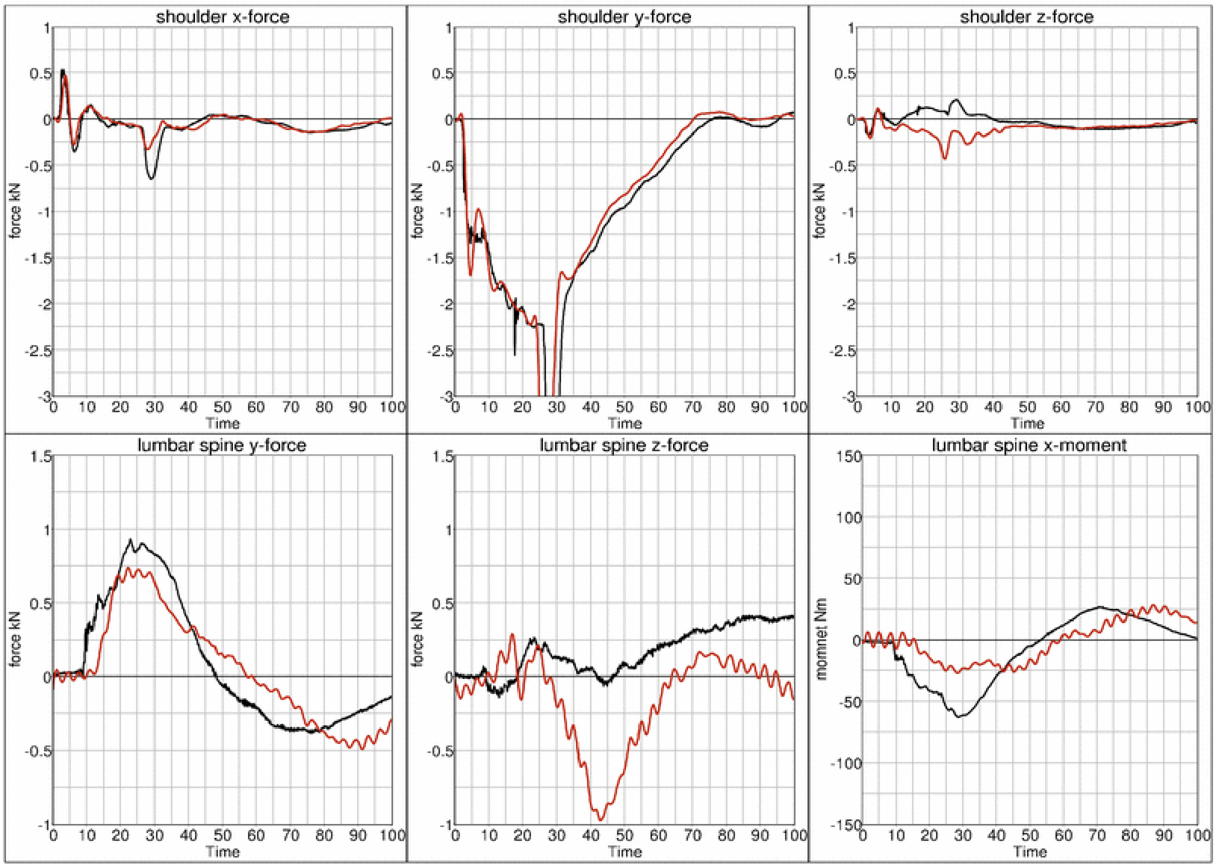

sacro iliac y-force
sacro iliac z-force
sacro iliac z-moment
pubic force
femoral neck y-force
femoral neck z-force
force kN
momnet Nm
Time

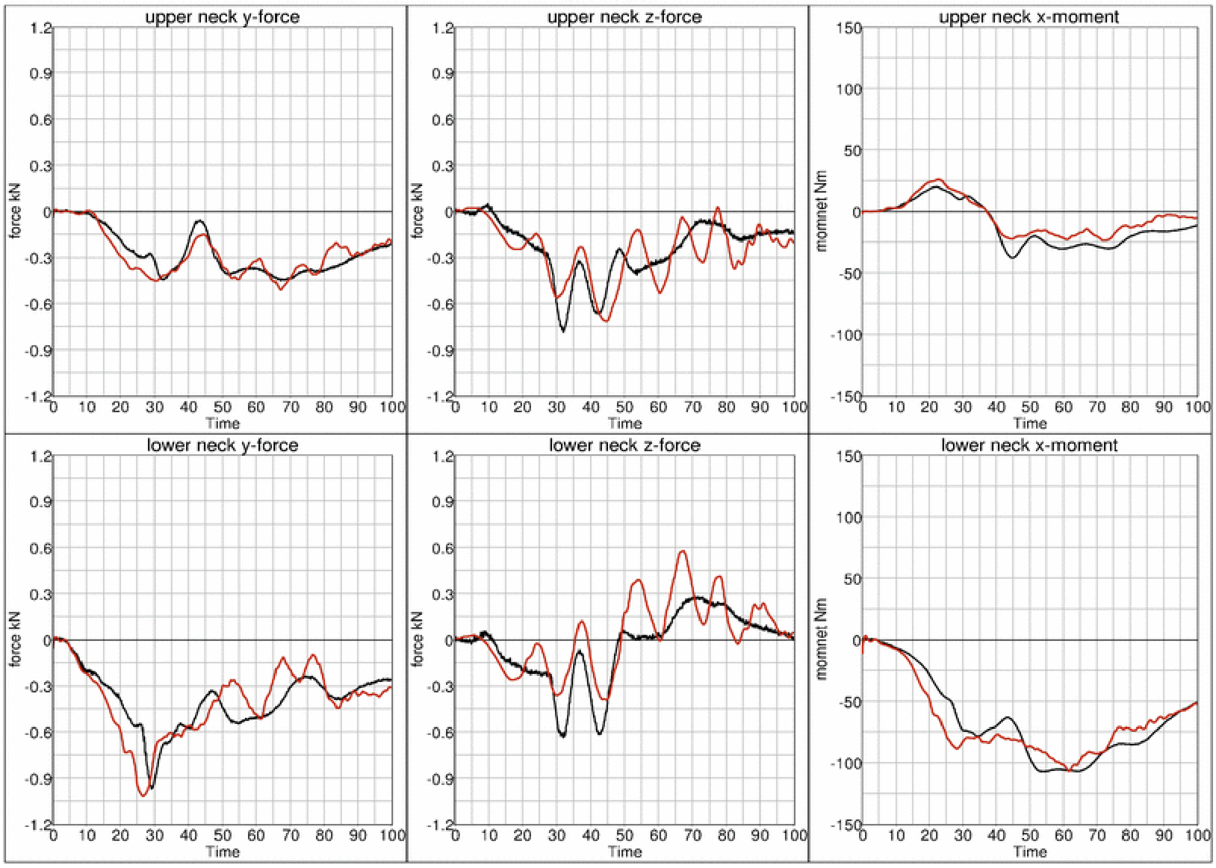


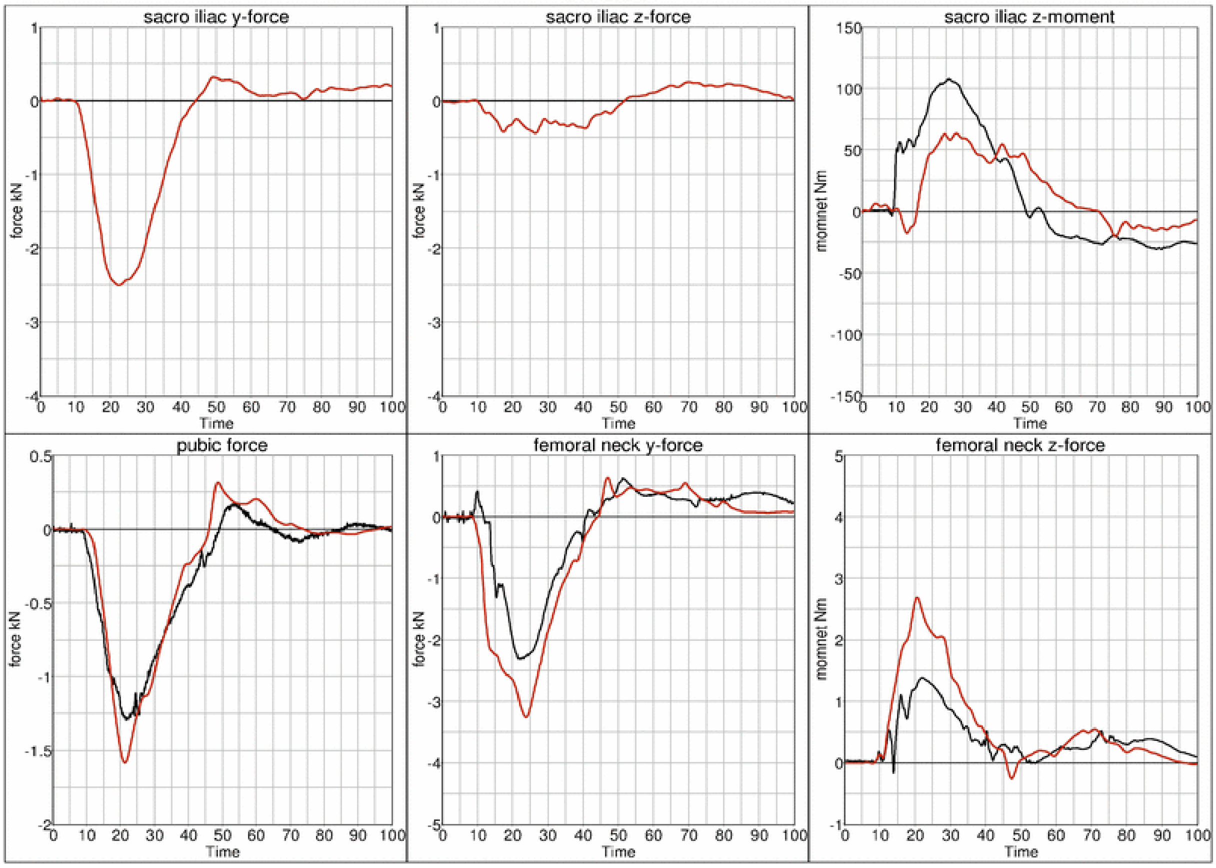
High velocity:

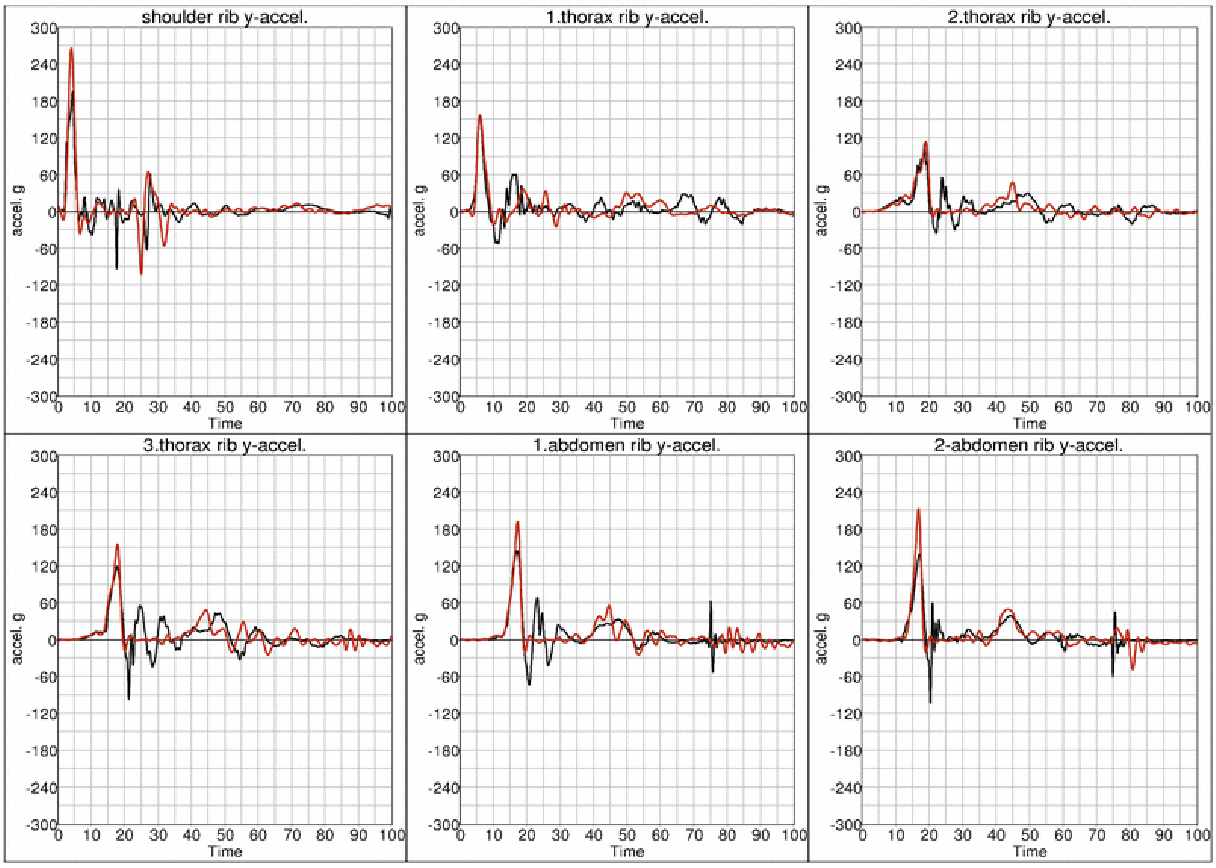



shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
ir-tracc displ. mm
Time


shoulder x-force
shoulder y-force
shoulder z-force
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
force kN
momnet Nm
Time


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
momnet Nm
Time


sacro iliac y-force
sacro iliac z-force
sacro iliac z-moment
pubic force
femoral neck y-force
femoral neck z-force
force kN
momnet Nm
Time


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
300
240
180
120
60
0
-60
-120
-180
-240
-300
0
10
20
30
40
50
60
70
80
90
100

8.3.1.2 Arm position first notch

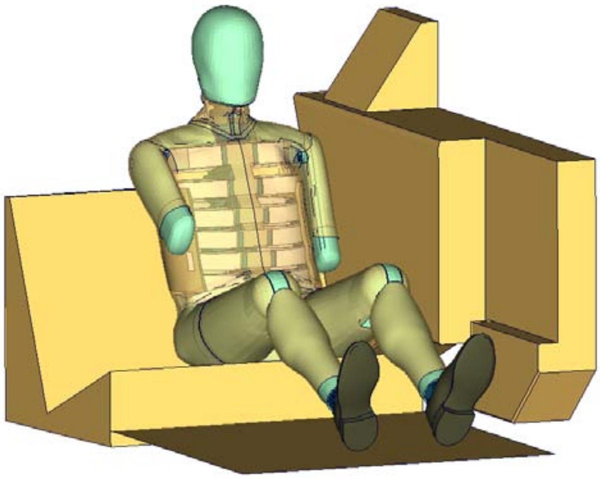
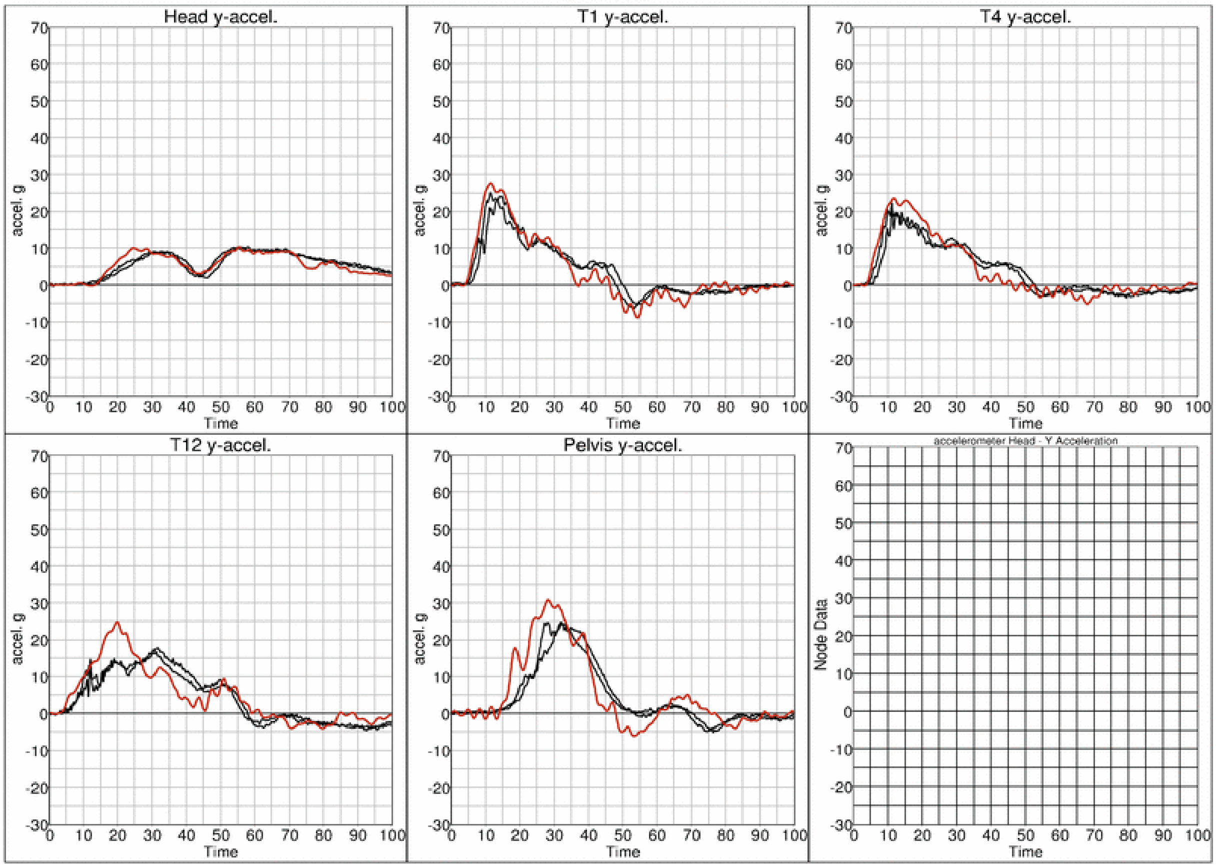
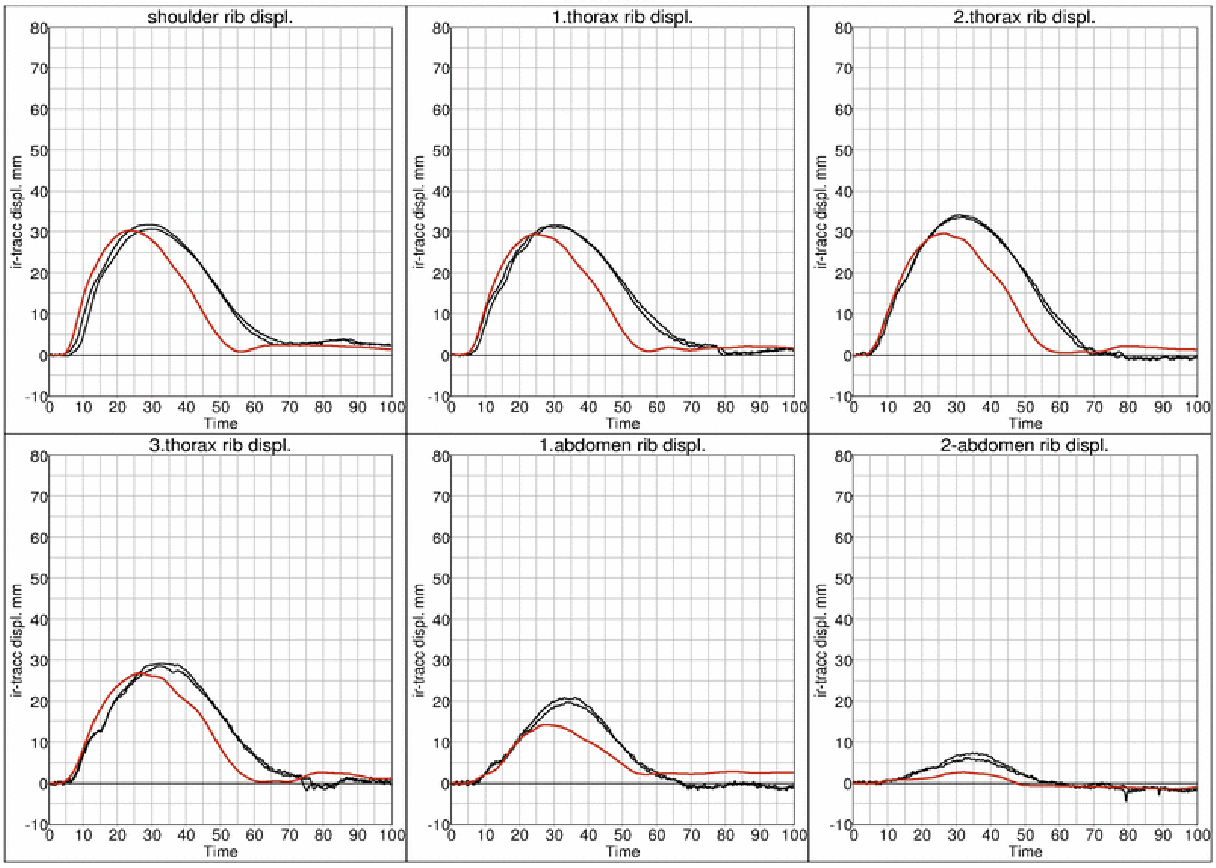
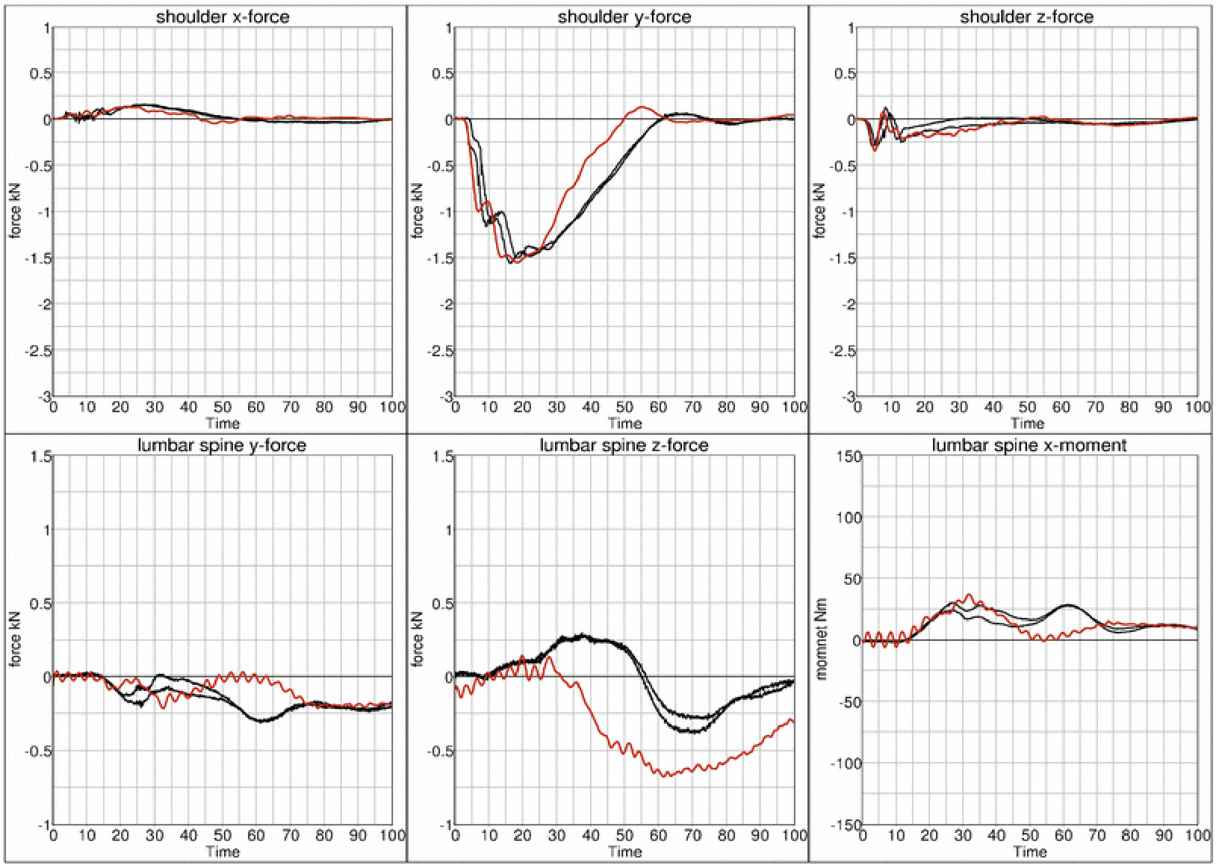


