HBM4VT – WG 2

Hub simulation setup - pelvis

Bouquet et al. 1994

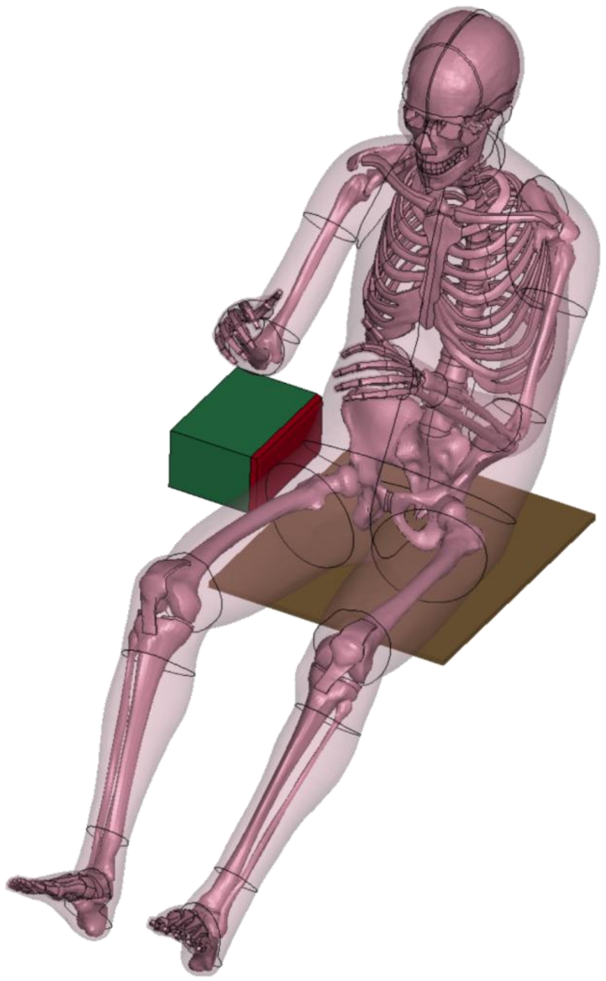
General Overview

Model Setup

Hub tests by Bouquet et al. 1994

Key factors to replicate from PMHS tests:

- HBM seated on a platform
  - Simulation performed with HBM in occupant model posture → model is rotated to align sternum angle to TB024 sternum angle (which has a more upright torso)
- No clear lower extremities angle from the experiment
  - Re-positioning of the lower extremities to zero degree in the simulation → to maintain uniformity across different HBMs



