SCIENCE
PASSION
TECHNOLOGY

HBM4VT – WG 2

Hub simulation setup

Leport et al. 2007

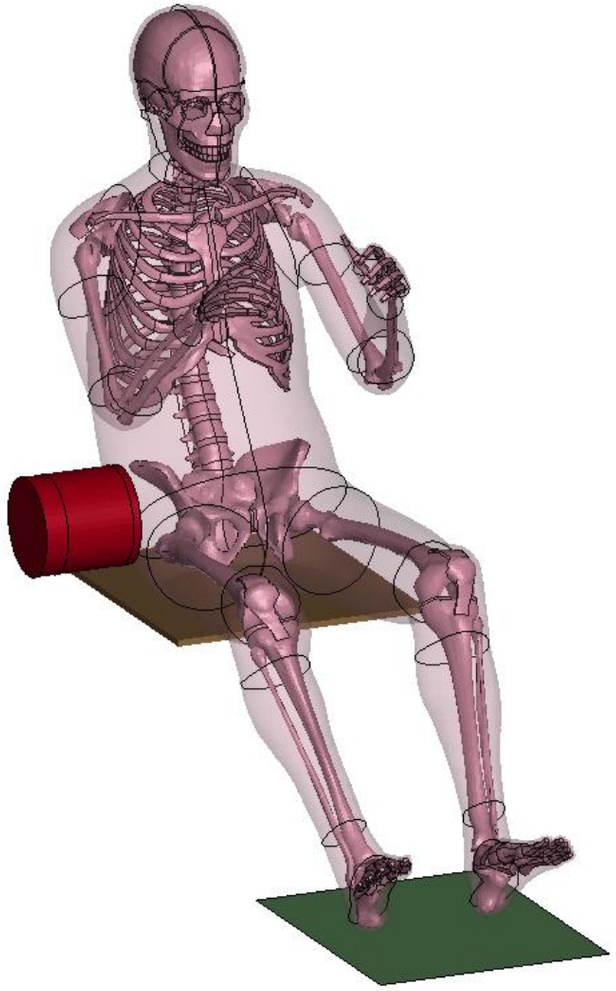
General Overview

Model Setup

Hub tests by Leport 2007

Key factors to replicate from PMHS tests:

- HBM in seating position with straight spine
  - No positioning of the spine in the simulation → hub is only in contact with pelvis
  - Thighs rest on seat
- Extremities fixed in defined position
  - No positioning of the upper extremities in the simulation → hub is only in contact with pelvis
- Impact on right hip
- Feet on footrest
- Measure forces on hub and pubic symphysis



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:

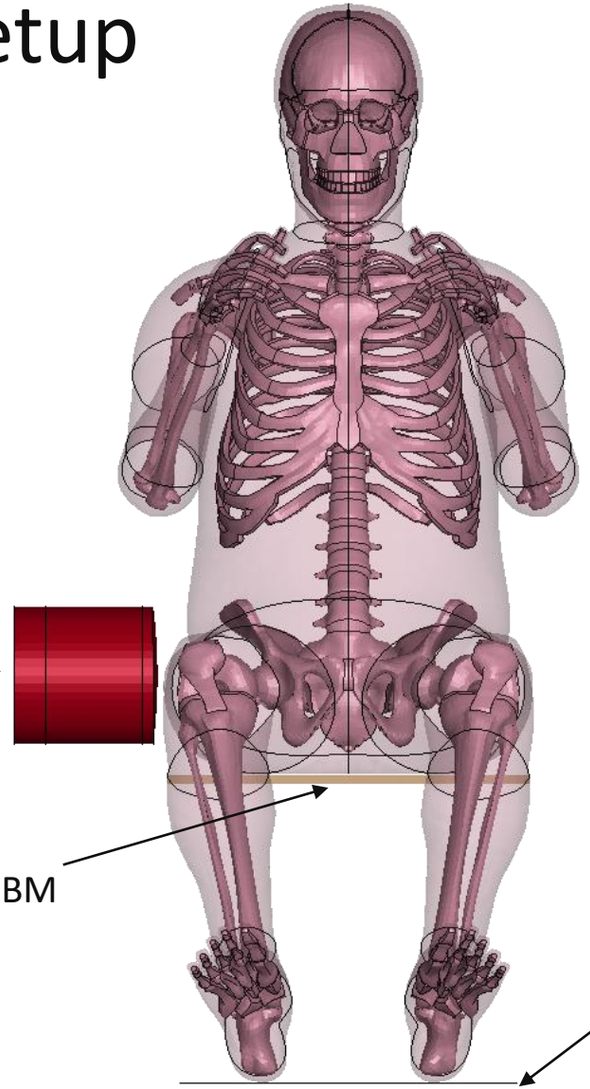
- THUMS v4.1 50th percentile male
- VIVA+ v1.0.0 50th percentile female