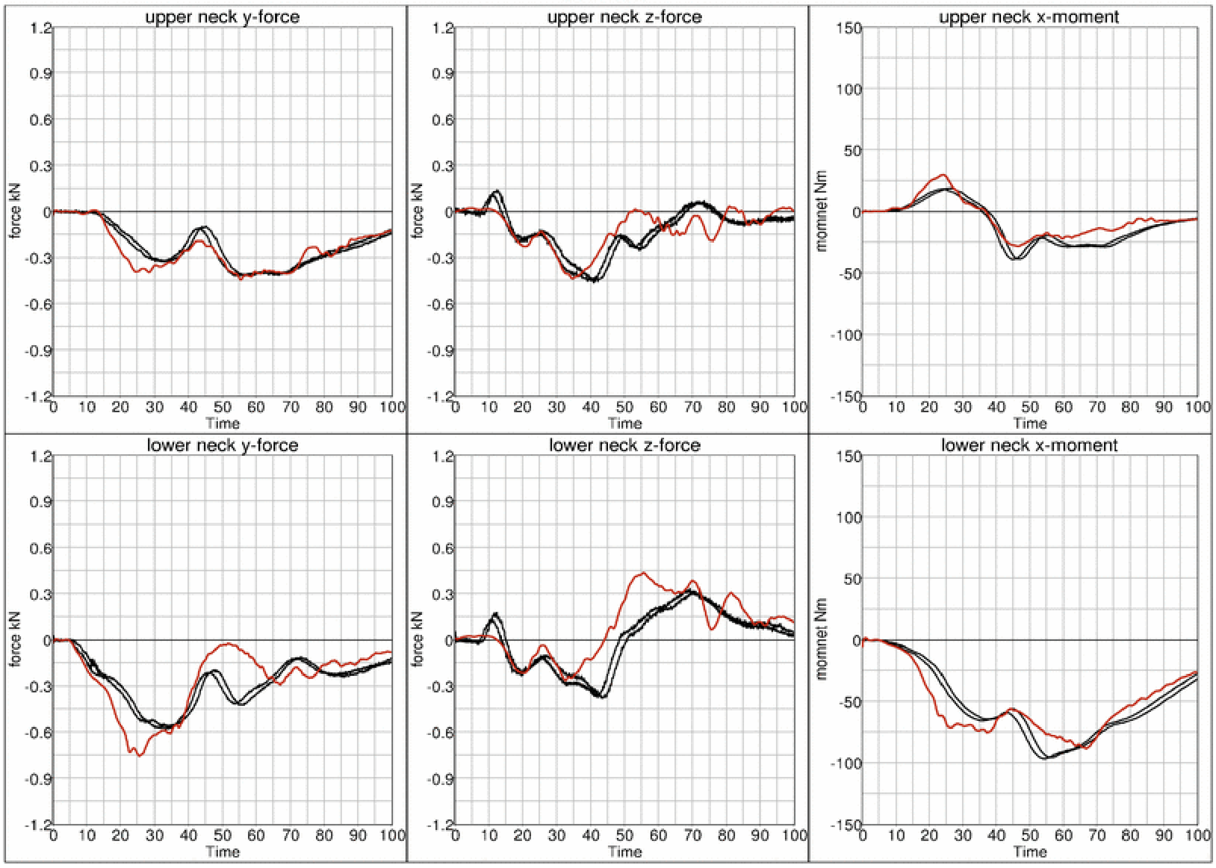
Figure 126: Flat barrier and arm first notch.

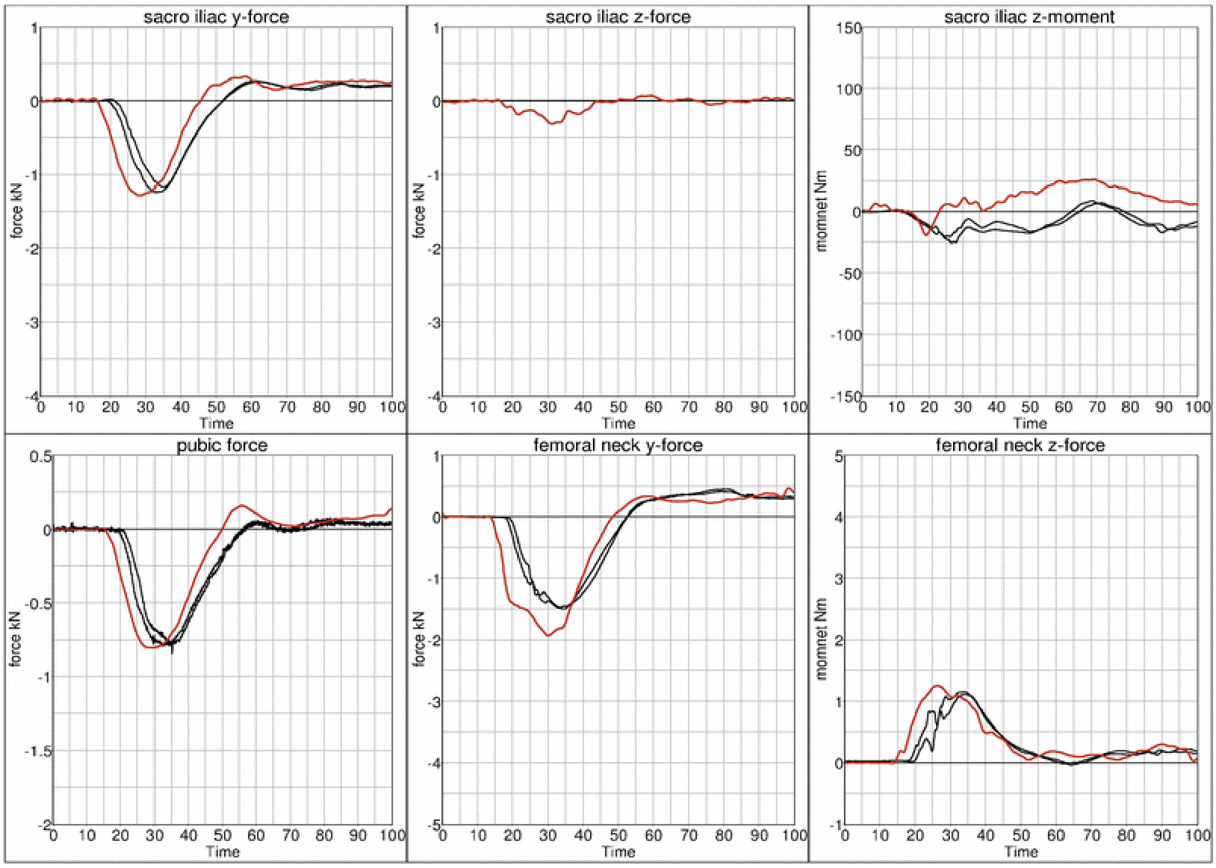
Low velocities:

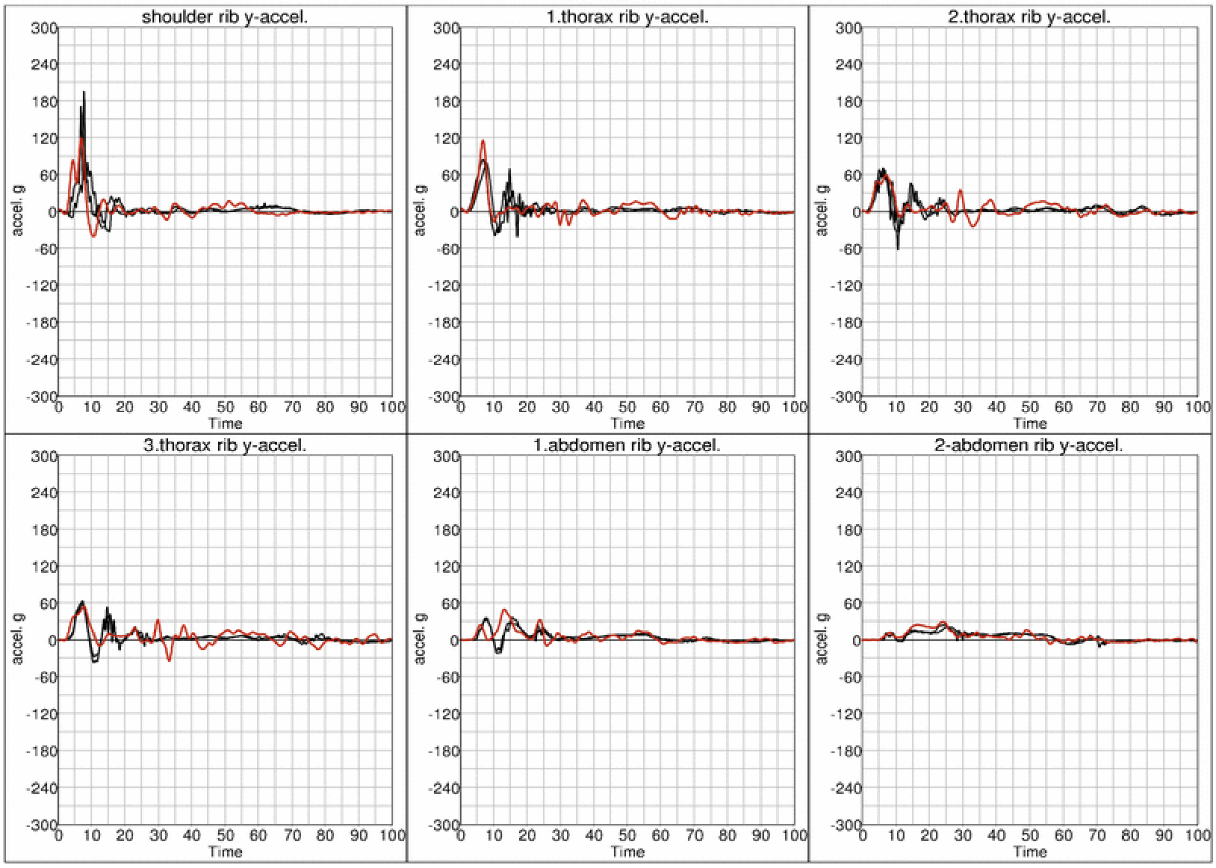



shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
ir-tracc displ. mm
Time

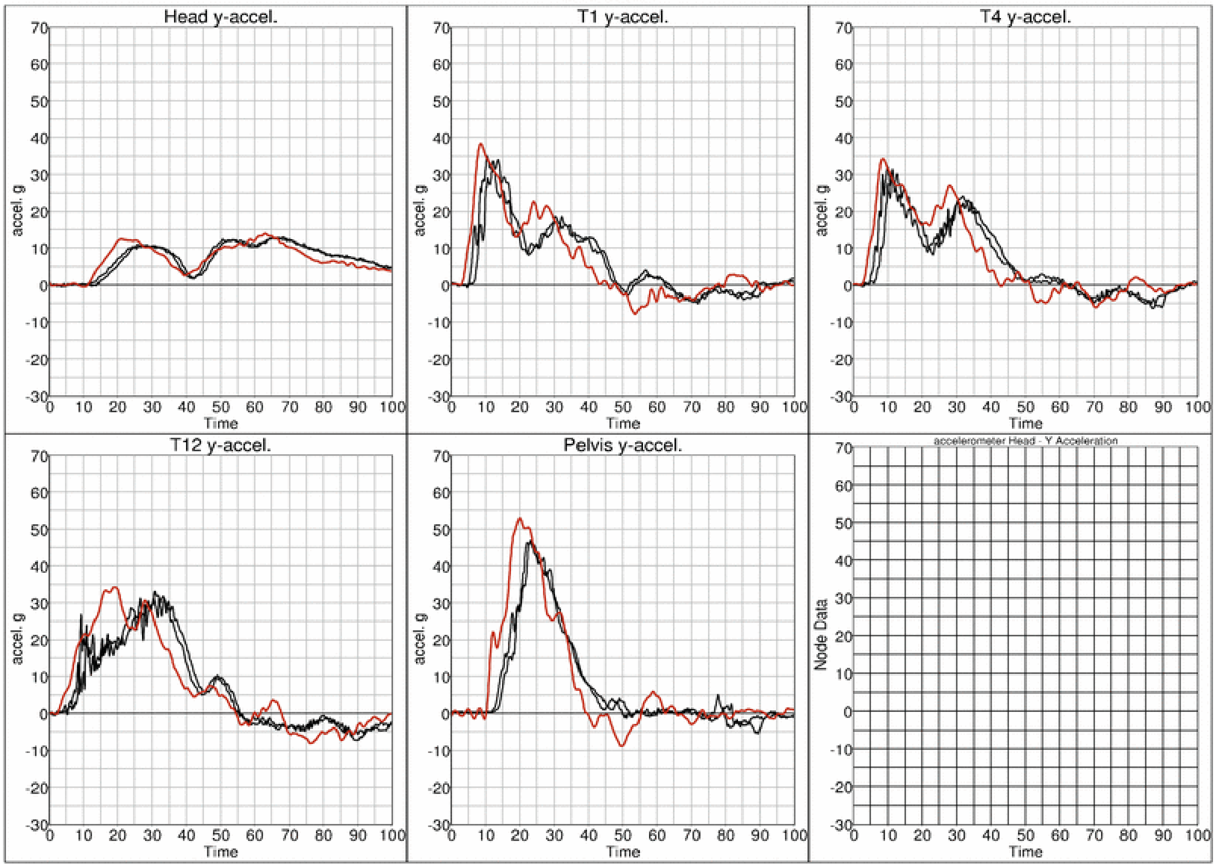

shoulder x-force
shoulder y-force
shoulder z-force
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
force kN
momnet Nm
Time

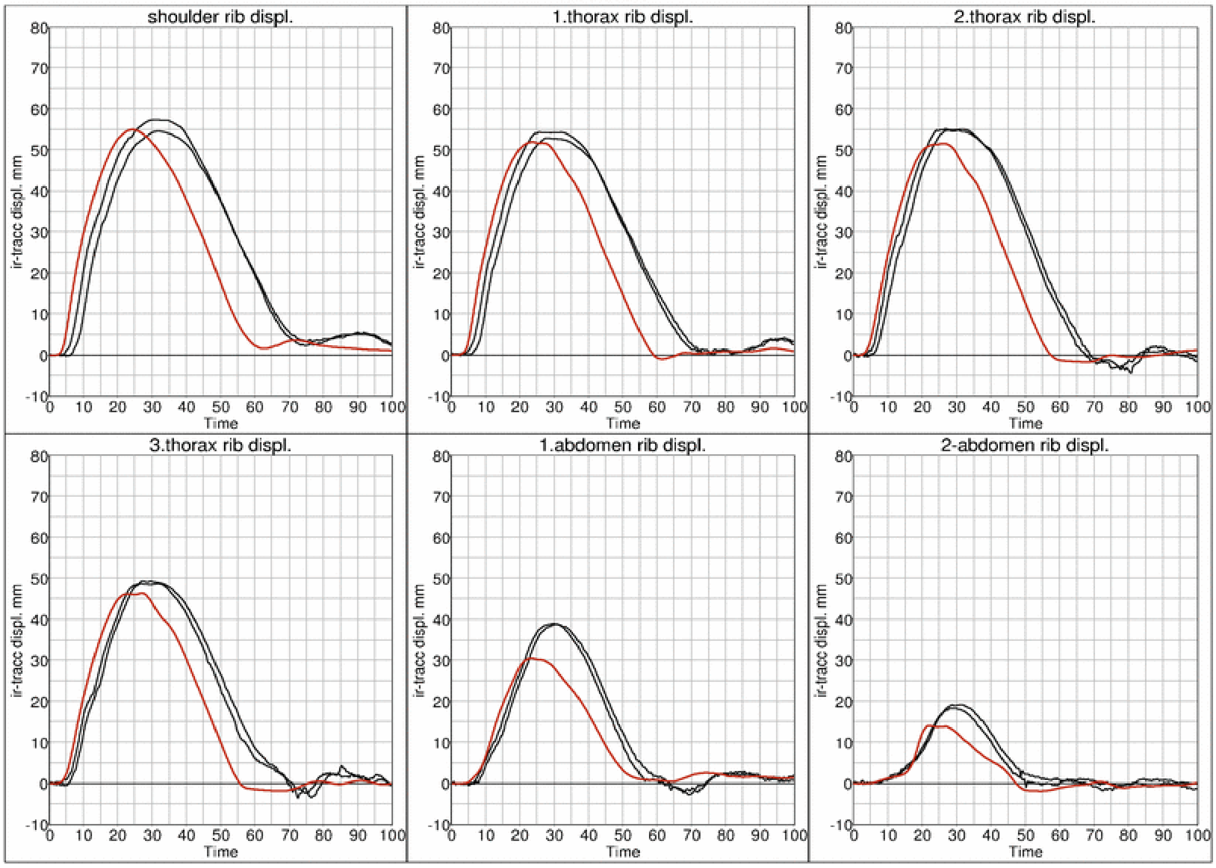

upper neck y-force
upper neck z-force
upper neck x-moment
lower neck y-force
lower neck z-force
lower neck x-moment
force kN
momnet Nm
Time