Development notes

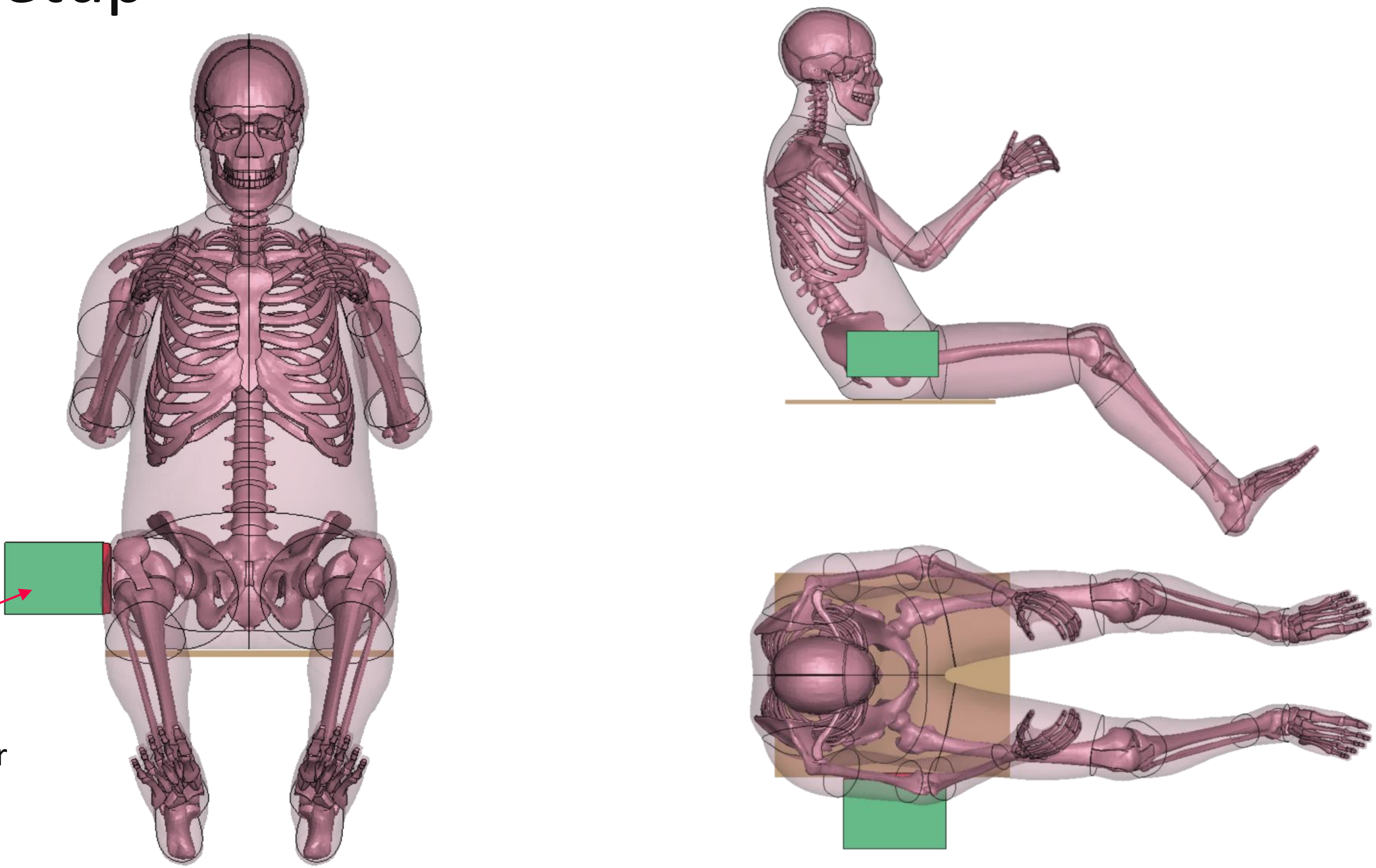
LS-Dyna version used for development:

- R12.2_217 mpp single precision (R12.2-217-gfcd6dde0c9)
- Time step: dt2ms = -4.44E-4 ms (tssfac = 0.9)

HBMs used in testing:

- THUMS v4.1 50th percentile male
- VIVA+ v1.0.0 50th percentile female

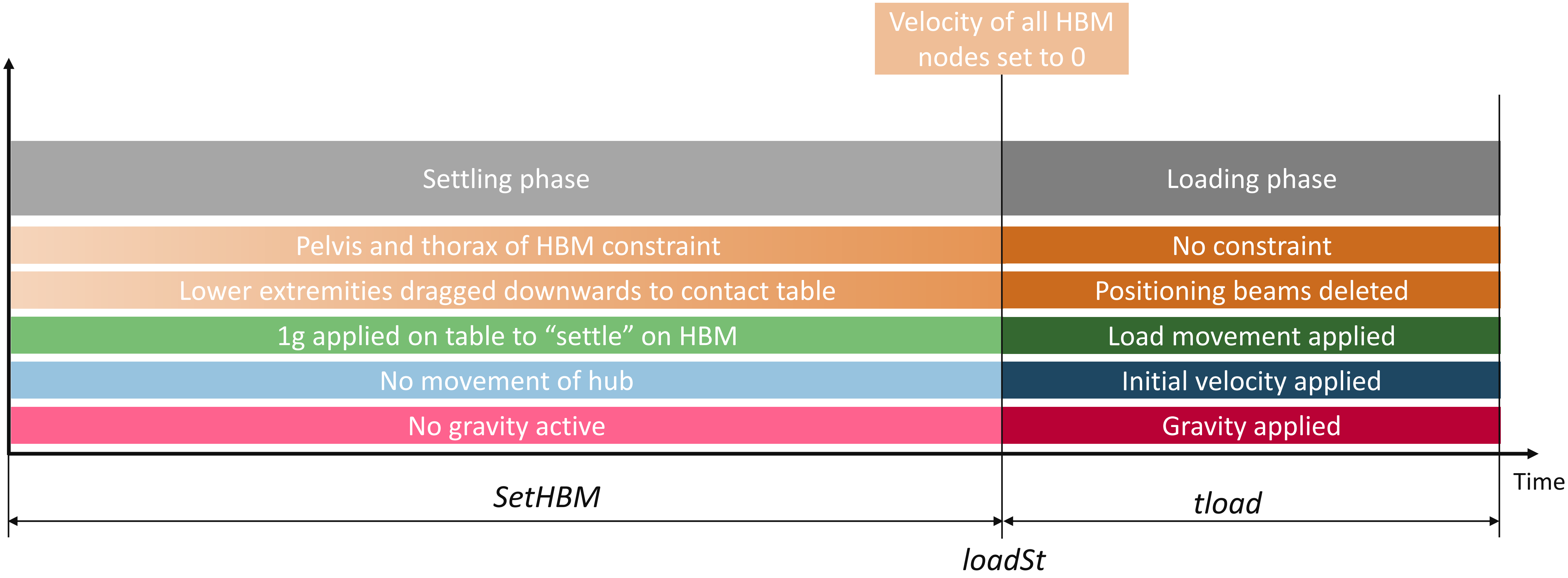
Simulation setup



Rigid hub
- Mass: 23.4kg

Impact location
- at the acetabulum center

Simulation phases



Overview – hub load case

- 00_Master_Hub_Pelvis.k → Single file to be changed
  Follow the descripted procedure
  - _HBM
    - “HBM_include”.k → Add your HBM-include in the folder „_HBM“
  - _env
    - 00_Database_Control.k
    - 01_Table.k
    - 02_Plate.k
    - 03_Boundary_Condition_Pelvis.k
    - 05_Calculations_Pelvis.k

Procedure

Setting the parameters

Set up the include files

1) Put the main HBM file in the folder directory "_HBM“
2) Open the main HBM file in a pre-processor
3) Open the file 00_Master_Hub_Pelvis.k in a text editor
4) Define the main HBM file in the I N C L U D E S section
5) Follow the instructions from STEP 1 to STEP 8 (following slides)

Instrumentation requirements

- Note: The required output rate is defined in the file “00_Database_Control.k”
  - 10kHz for contact and nodal outputs since CFC filtering is applied in Jupyter notebook
  - The output rate for strain output is defined via a curve to only generate data in the crash phase
- Update all NODE and OBJECT IDs in the HBM ID-file in “…\data\metadata” accordingly (see THUMS file for example)

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and ID offset if necessary
4) Definition of the location where hub contacts HBM
5) Definition of the HBM rotations in order to reach target orientation
6) Check for intersections of the HBM to the hub
7) Define attachment nodes for positioning beams
8) Run simulation and check results

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case

Goal:

- Define the impact severity

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case

2) Definition of global parameter

Goal:

- Set factor to scale environment to the unit system of the HBM

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and ID offset if necessary
4) Definition of the location where hub contacts HBM

Goal:

- Define sensible HBM contact set
- Localise points where hub should impact HBM in default HBM position

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
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4) Definition of the location where hub contacts HBM
5) Definition of the HBM rotations in order to reach target orientation

Goal:

- Define the position and orientation of the HBM

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
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3) Define ID for contact sets and ID offset if necessary
4) Definition of the location where hub contacts HBM
5) Definition of the HBM rotations in order to reach target orientation
6) **Check for intersections of the HBM to the hub**

Goal:

- Move seat to avoid intersections to HBM

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and ID offset if necessary
4) Definition of the location where hub contacts HBM
5) Definition of the HBM rotations in order to reach target orientation
6) Define Nodouts and check for intersections of the HBM to the hub
7) **Define attachment nodes for positioning beams**

Goal:

- Define how extremities are moved during settling

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and ID offset if necessary
4) Definition of the location where hub contacts HBM
5) Definition of the HBM rotations in order to reach target orientation
6) Define Nodouts and check for intersections of the HBM to the hub
7) Define attachment nodes for positioning beams
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STEP 1
Definition of the load case

Define impact severity

- LS: set to 1 for low speed (set other parameter to 0)
- HS: set to 1 for highest speed (set other parameter to 0)

	Velocity [m/s]
Low speed	3.463
Highest speed	6.663

S T E P 2
Definition of global HBM parameter

Define the scale factors depending on the unit system of the HBM

- U_Scal: 0.001 for unit system t-mm-s
- U_Scal: 1 for unit system kg-mm-ms

→ The testbed environment will be scaled by *UScal* to the preferred unit system

Define the correct unit system in the Jupyter notebook

- ms_mm_kg
- s_mm_ton

Attention: all parameters in the **main key file** need to be defined in the unit system **kg-mm-ms**

STEP 3

Define ID for contact sets and ID offset if necessary

Define the part set of the HBM

- *P_hbm*: ID of the set including all HBM parts

→ This part set will be damped

Define the part set of all skin parts of the HBM

- *P_hski*: ID of the set including all skin parts except the head of the HBM

→ This part set will be in contact to the testbed

Define the mass of the HBM without legs

- *M_HBMt*: Mass of the HBM without legs in [kg]

→ The mass of the seat will matched to the mass of the HBM without legs to reproduce a realistic settling behaviour

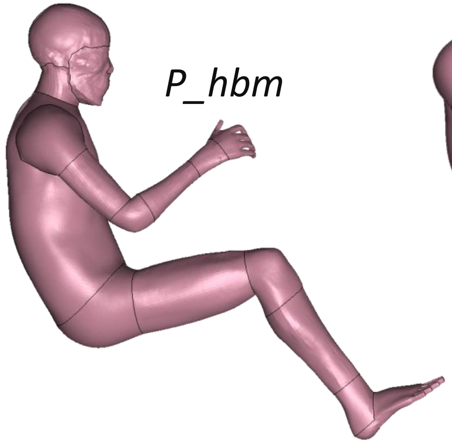
Define the node set including several nodes on the bones of the pelvis and the thorax (e.g. choose three nodes per bone, not all nodes of a bone are required to be constrained)

- *N_bone*: ID of the set including nodes on bones of pelvis, spine and ribs

→ This node set will be constrained in the settling phase (do not choose nodes belonging to rigid materials or rigid bodies)

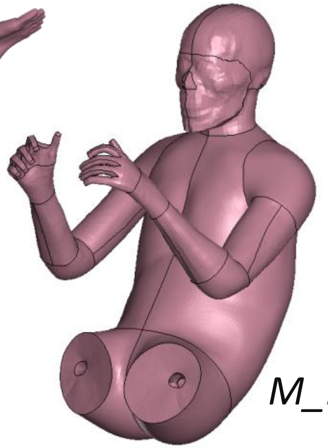
IF the testbed shares node IDs with HBM, define an ID offset for the HBM

- *IDoff*: default: 0.

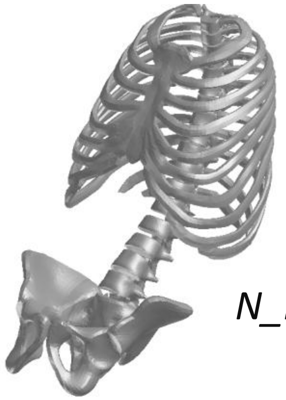


P_hbm

P_hski



M_HBMt



N_bone

STEP 4

Definition of the location where hub contacts HBM:

Define the coordinates of the location of the acetabulum centre point (AC) between the left and right acetabulum (in midsagittal plane):