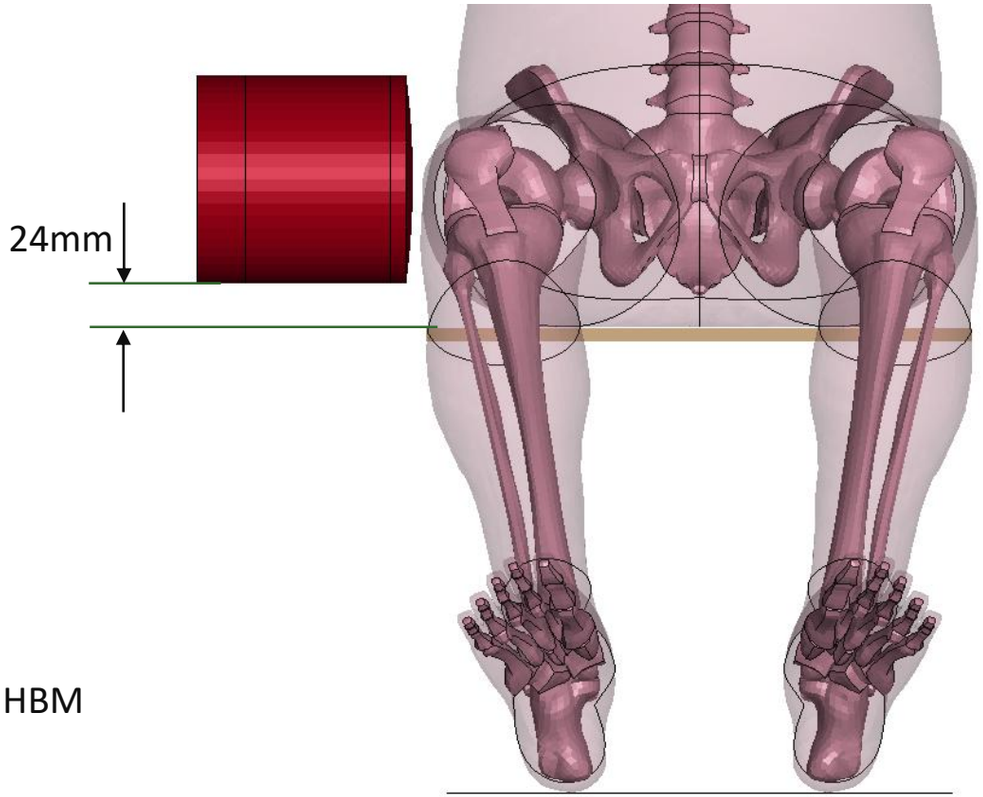
Simulation setup

Rigid hub
- Mass: 23.4kg
- Velocity: 3.9 m/s

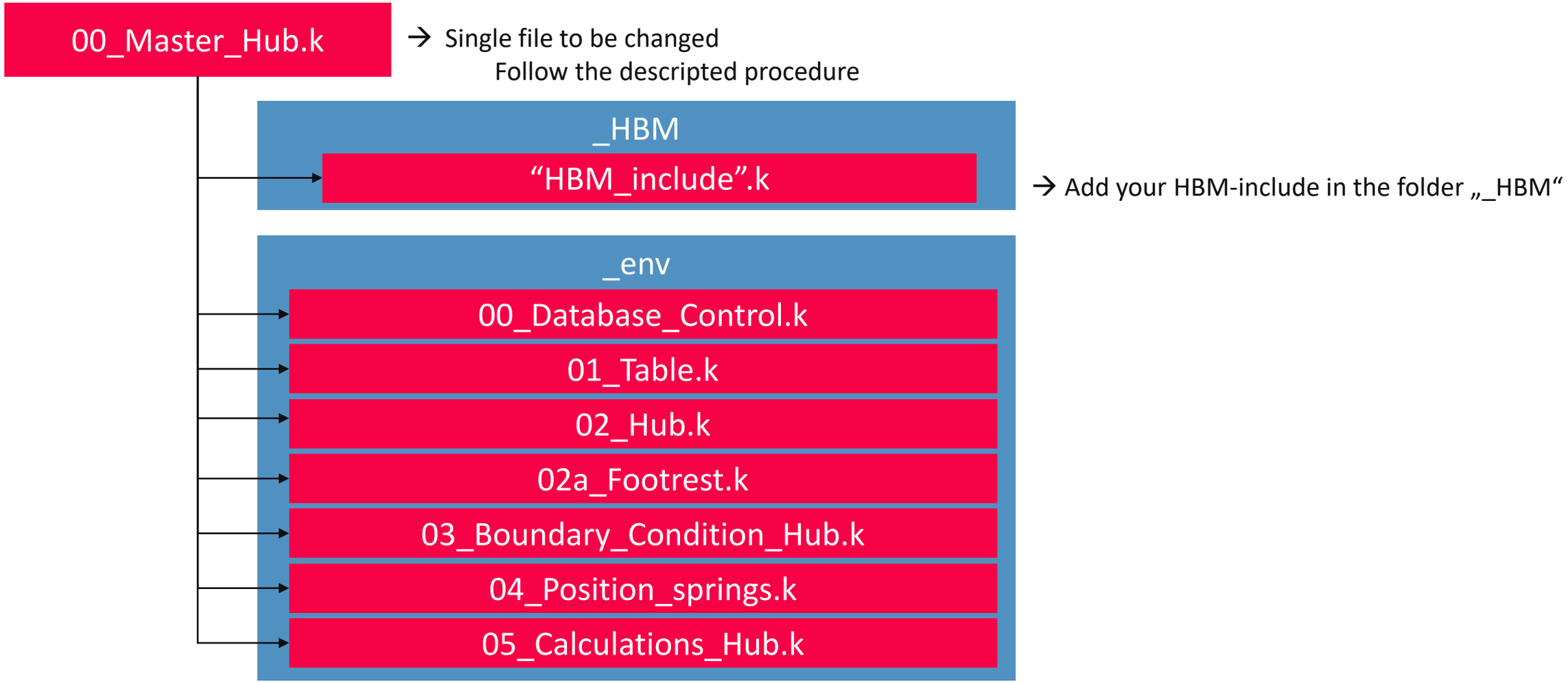
Rigid seat
- Settles on HBM

Rigid footrest
- Settles on HBM





Overview – hub load case



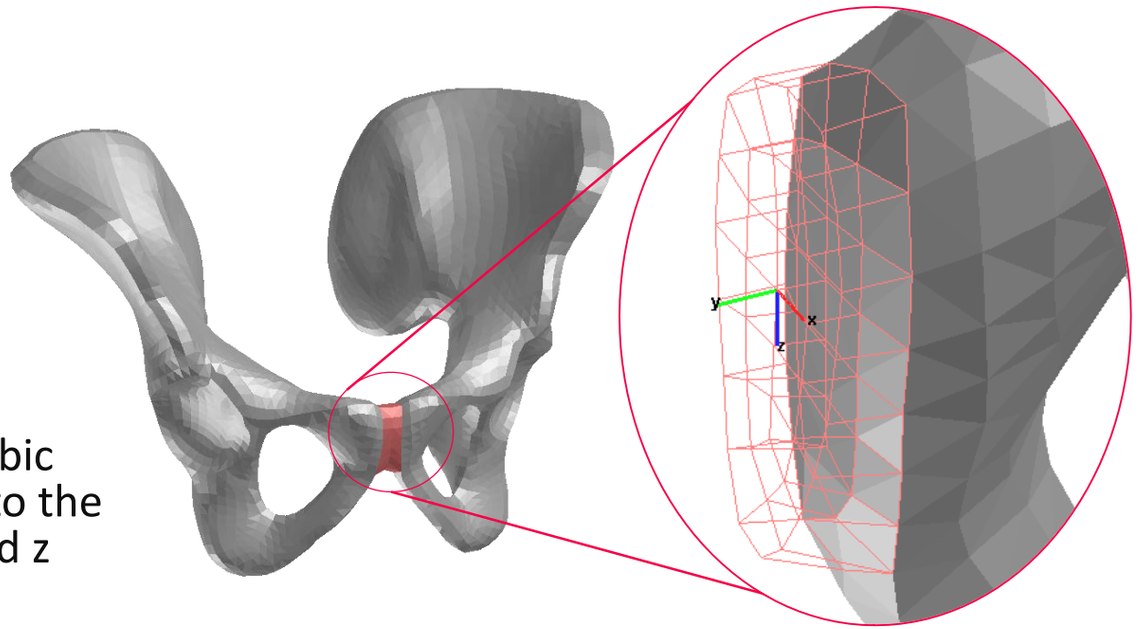
Procedure

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.k in a text editor
4) Define the main HBM file in the I N C L U D E S section
4) Follow the instructions from STEP 1 to STEP 8 (following slides)

Instrumentation requirements



- Equip your HBM with the required output
  - Strains in cortical bones of pelvis
  - Cross section output in the pubic symphysis
    - With local coordinate system in mid-sagittal pubic symphysis cross-section where y faces normal to the cross-sectional surface and x facing anterior and z inferior
- Note: The required output rate is defined in the file “00_Database_Control.k”
  - 10kHz for contact, cross section and nodal outputs since CFC filtering is applied in Jupyter notebook
  - 1kHz for strain output
- 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 global parameter
2) Define ID for contact sets and ID offset if necessary
3) Definition of the location where hub contacts HBM
4) Definition of the HBM rotations in order to reach target orientation