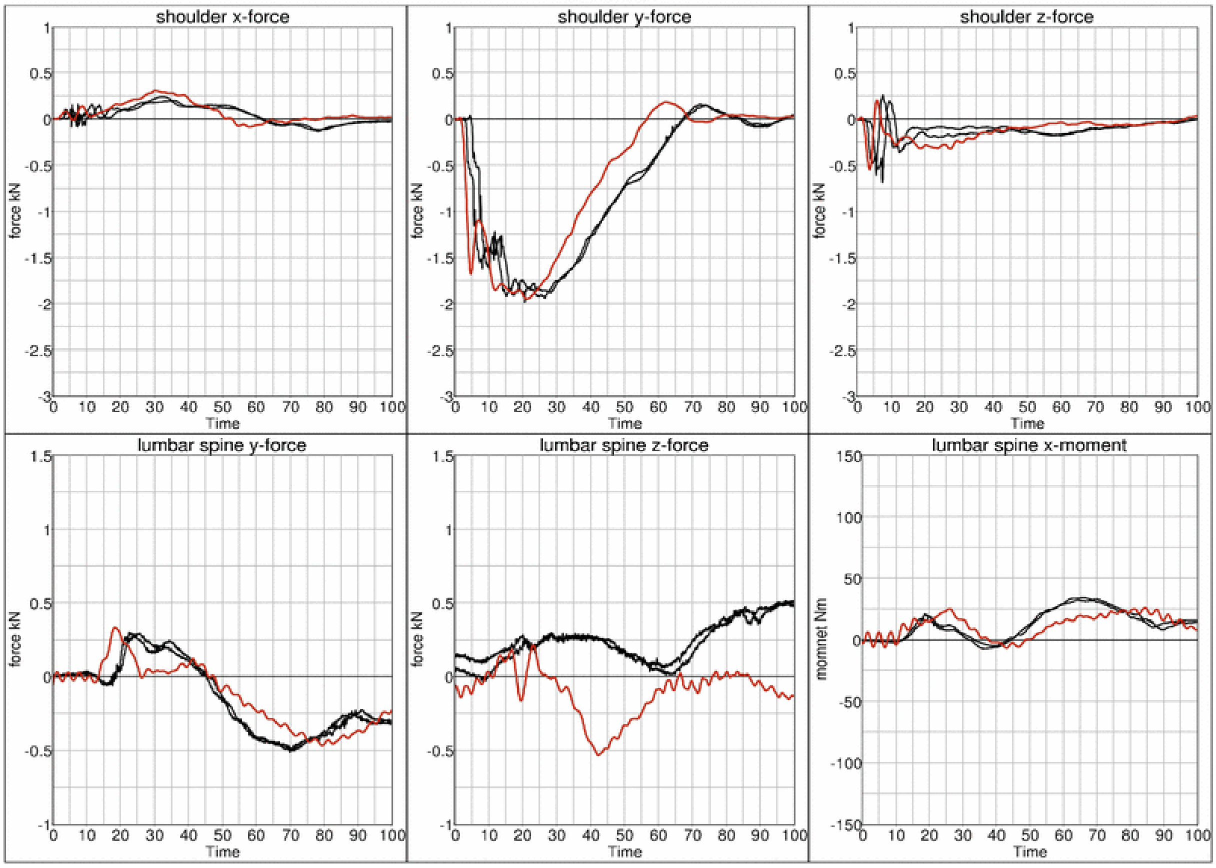

sacro iliac y-force
sacro iliac z-force
sacro iliac z-moment
pubic force
femoral neck y-force
femoral neck z-force
force kN
momnet Nm
Time

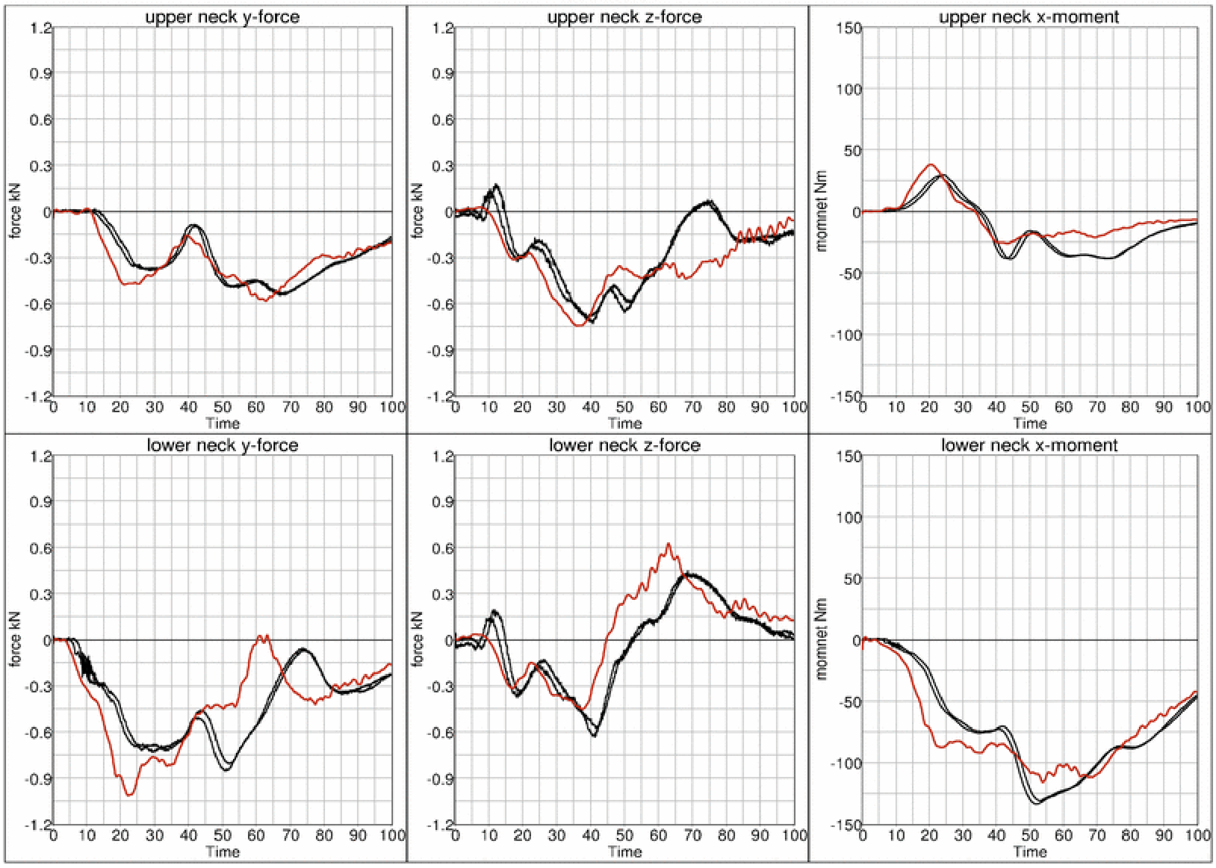


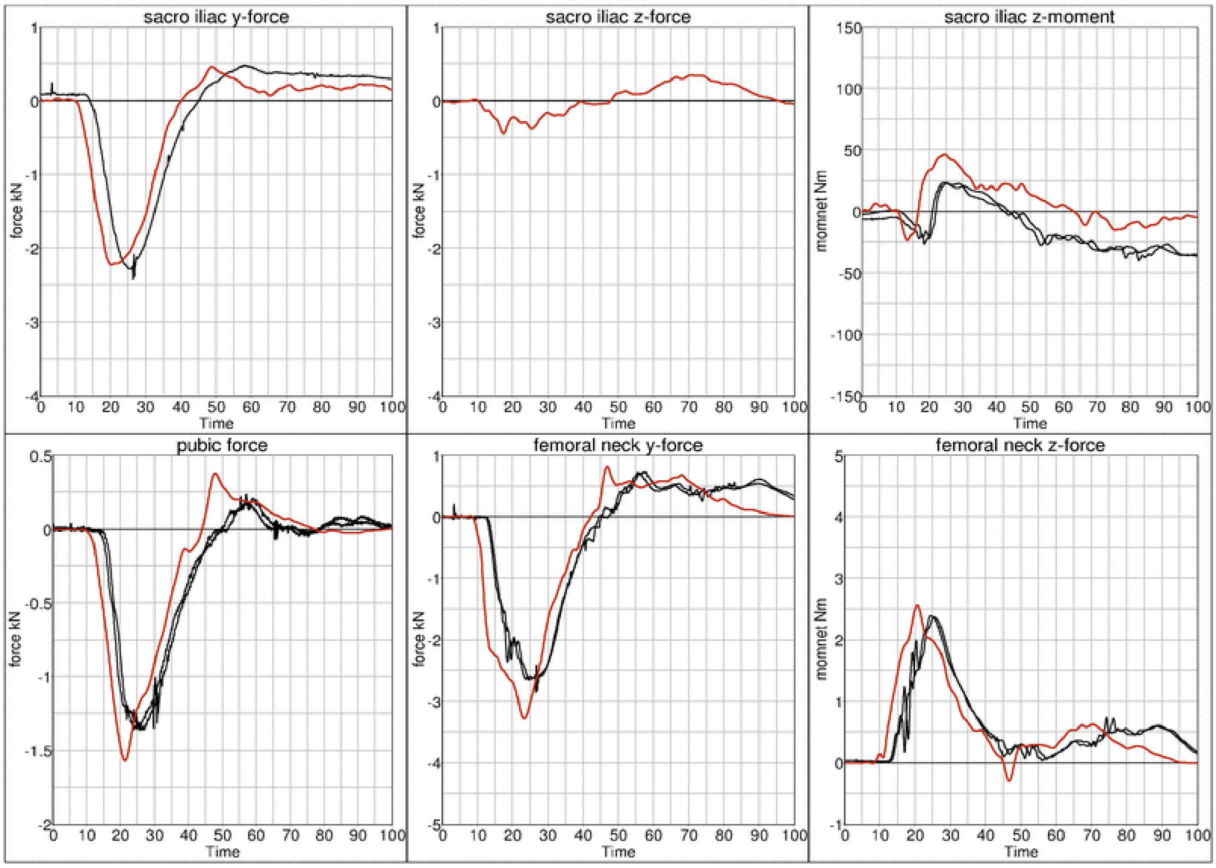
High velocity:

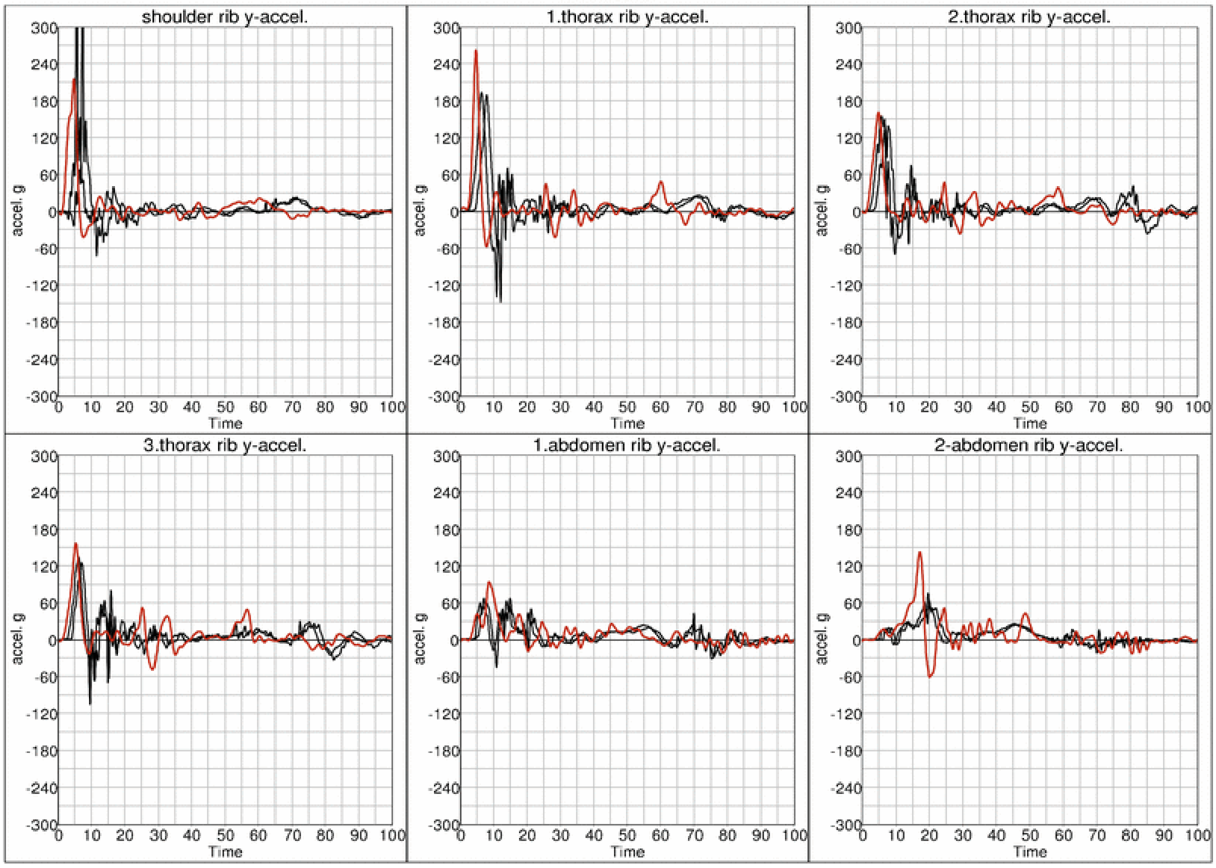



shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
ir-tracc displ. mm
Time


shoulder x-force
shoulder y-force
shoulder z-force
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
force kN
momnet Nm
Time


upper neck y-force
force kN
Time
upper neck z-force
force kN
Time
upper neck x-moment
mommet Nm
Time
lower neck y-force
force kN
Time
lower neck z-force
force kN
Time
lower neck x-moment
mommet Nm
Time


sacro iliac y-force
force kN
Time
sacro iliac z-force
force kN
Time
sacro iliac z-moment
mommet Nm
Time
pubic force
force kN
Time
femoral neck y-force
force kN
Time
femoral neck z-force
mommet Nm
Time


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
300
240
180
120
60
0
-60
-120
-180
-240
-300
0 10 20 30 40 50 60 70 80 90 100

8.3.2 Pelvis shape barrier

8.3.2.1 Arm position second notch

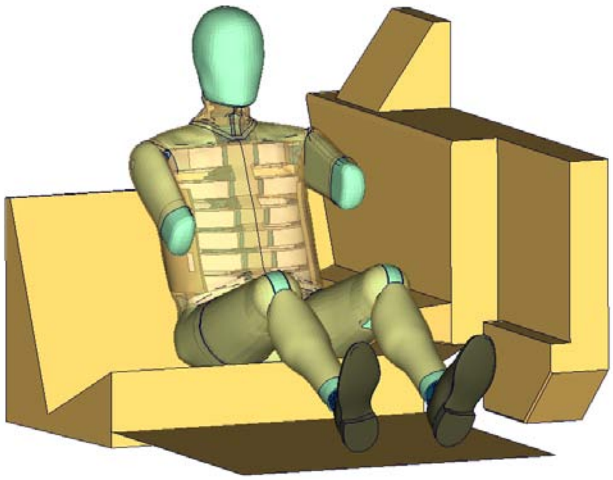
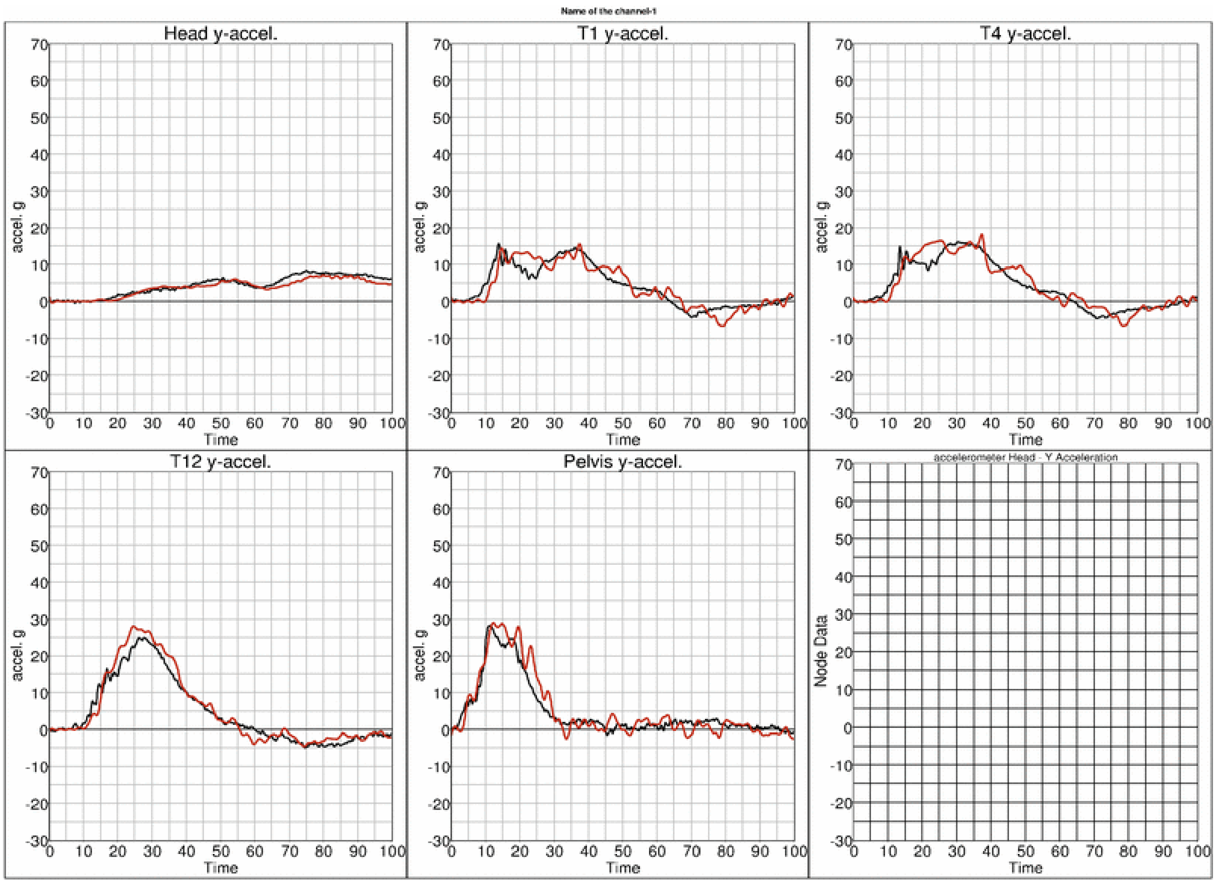
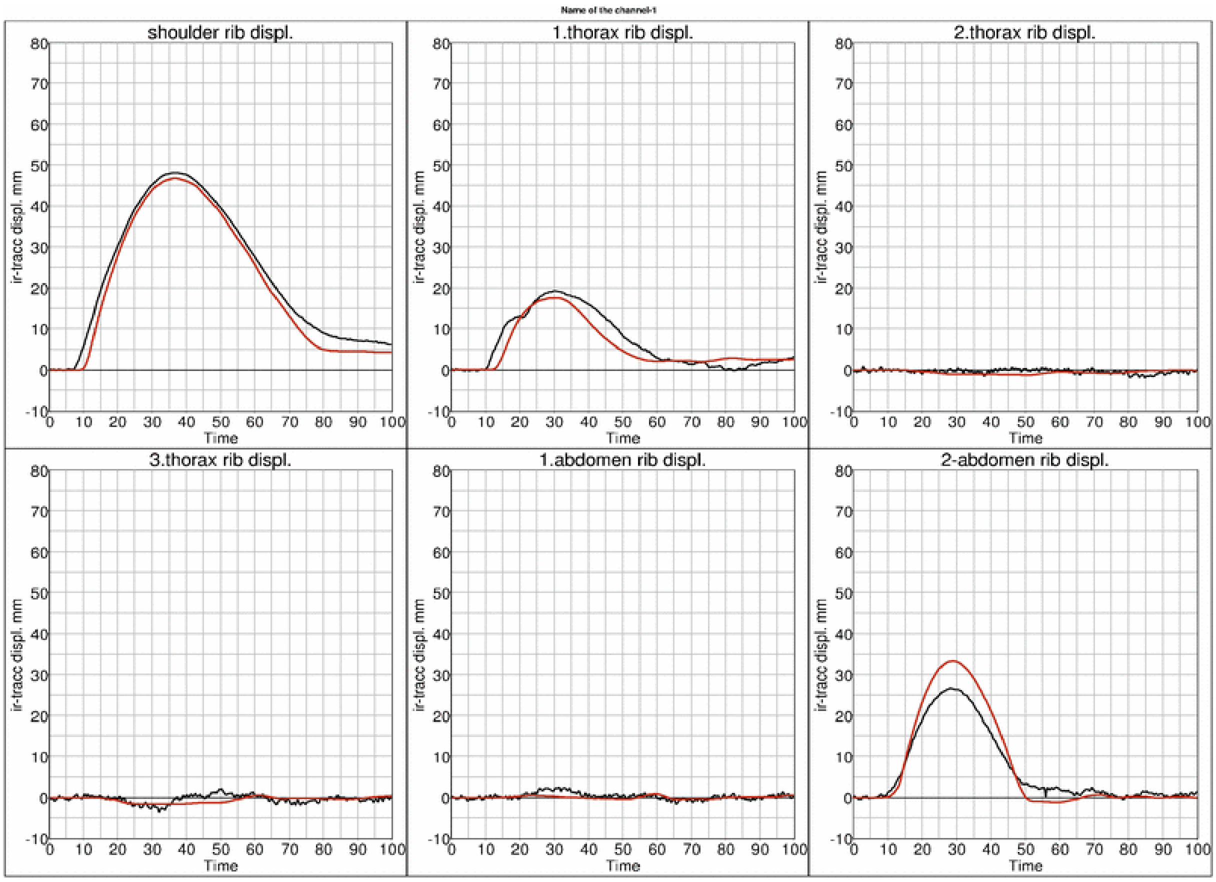
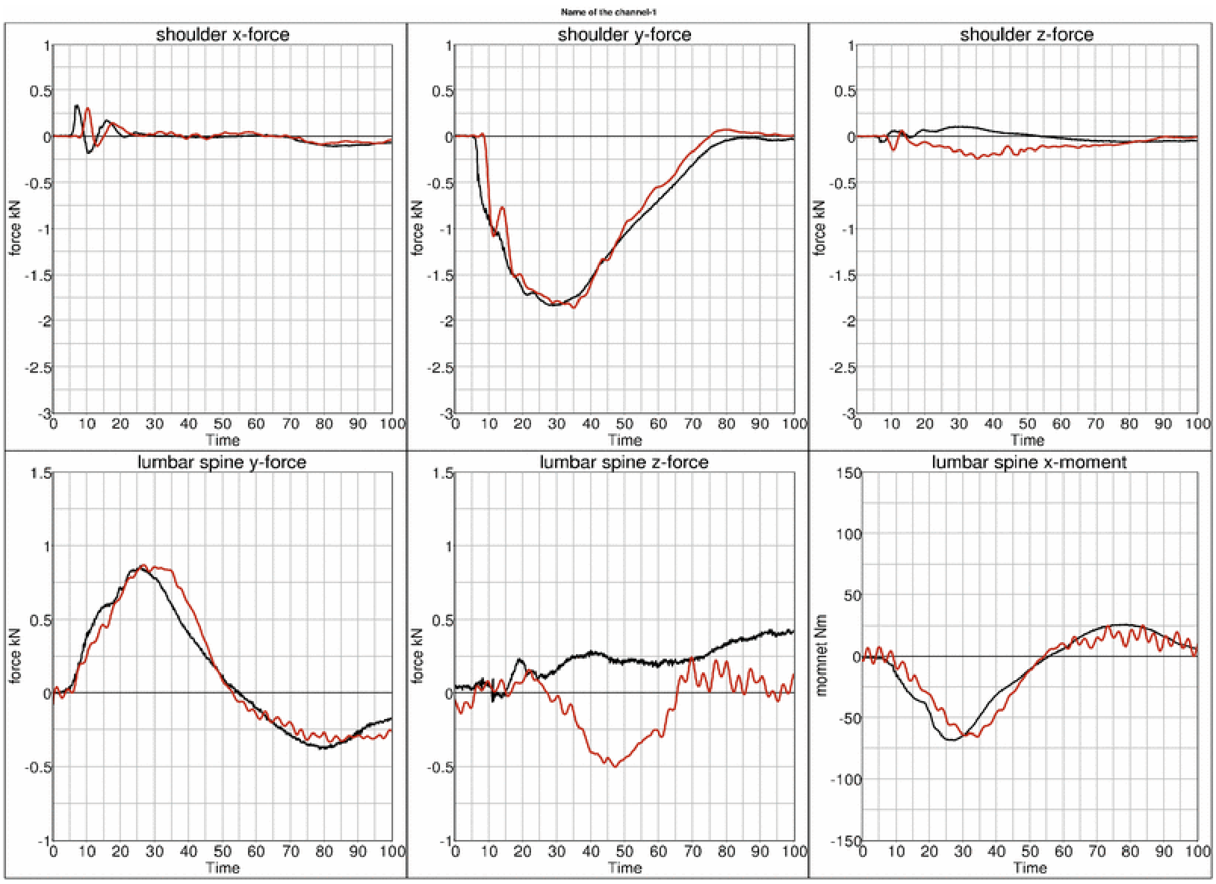