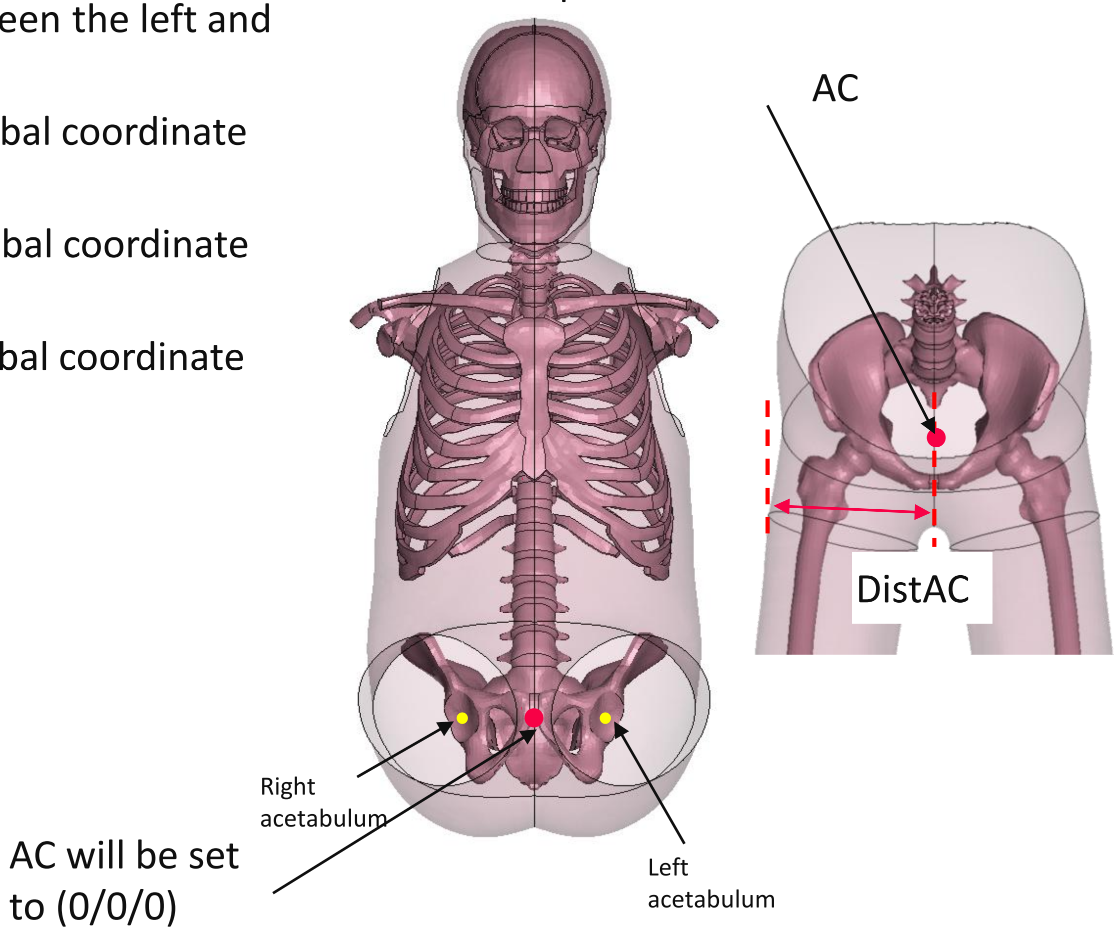
- *x_AC*: x-coordinate of AC in the default HBM position with respect to the global coordinate system
- *y_AC*: y-coordinate of AC in the default HBM position with respect to the global coordinate system
- *z_AC*: z-coordinate of AC in the default HBM position with respect to the global coordinate system

→ The HBM will be transferred so that the AC is at 0/0/0

Define the lateral distance between AC in the sagittal to the most outer contour:

- *DistAC*: distance in lateral direction

Default HBM position



STEP 5

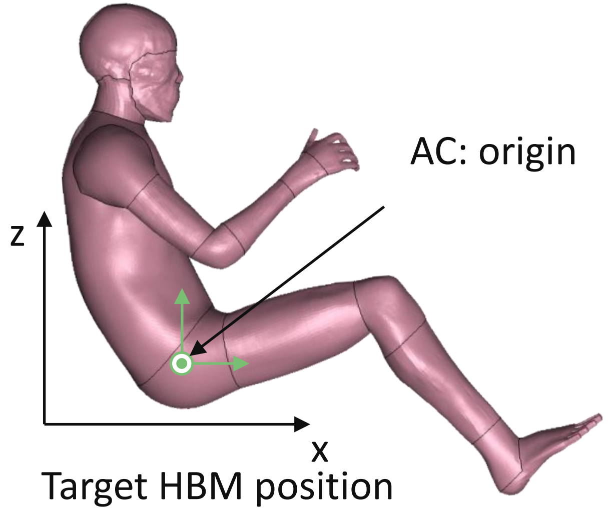
Definition of the HBM rotations to reach target orientation

Check the actual HBM orientation and compare to target orientation as illustrated

Define the flag for all axes:

- *x_rt*: “1” for correct axis orientation and “-1” to rotate the model 180deg about the x axis
- *y_rt*: “1” for correct axis orientation and “-1” to rotate the model 180deg about the y axis
- *z_rt*: “1” for correct axis orientation and “-1” to rotate the model 180deg about the z axis

→ HBM will be rotated to reach target orientation

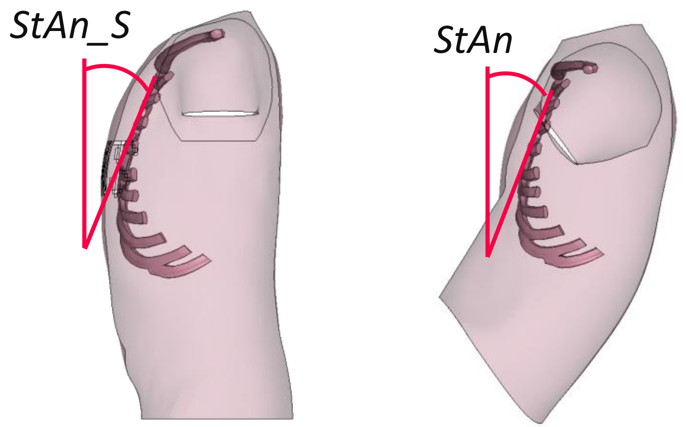


Target HBM position

Measure the sternum angle between the center of attachment of 4th to 2nd rib relative to frontal plane

- *StAn*: angle in default posture of HMB used here (insert a positive value)
- *StAn_S*: angle in default posture of corresponding HBM in TB024 (insert a positive value)
  - If the used HBM is already in standing posture, define both angles as 0 and no rotation is applied to the hub
  - If no standing posture of the HBM is available, define both angles as 0 and no rotation is applied to the hub

→ The hub will be rotated in a way so that the hub impact orientation on the seating HBM equals the hub impact orientation on the standing HBM