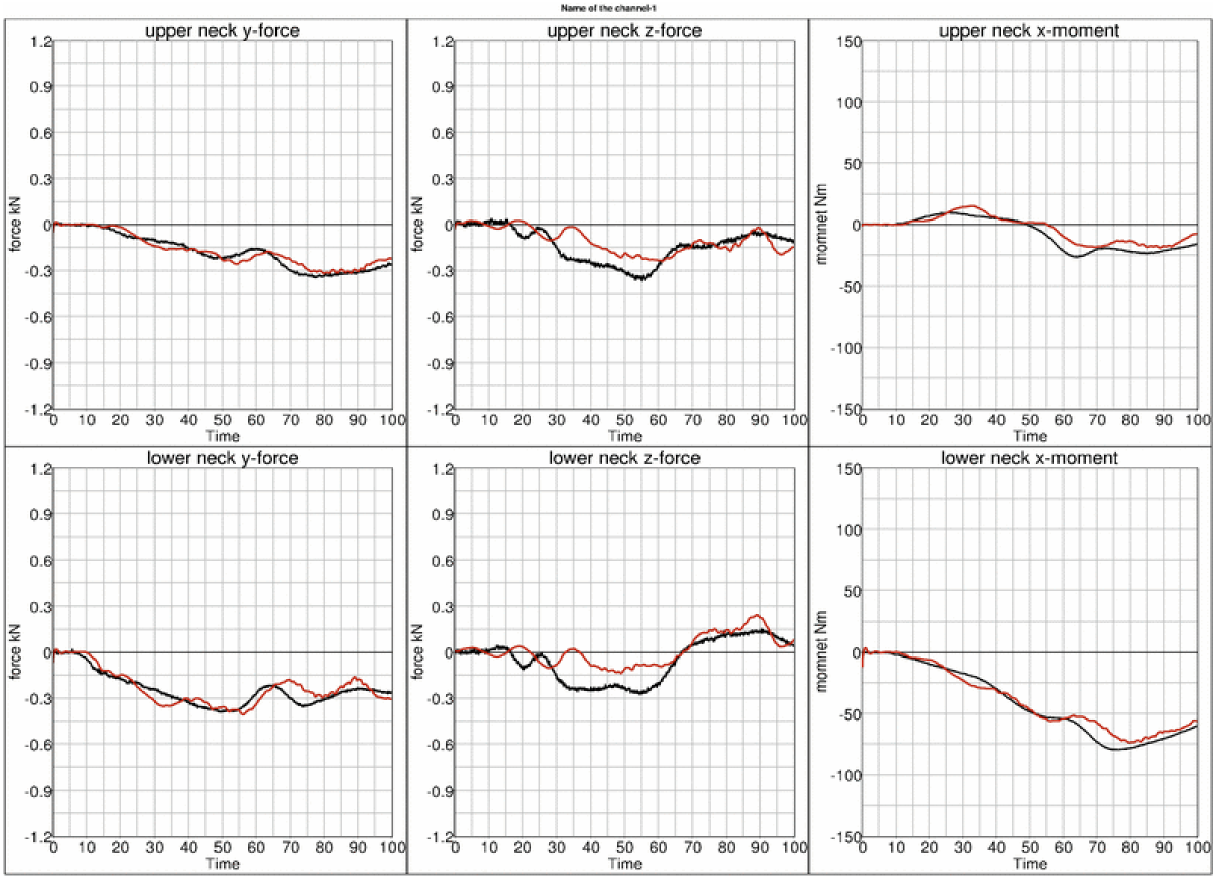
Figure 127: Pelvis barrier and arm second notch.

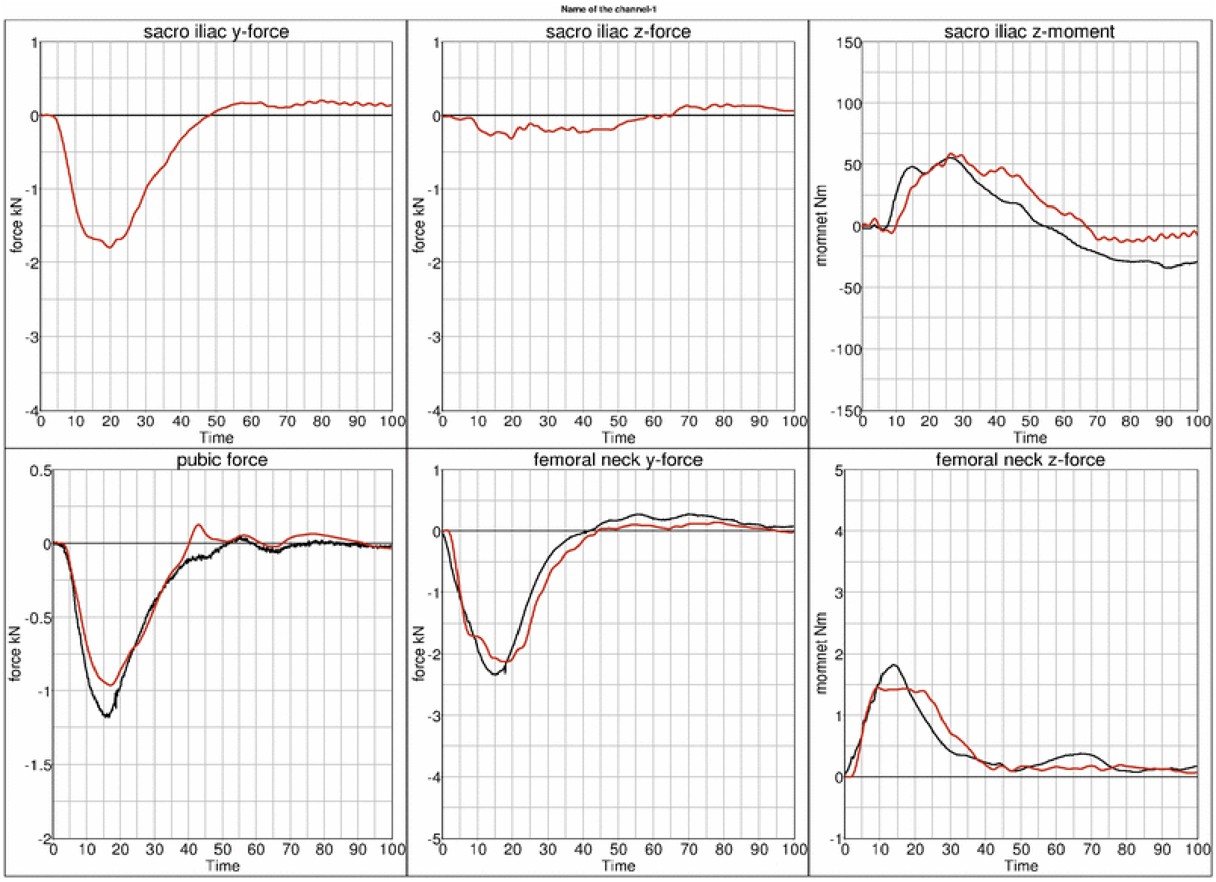
Low velocity:

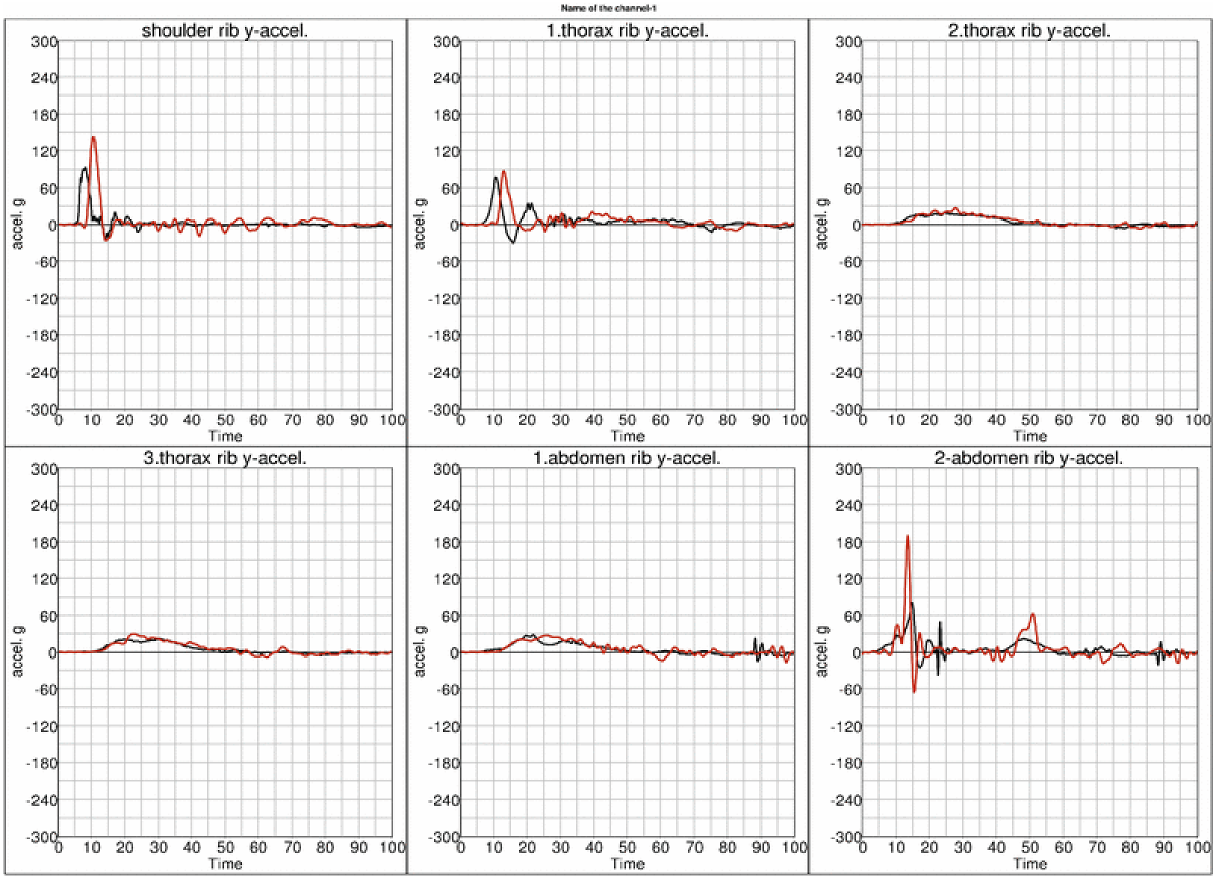



Name of the channel-1
shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
ir-tracc displ. mm
Time


Name of the channel-1
shoulder x-force
shoulder y-force
shoulder z-force
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
force kN
momnet Nm
Time


Name of the channel-1
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
momnet Nm
Time


Name of the channel-1
sacro iliac y-force
sacro iliac z-force
sacro iliac z-moment
pubic force
femoral neck y-force
femoral neck z-force
force kN
momnet Nm
Time


Name of the channel-1
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
300
240
180
120
60
0
-60
-120
-180
-240
-300
0 10 20 30 40 50 60 70 80 90 100

8.3.2.2 Arm position first notch

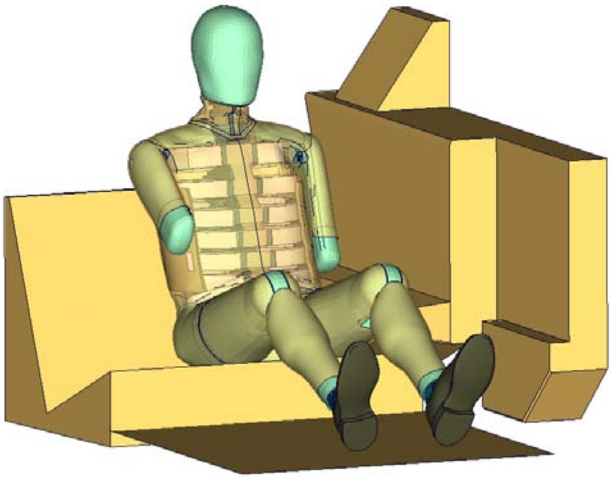
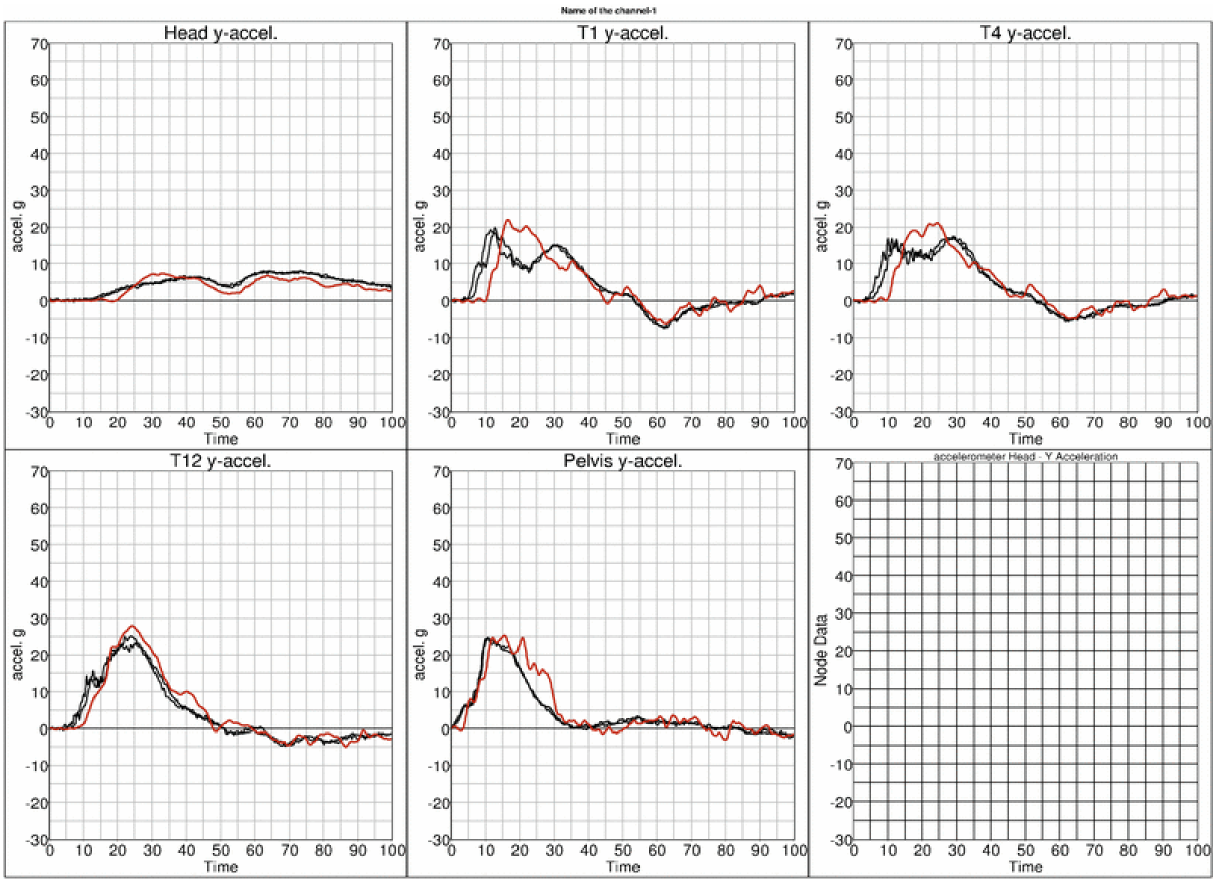
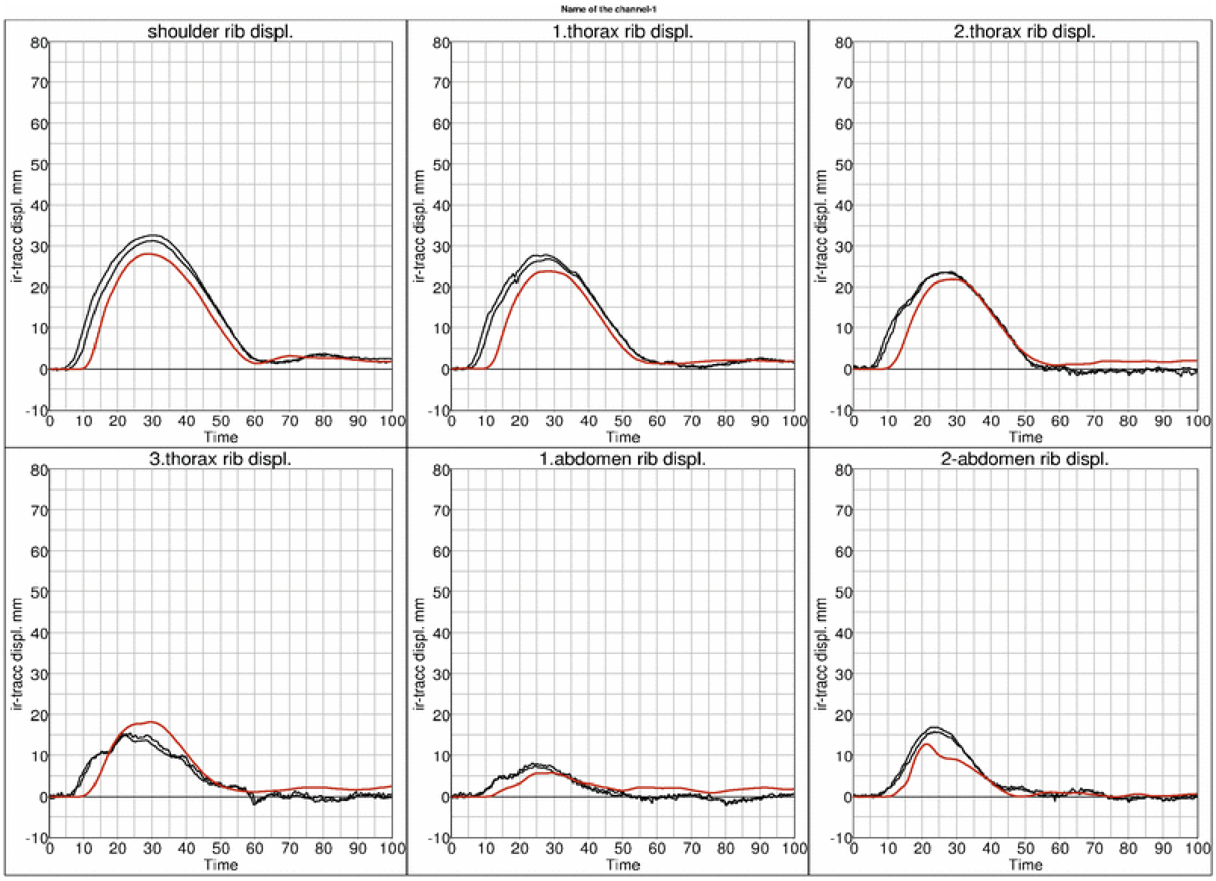
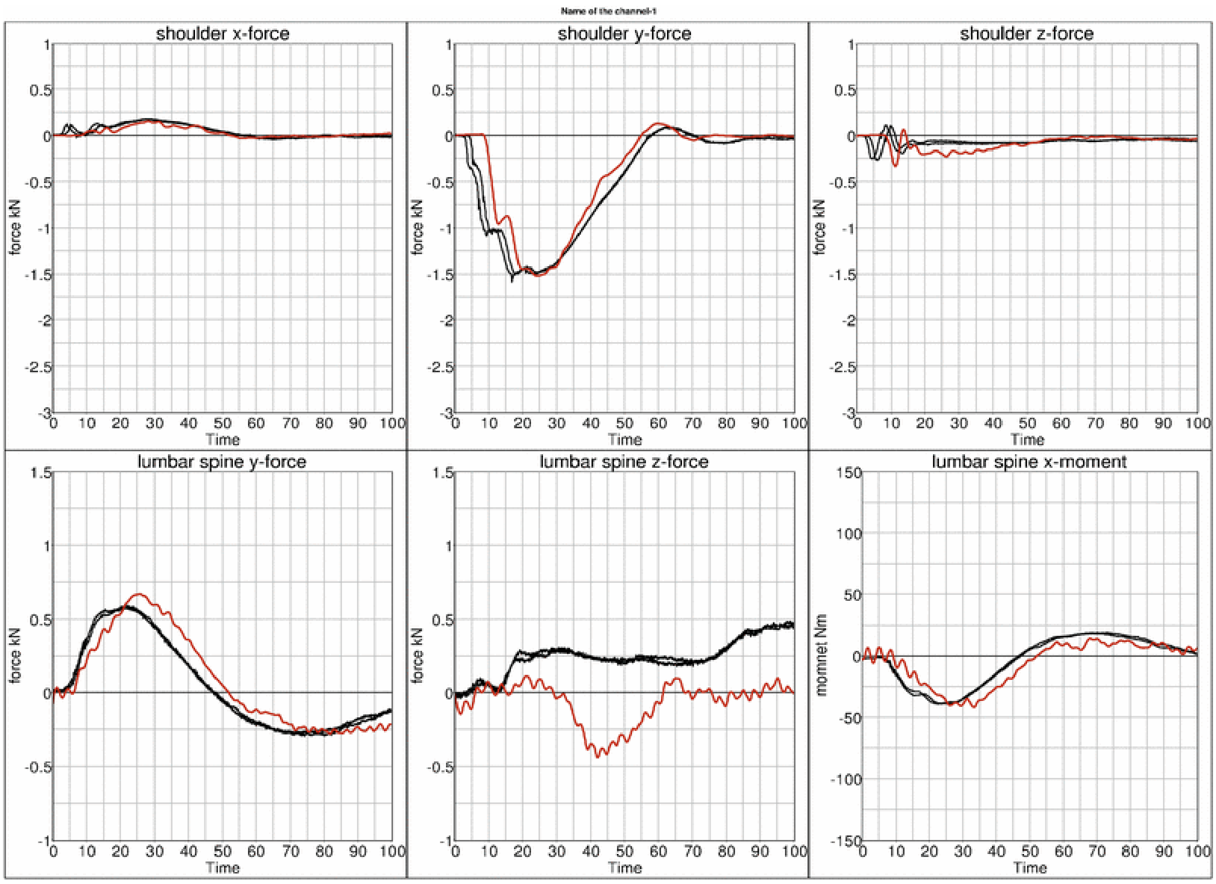


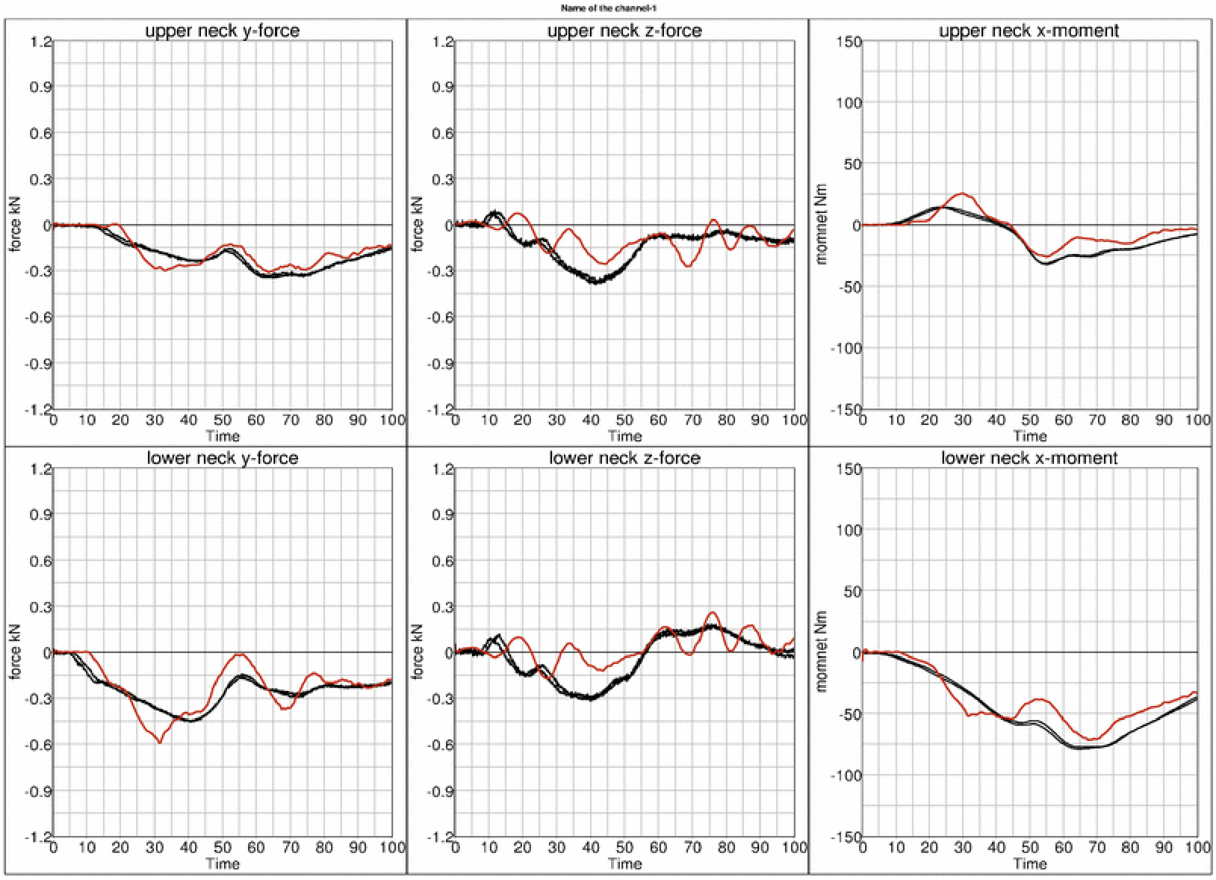
Figure 128: Pelvis barrier and arm first notch.

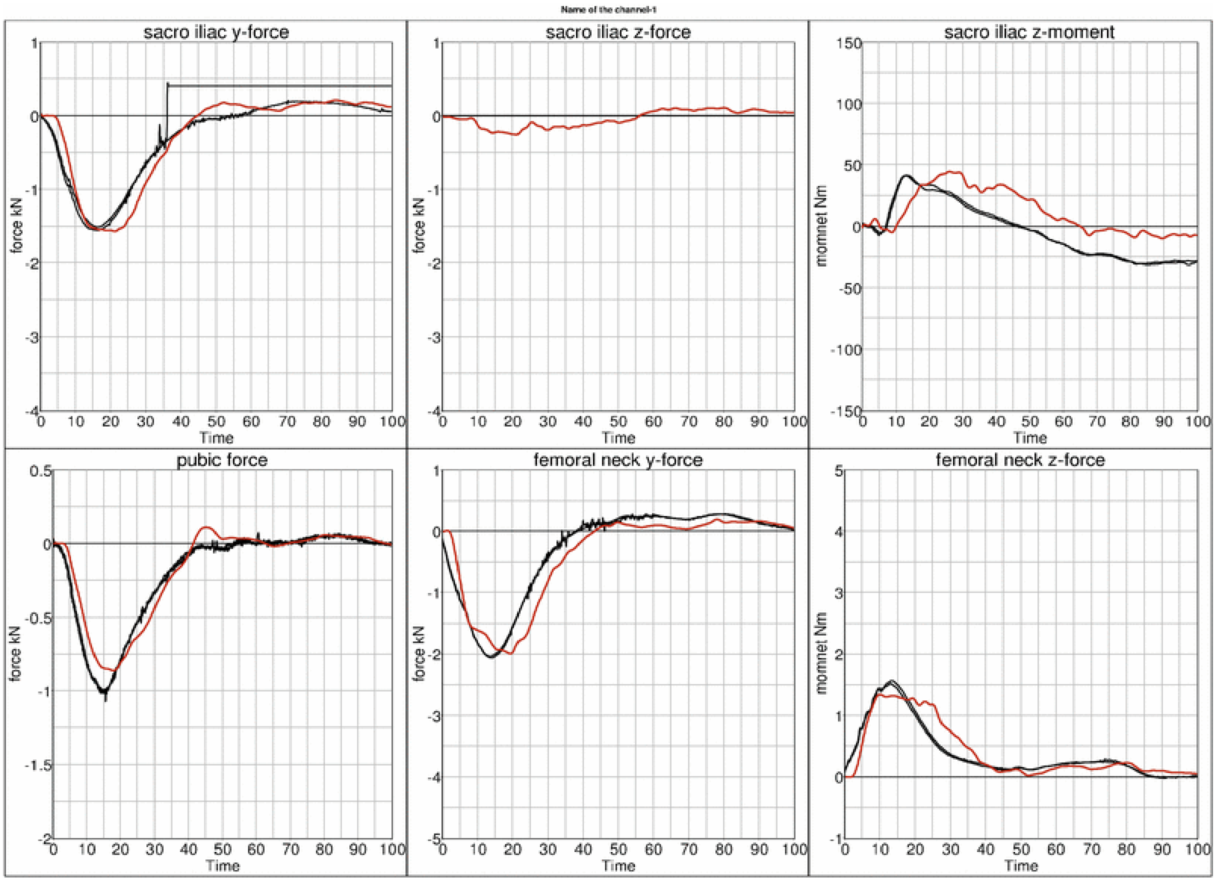
Low velocity:

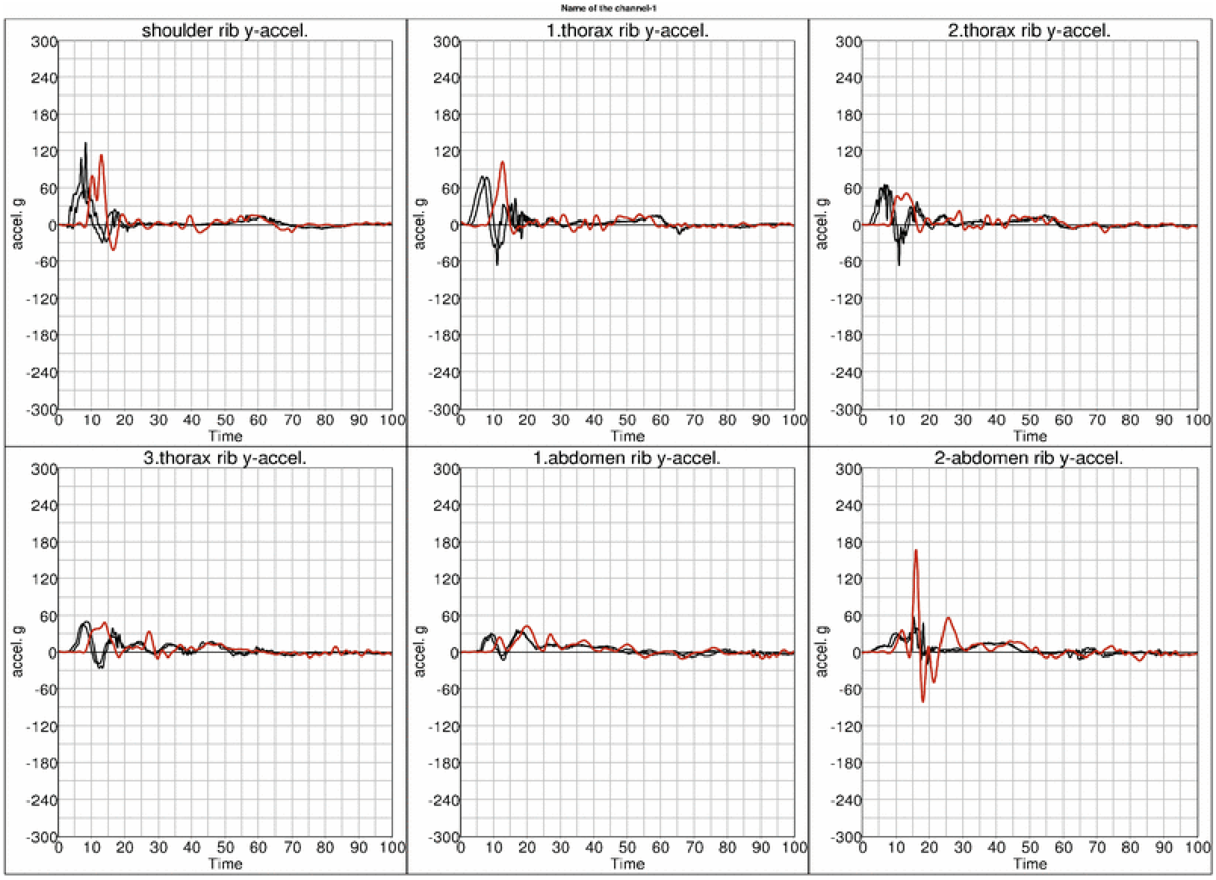



Name of the channel-1
shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
ir-tracc displ. mm
Time

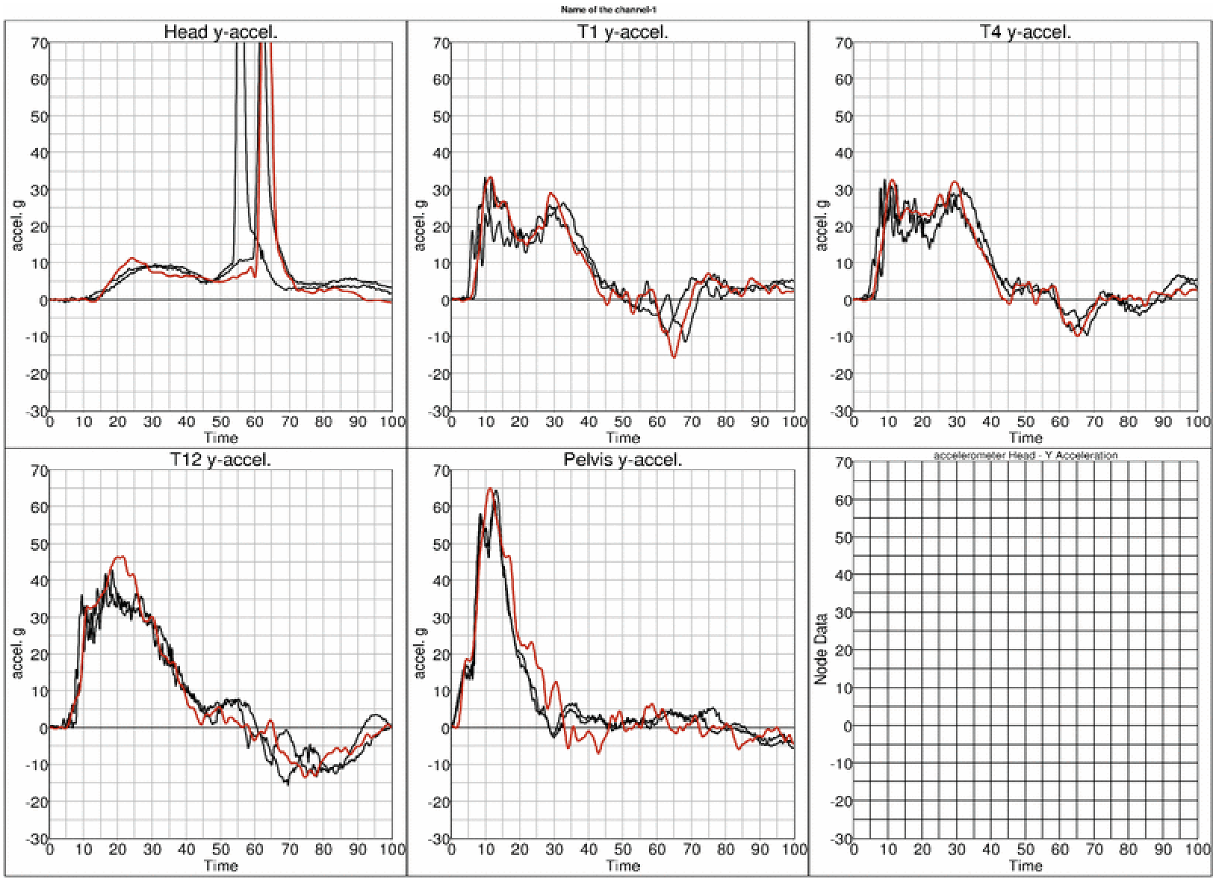

Name of the channel-1
shoulder x-force
shoulder y-force
shoulder z-force
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
force kN
momnet Nm
Time