STEP 6

Check for intersections of HBM to the hub

Save the file “00_Master_Hub_Pelvis” and open it in a pre-processor

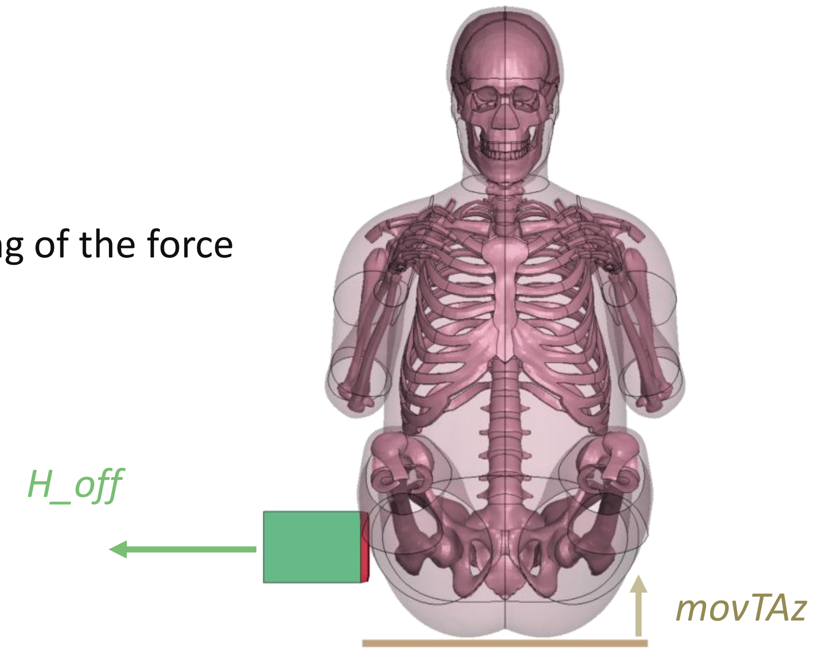
IF the hub has intersections to the HBM, adjust the hub offset

- *H_off:* distance in y (positive value: hub moves away from HBM)

Note: Keep a clearance between hub and HBM of at least 35mm to facilitate filtering of the force signal in the assessment notebook

IF the table has intersections to the HBM, adjust the table offset

- *movTAz:* distance in z (positive value: table moves upwards)



STEP 7

Define attachment nodes for positioning beams

Define the node IDs for the landmarks to be positioned

ri = right, le = left

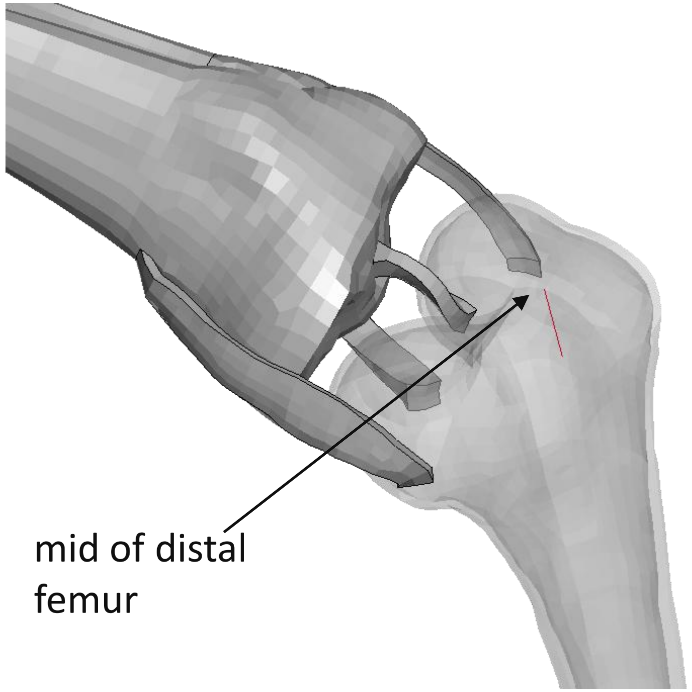
- *N_feri/N_fele*: Node at mid of distal femur

Define the final Z-coordinate of the distal femur w.r.t acetabulum center

- Zfefi: Final Z-coordinate of distal femur (A value of 0 indicates that the lower extremities will be positioned at an angle of 0 deg)

Coordinates of landmark nodes in updated “00_Master_Hub_Pelvis.k” file

- X...: x-coordinates of chosen landmarks in positioned model
- Y…: y-coordinates of chosen landmarks in positioned model



STEP 8

Run simulation and check results

Check the d3plot and adapt the parameters if needed:

IF settling phase is not long enough, change duration

- *SetHBM*: duration of settling phase (default: 350ms)

IF positioning beams do not fully compress, increase tension force (insert value in kN)

- *Fbeam*: default: 0.2 kN

IF contact issues occur, modify DEPTH flag for contact HBM to environment

- *Depth*: default: 25

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