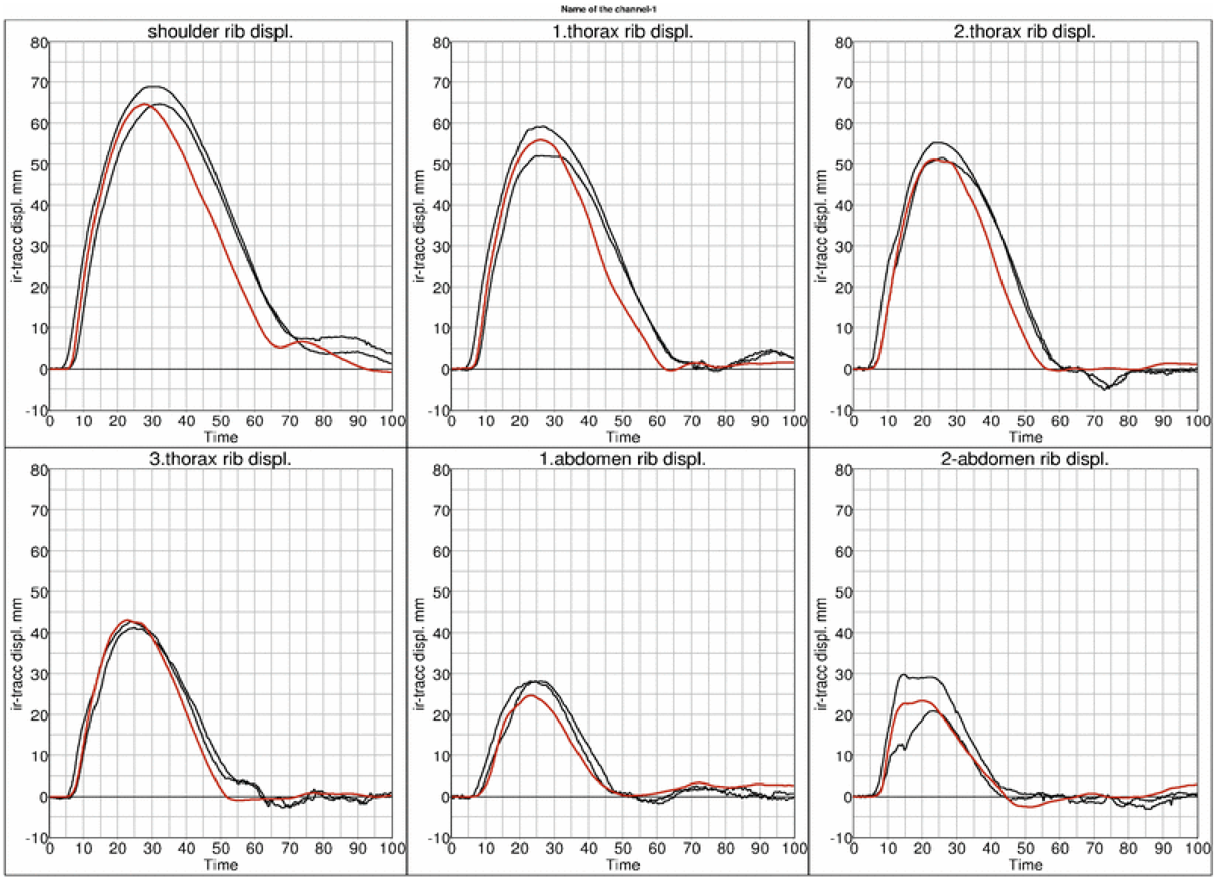

Name of the channel-1
upper neck y-force
upper neck z-force
upper neck x-moment
lower neck y-force
lower neck z-force
lower neck x-moment
force kN
momnet Nm
Time

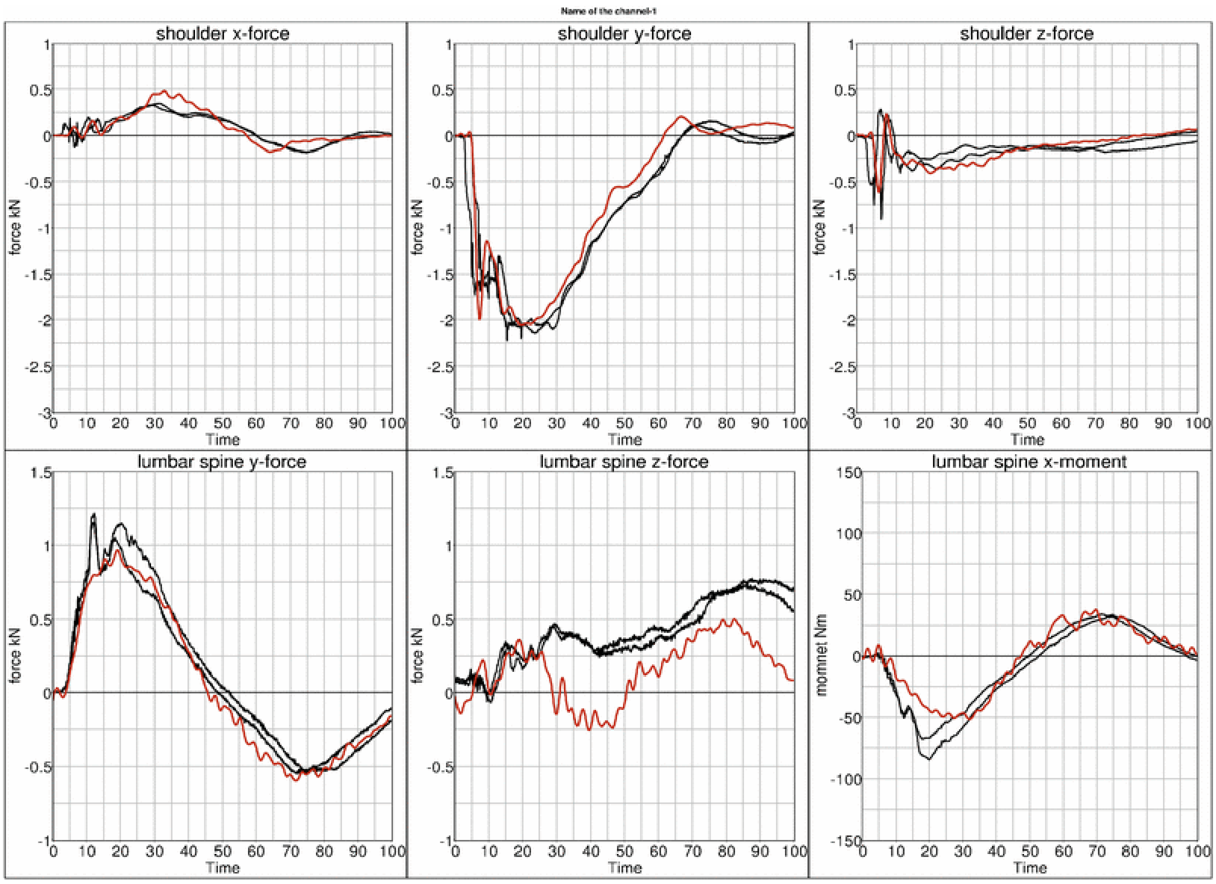

Name of the channel-1
sacro iliac y-force
sacro iliac z-force
sacro iliac z-moment
pubic force
femoral neck y-force
femoral neck z-force
force kN
momnet Nm
Time

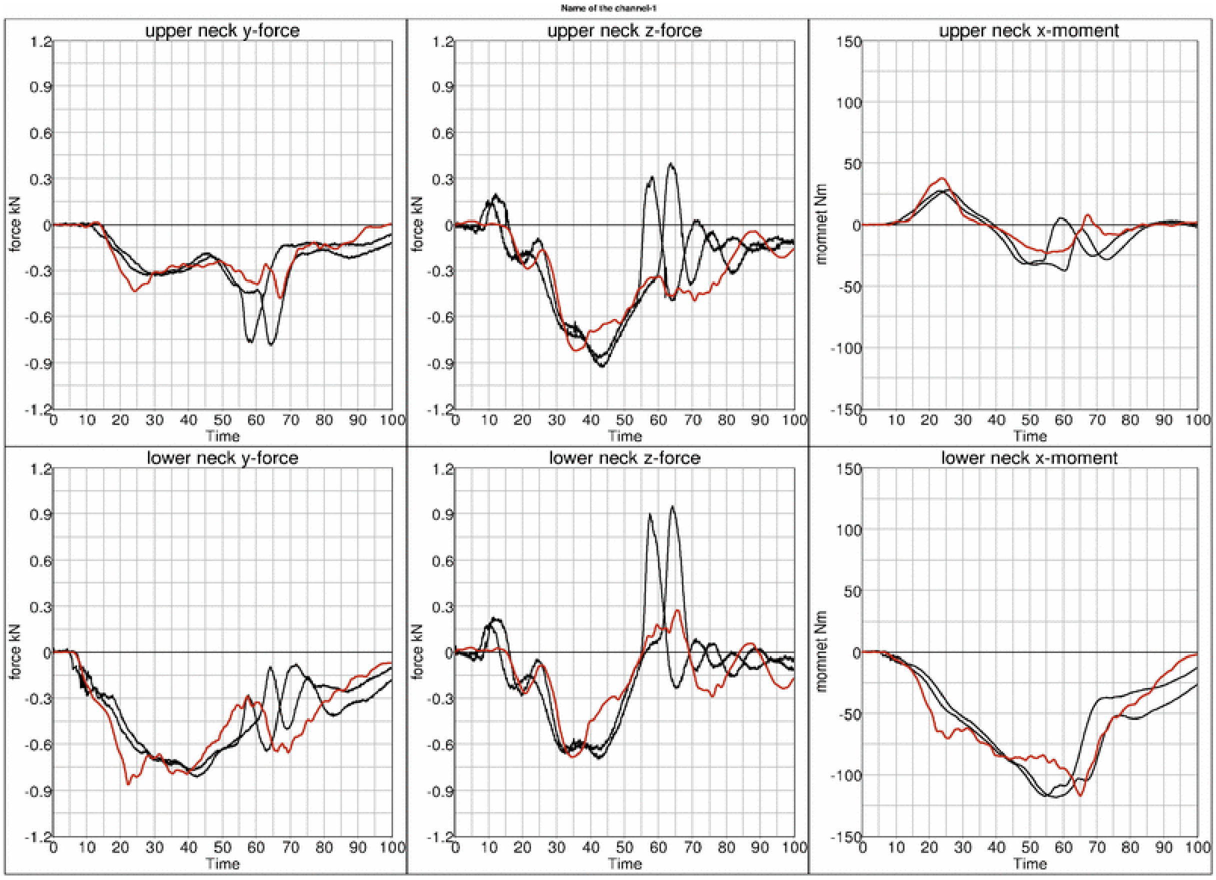


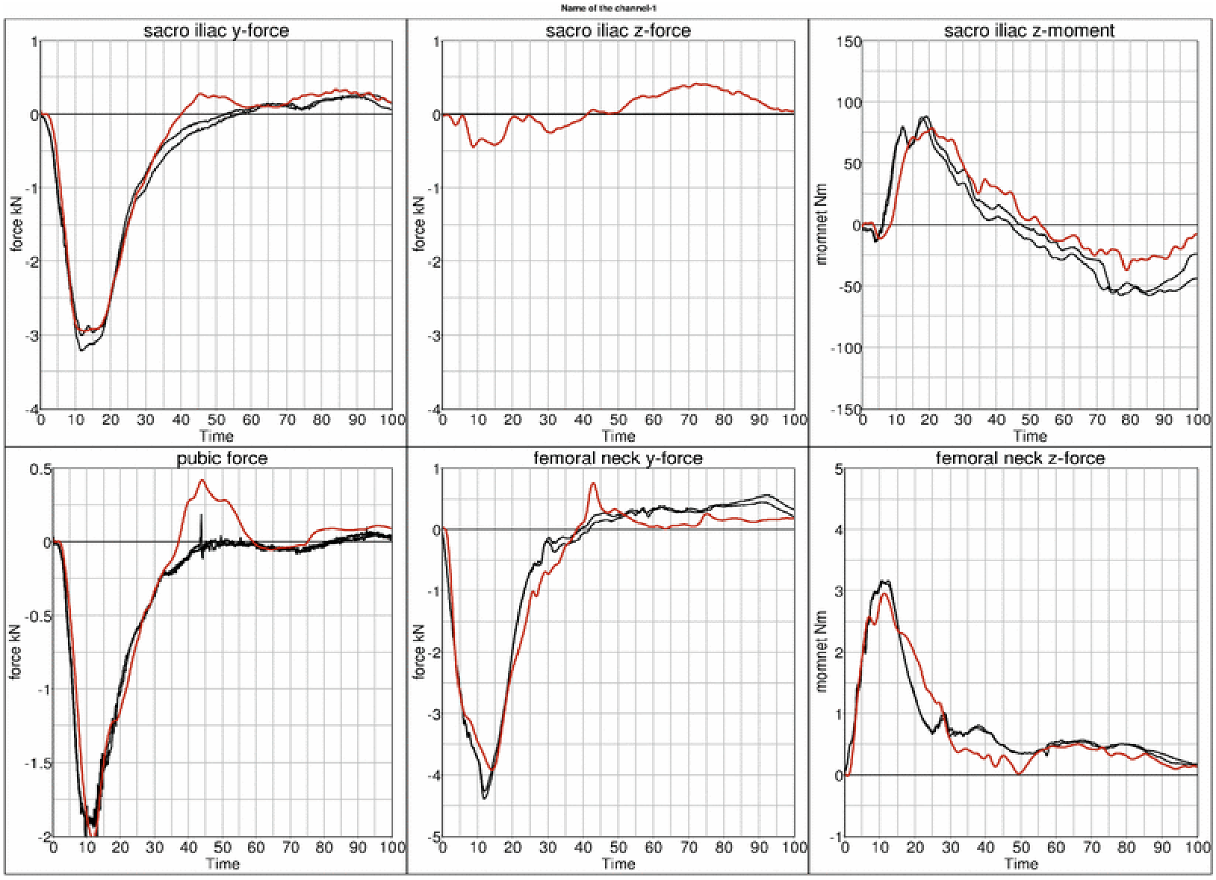
High velocity:

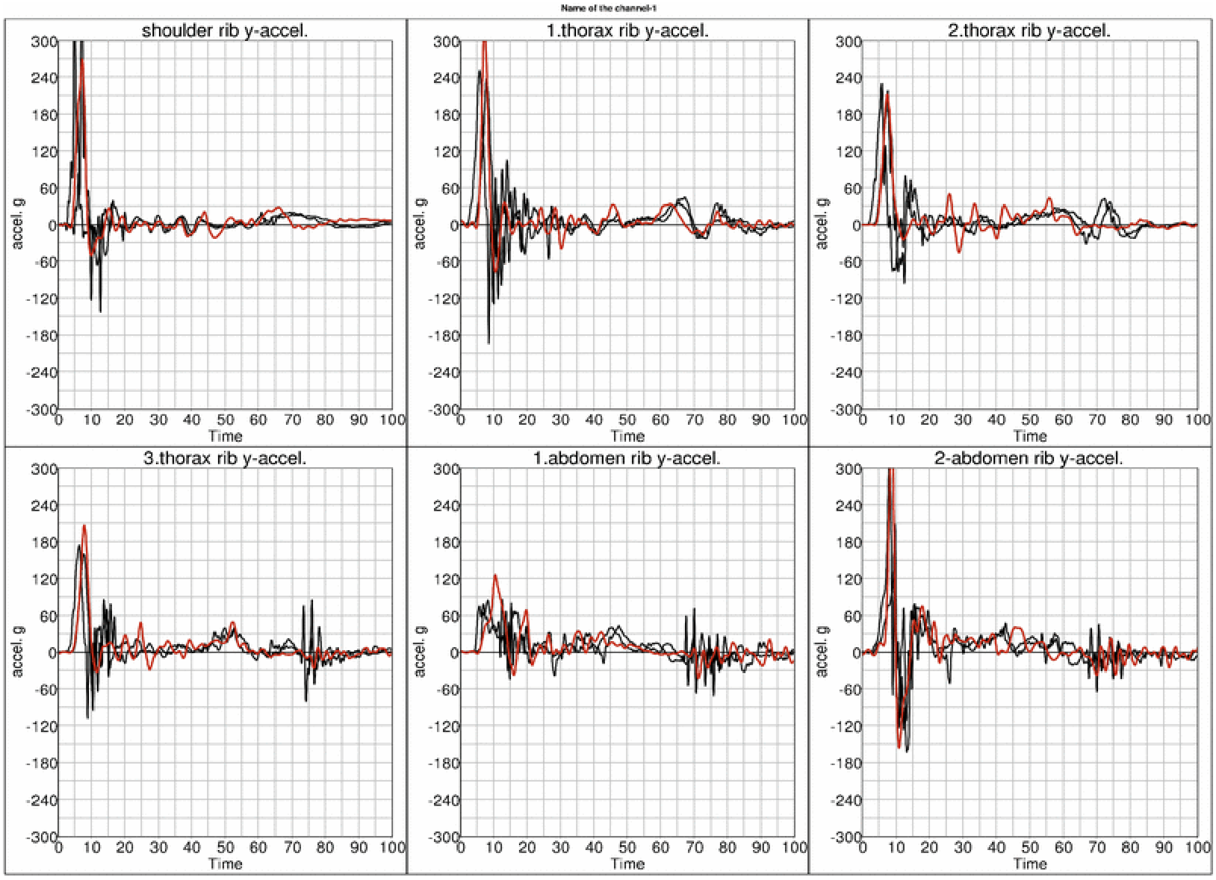



Name of the channel-1
shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
ir-tracc displ. mm
Time


Name of the channel-1
shoulder x-force
shoulder y-force
shoulder z-force
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
force kN
momnet Nm
Time


Name of the channel-1
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
momnet Nm
Time


Name of the channel-1
sacro iliac y-force
sacro iliac z-force
sacro iliac z-moment
pubic force
femoral neck y-force
femoral neck z-force
force kN
momnet Nm
Time


Name of the channel-1
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

8.3.3 Flat barrier and WorldSID without arm

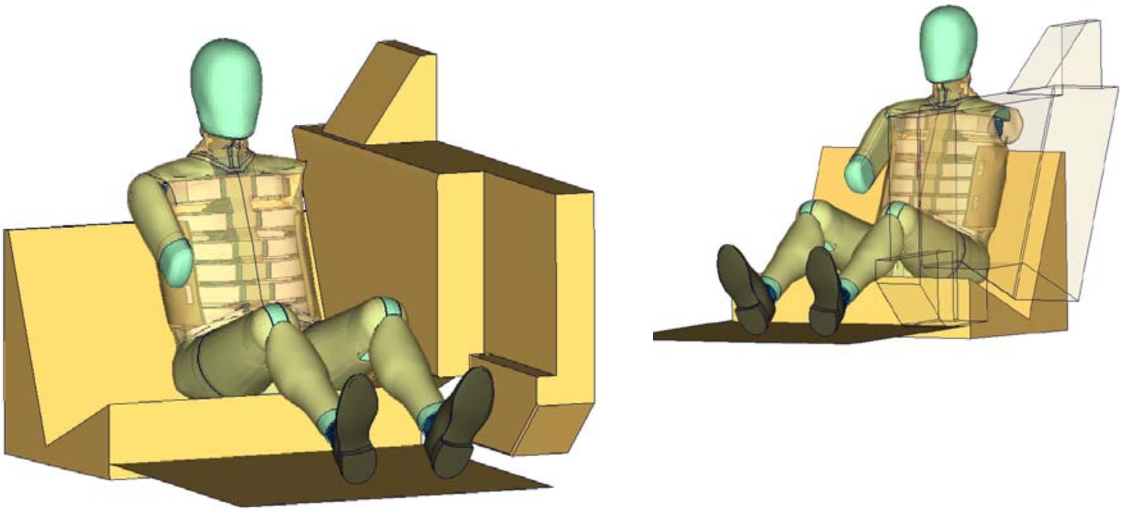
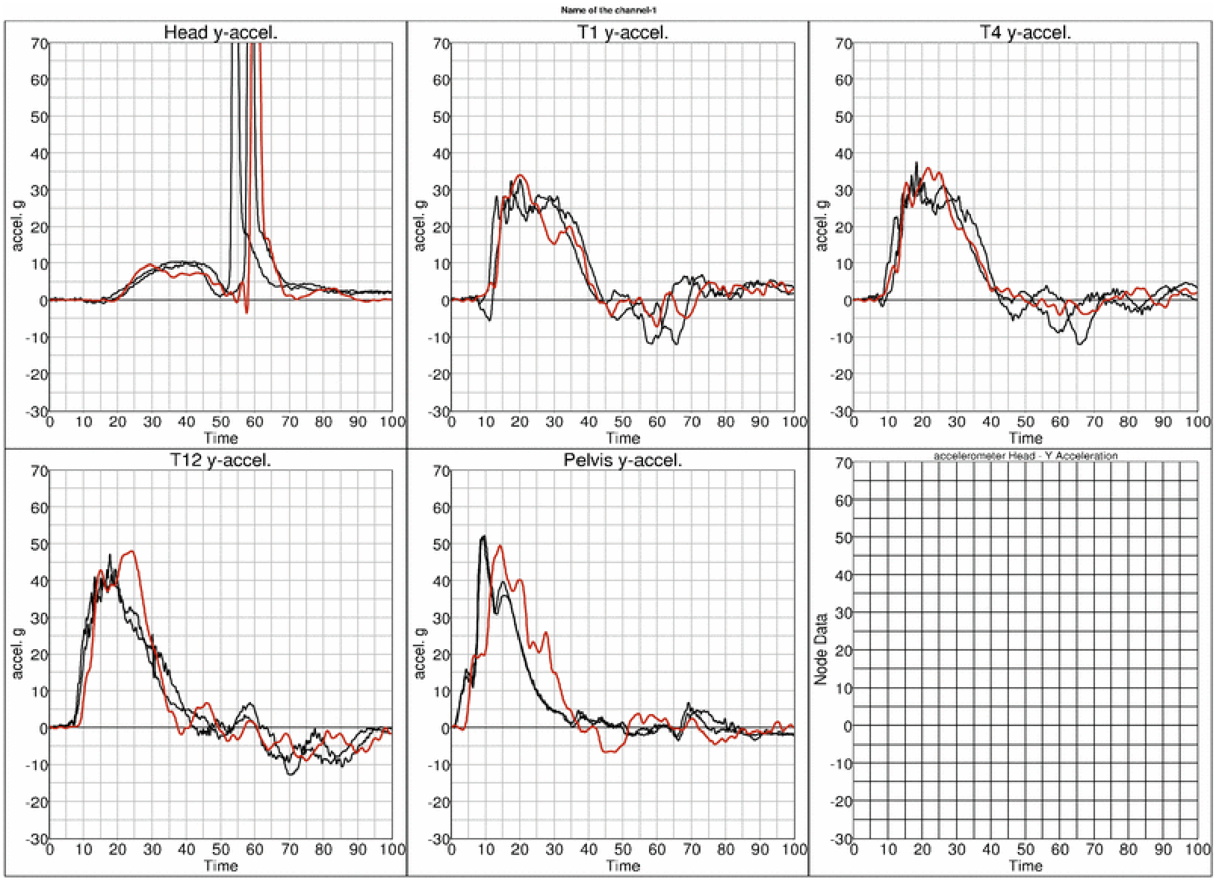
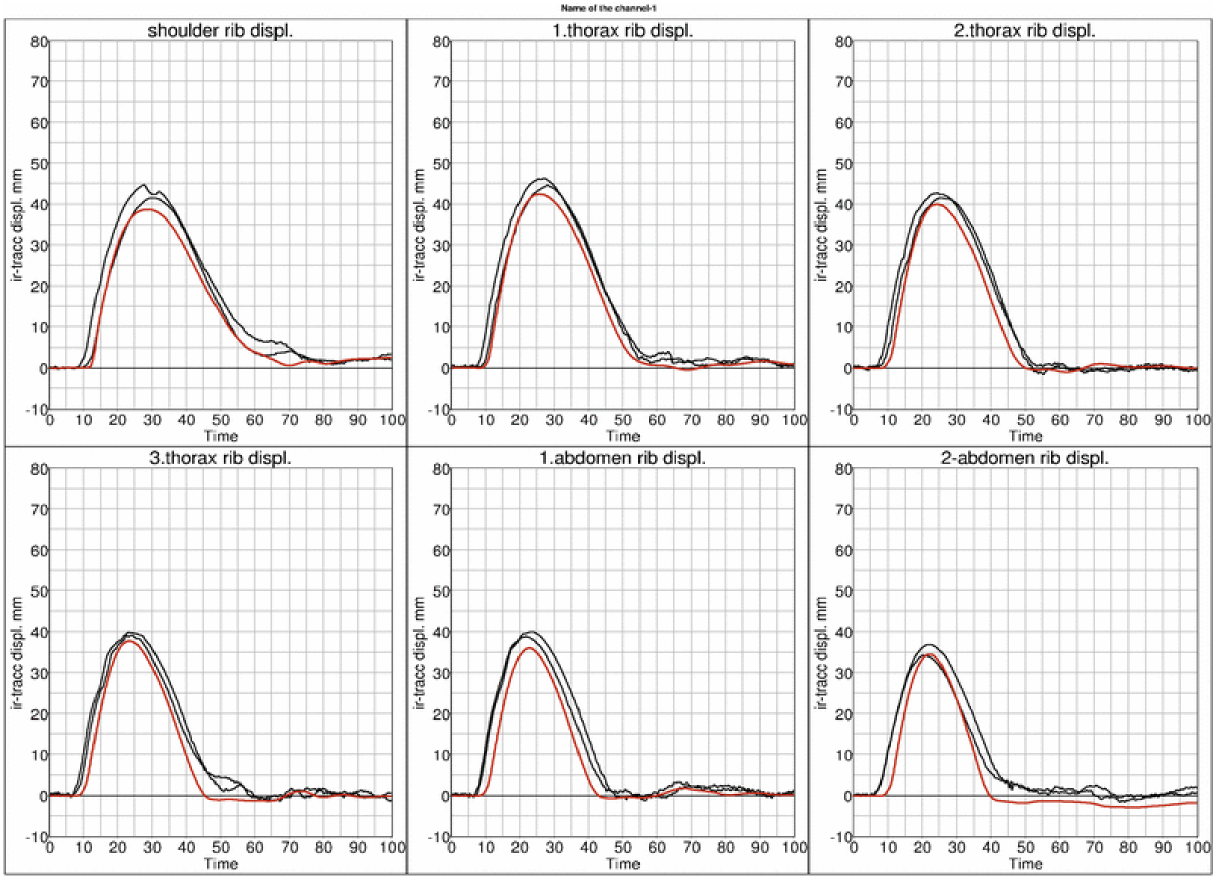
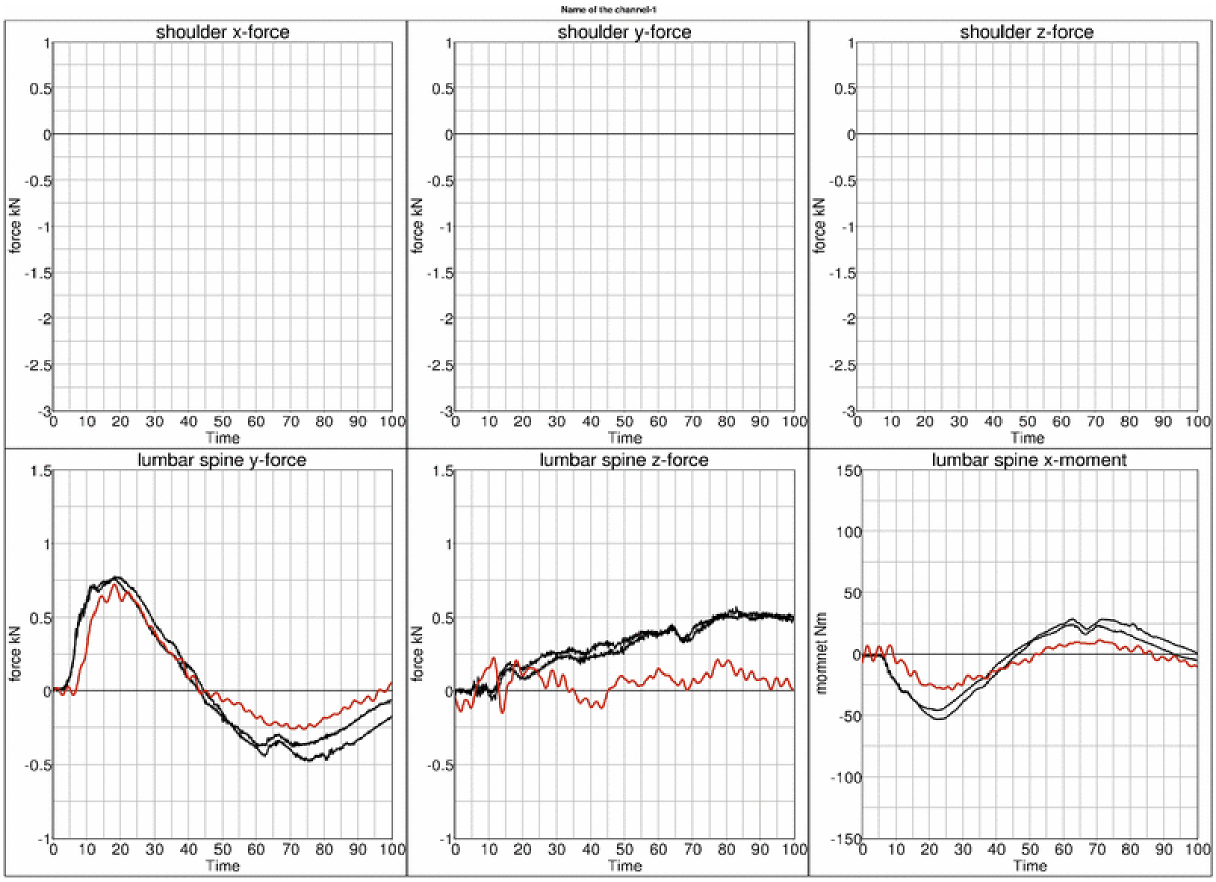


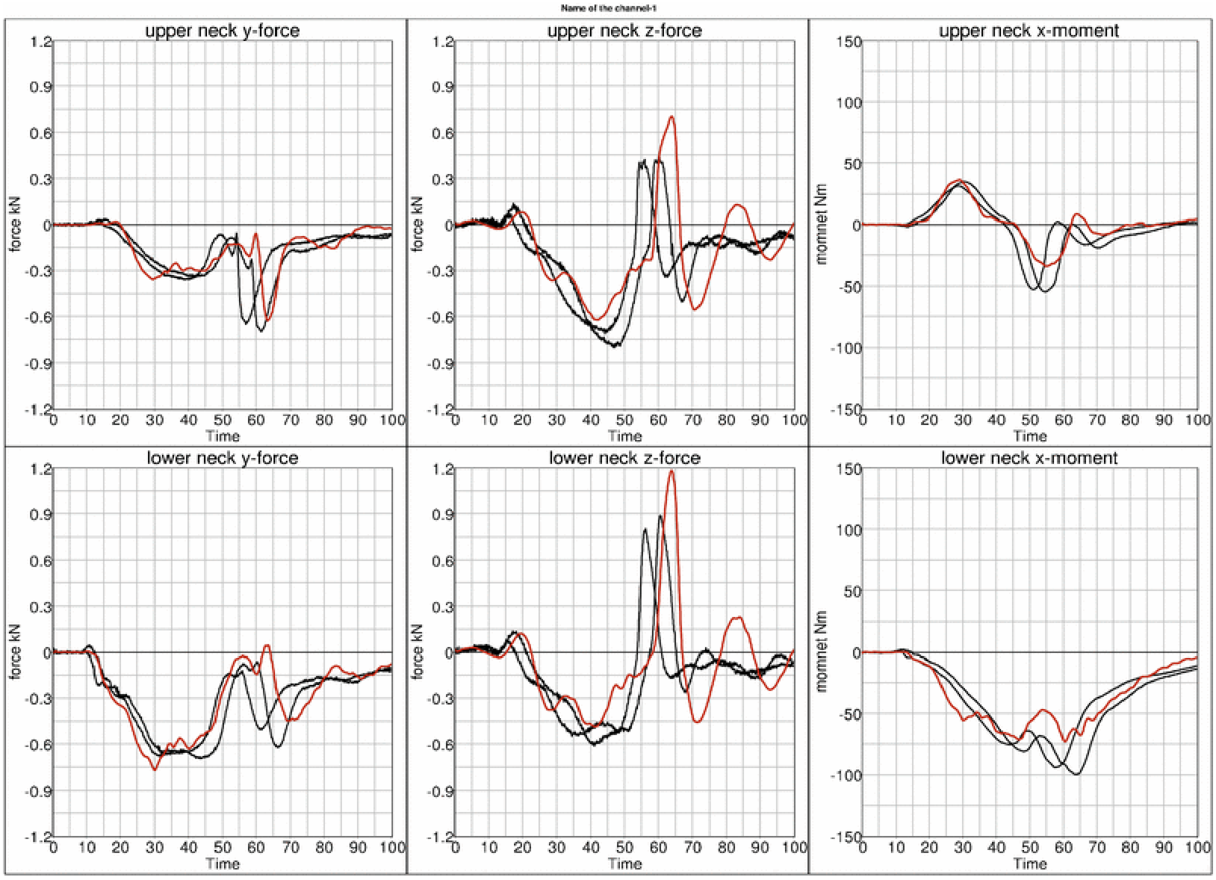
Figure 129: Flat barrier and without arm.

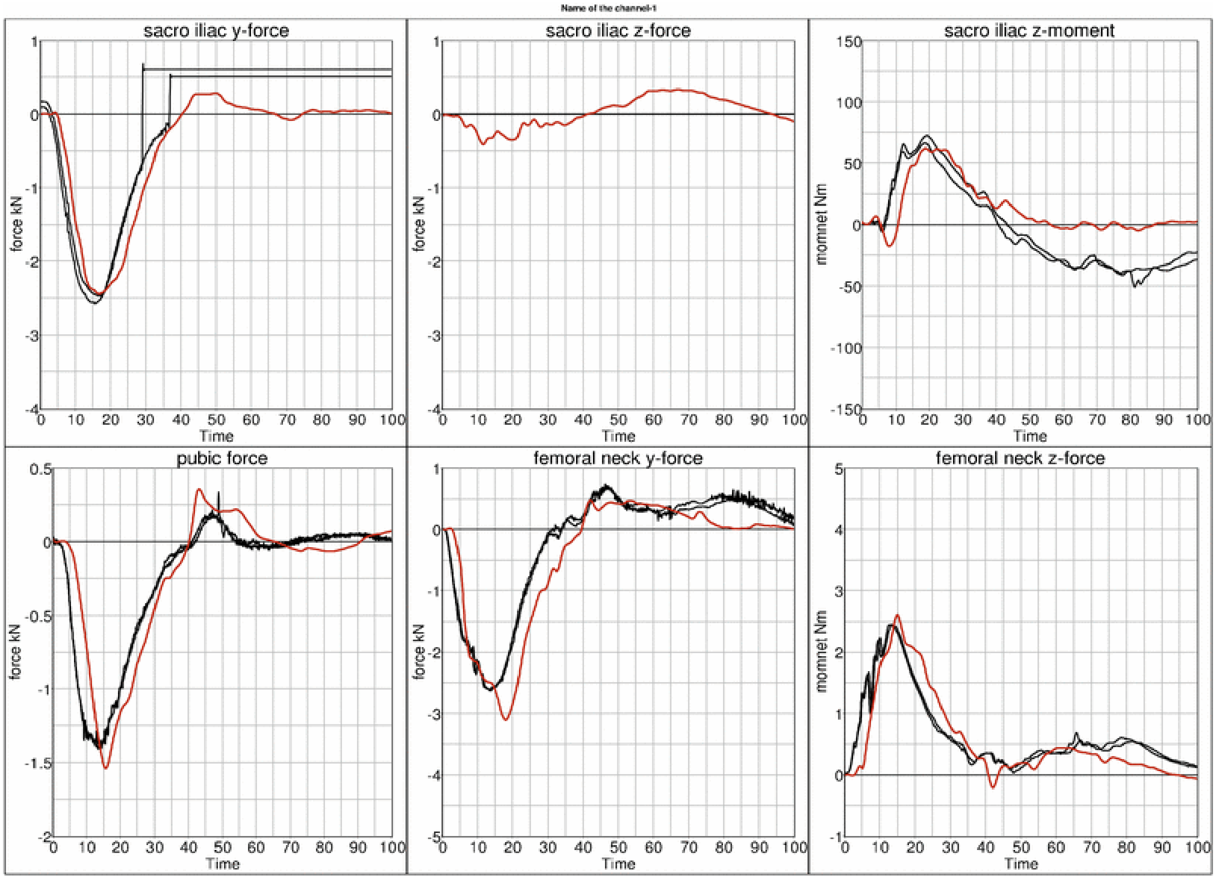
High velocity:

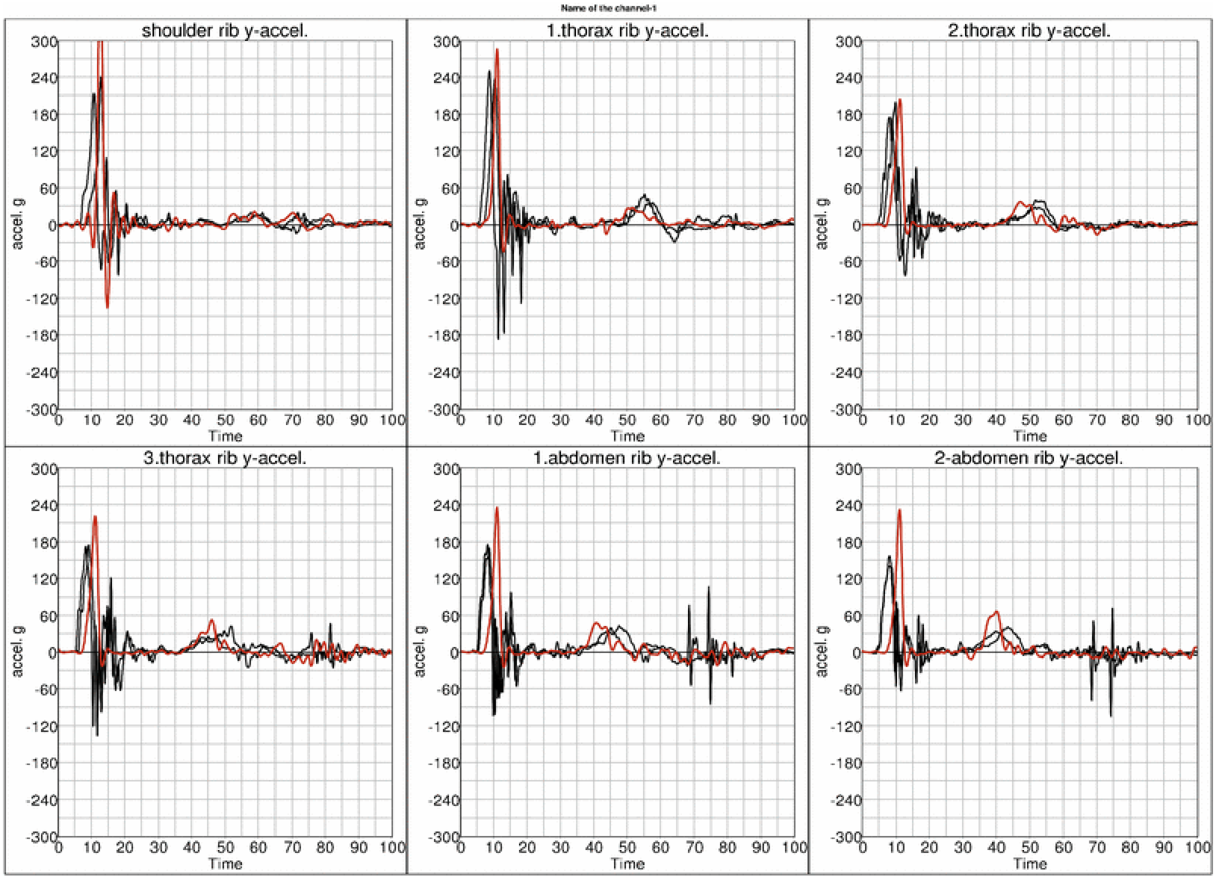



Name of the channel-1
shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
ir-tracc displ. mm
Time


Name of the channel-1
shoulder x-force
shoulder y-force
shoulder z-force
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
force kN
momnet Nm
Time


Name of the channel-1
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
momnet Nm
Time
1.2
0.9
0.6
0.3
0
-0.3
-0.6
-0.9
-1.2
150
100
50
-50
-100
-150
10
20
30
40
50
60
70
80
90
100


Name of the channel-1
sacro iliac y-force
sacro iliac z-force
sacro iliac z-moment
pubic force
femoral neck y-force
femoral neck z-force
force kN
momnet Nm
Time
1
0
-1
-2
-3
-4
-5
0.5
-0.5
-1.5
150
100
50
-50
-100
-150
5
4
3
2
10
20
30
40
50
60
70
80
90
100


Name of the channel-1
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
300
240
180
120
60
0
-60
-120
-180
-240
-300
0 10 20 30 40 50 60 70 80 90 100

8.3.4 Pelvis shape barrier and WorldSID without Jacket

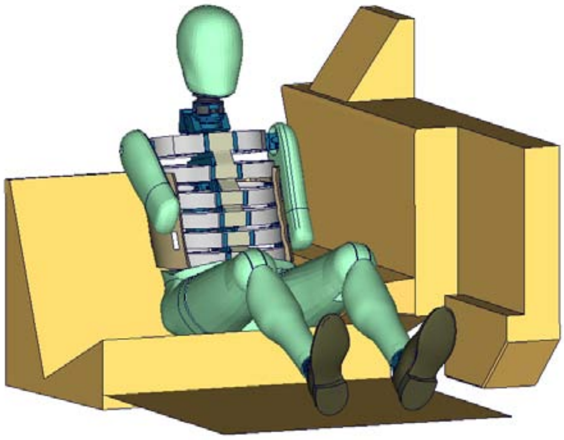
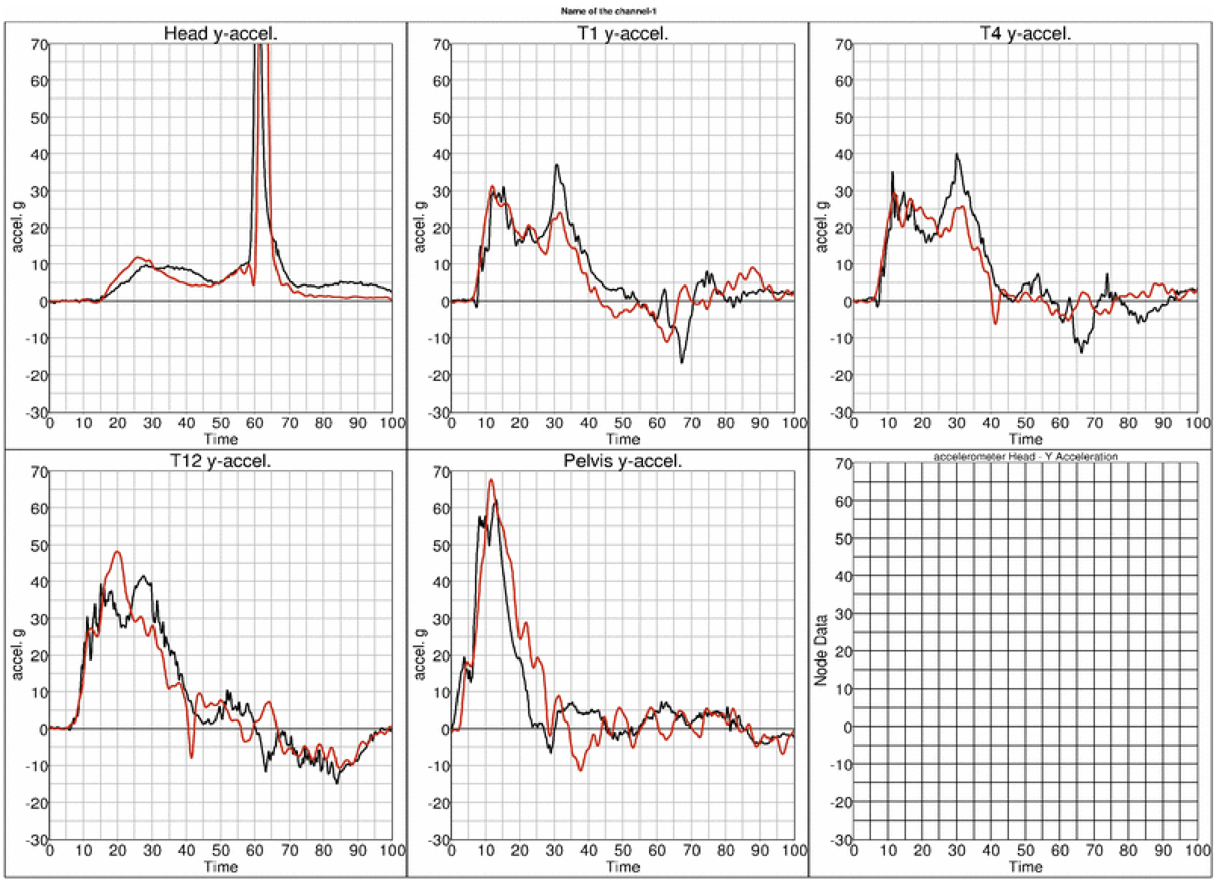
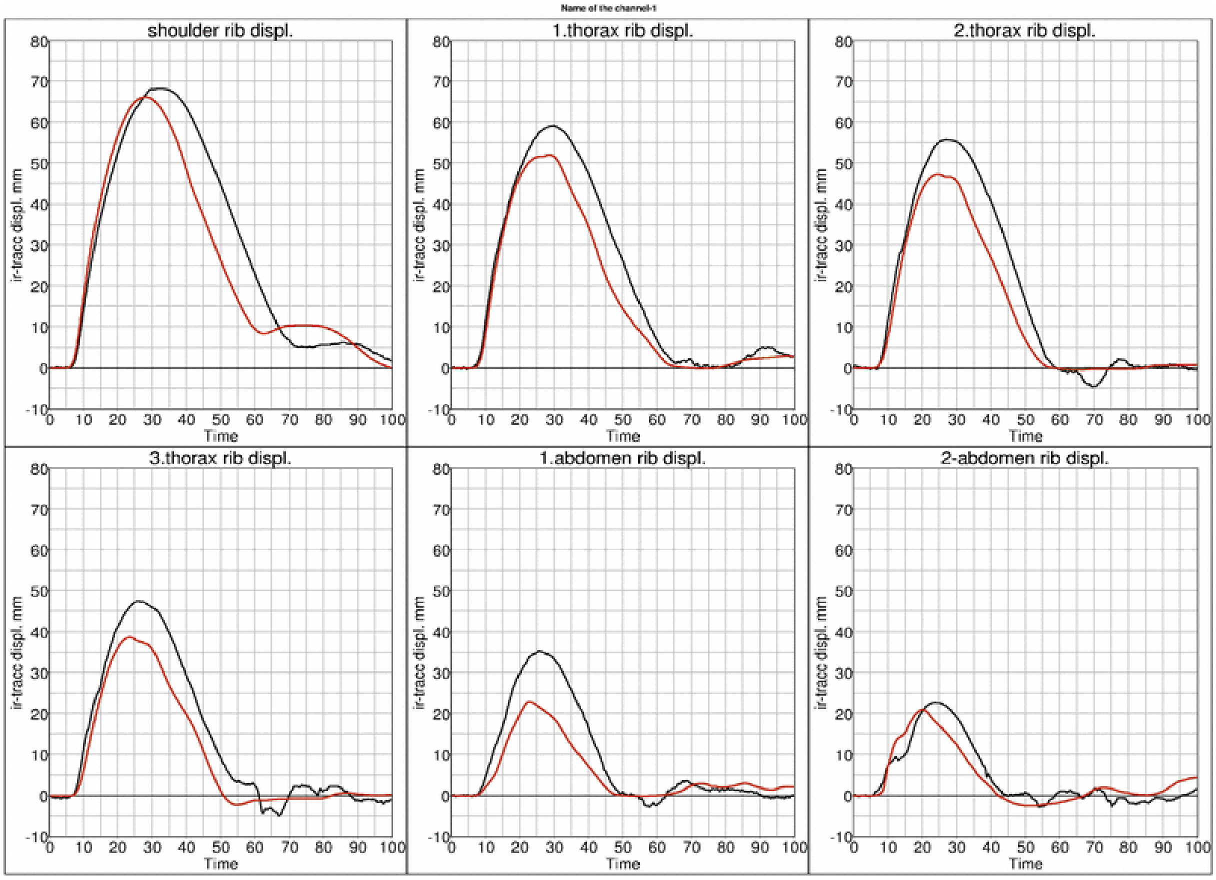
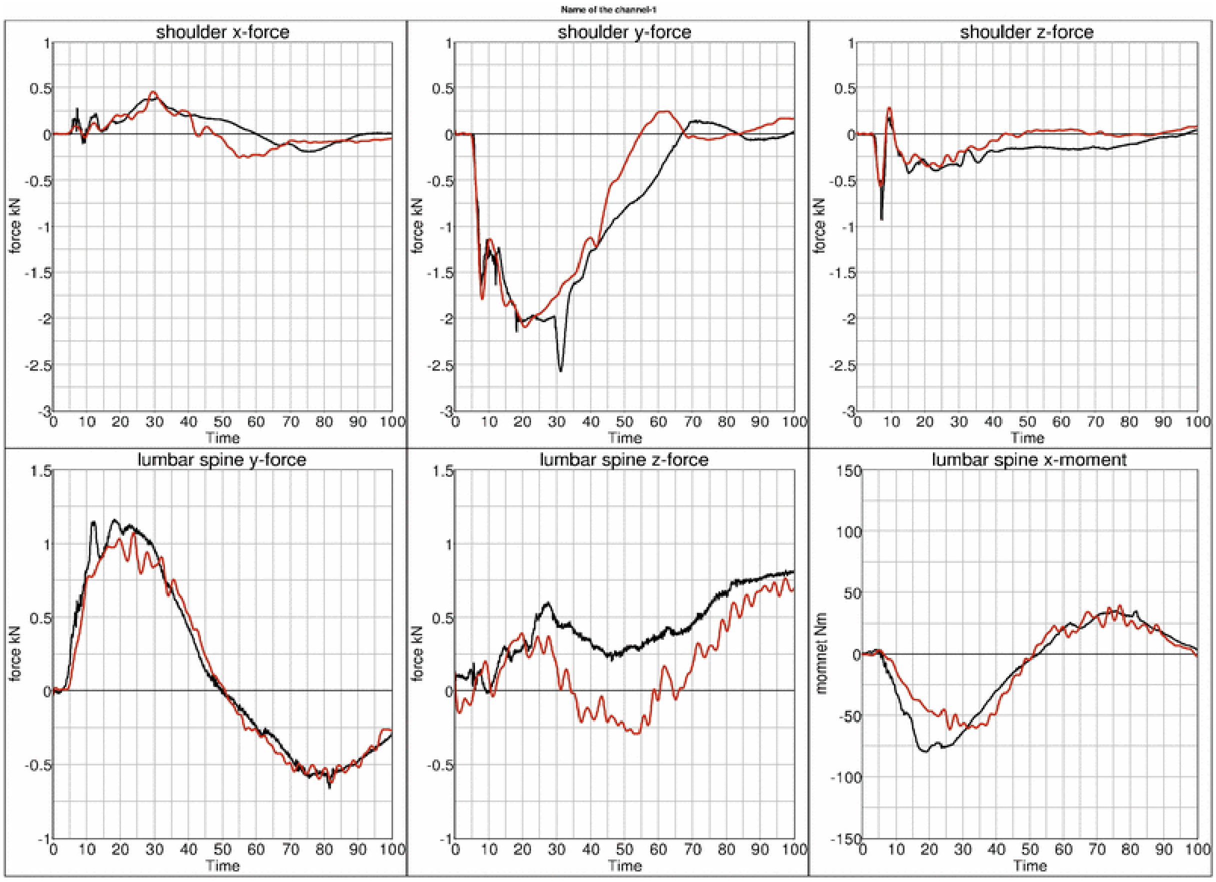


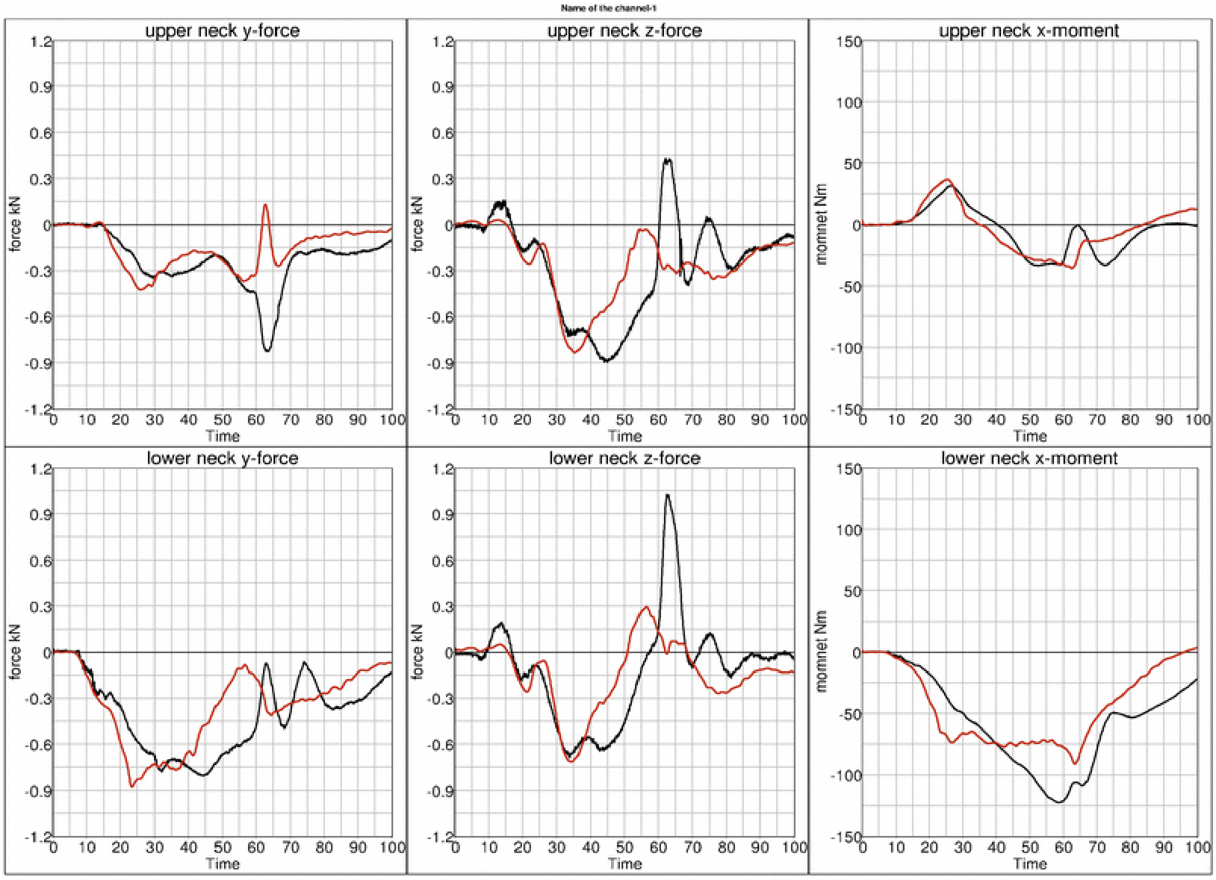
Figure 130: Pelvis barrier and arm first notch without jacket.

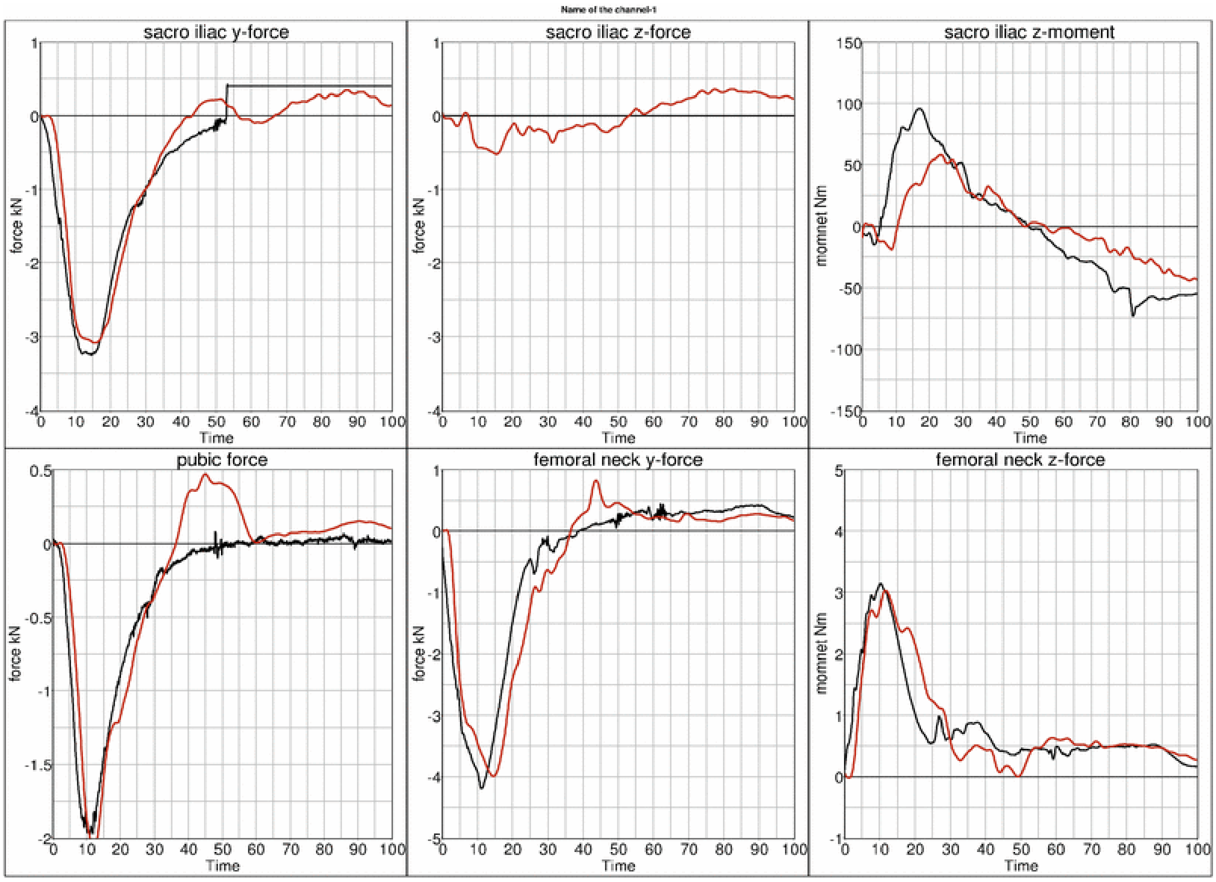
High velocity:

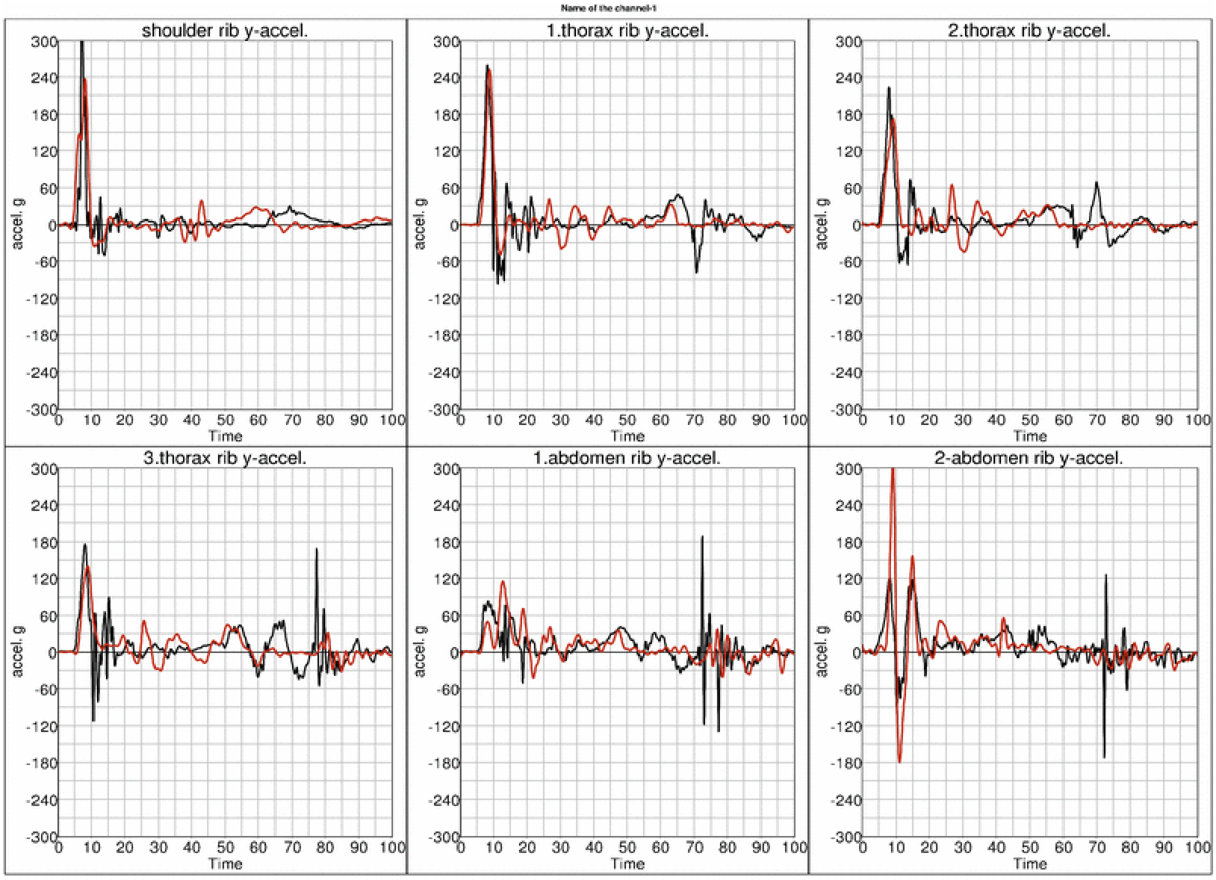



Name of the channel-1
shoulder rib displ.
1.thorax rib displ.
2.thorax rib displ.
3.thorax rib displ.
1.abdomen rib displ.
2-abdomen rib displ.
ir-tracc displ. mm
Time


Name of the channel-1
shoulder x-force
shoulder y-force
shoulder z-force
lumbar spine y-force
lumbar spine z-force
lumbar spine x-moment
force kN
momnet Nm
Time


Name of the channel-1
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
momnet Nm
Time


Name of the channel-1
sacro iliac y-force
sacro iliac z-force
sacro iliac z-moment
pubic force
femoral neck y-force
femoral neck z-force
force kN
momnet Nm
Time


Name of the channel-1
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

9. Literature

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[4] Christian Gehre, PDB – Partnership for Dummy Technology and Biomechanics: "DEVELOPMENT OF A COMPUTATIONAL MODEL OF THE WORLDSID 50TH MALE", Paper Number 09-0411, ESV Conference, 2009, Stuttgart.

[5] A. Gromer, S. Stahlschmidt, R. D'Souza: "Development of the PDB WorldSID 50th Model with the German Automotive Industry", 7th European LS-DYNA Conference, 2009, Salzburg.

[6] S. Stahlschmidt, A. Gromer, M. Walz: "WorldSID 50th vs. ES-2. A Comparison Based on Simulations", 11th International LS-DYNA® Users Conference, 2010, Detroit.