5) Measure initial angles
6) Define Nodouts and 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 global parameter
2) Define ID for contact sets and ID offset if necessary

Goal:

- Set factor to scale environment to the unit system of the HBM
- Define sensible HBM contact set

Overview on stepwise simulation setup (see following slides)

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

Goal:

- Locate points were hub should impact HBM in default HBM position

Overview on stepwise simulation setup (see following slides)

1) Definition of global parameter
2) Define ID for contact sets and ID offset if necessary
3) Definition of the location where hub contacts HBM
4) Definition of the HBM rotations in order to reach target orientation

Goal:

- Rotate HBM to target orientation

Overview on stepwise simulation setup (see following slides)

1) Definition of global parameter
2) Define ID for contact sets and ID offset if necessary
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4) Definition of the HBM rotations in order to reach target orientation
5) Measure initial angles

Goal:

- Define initial angles of lower extremities

Overview on stepwise simulation setup (see following slides)

1) Definition of global parameter
2) Define ID for contact sets and ID offset if necessary
3) Definition of the location where hub contacts HBM
4) Definition of the HBM rotations in order to reach target orientation
5) Measure initial angles
6) **Define Nodouts and check for intersections of the HBM to the hub**

Goal:

- Define nodes for output and check for intersections

Overview on stepwise simulation setup (see following slides)

1) Definition of global parameter
2) Define ID for contact sets and ID offset if necessary
3) Definition of the location where hub contacts HBM
4) Definition of the HBM rotations in order to reach target orientation
5) Measure initial angles
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 and fixed during loading

Overview on stepwise simulation setup (see following slides)

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

S T E P 1
Definition of the unit system of the HBM

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

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

→ The testbed environment will be scaled by *UnitScal* 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**

S T E P 2

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_ski*: ID of the set including all skin parts 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 be matched to the mass of the HBM without legs to reproduce a realistic settling behaviour

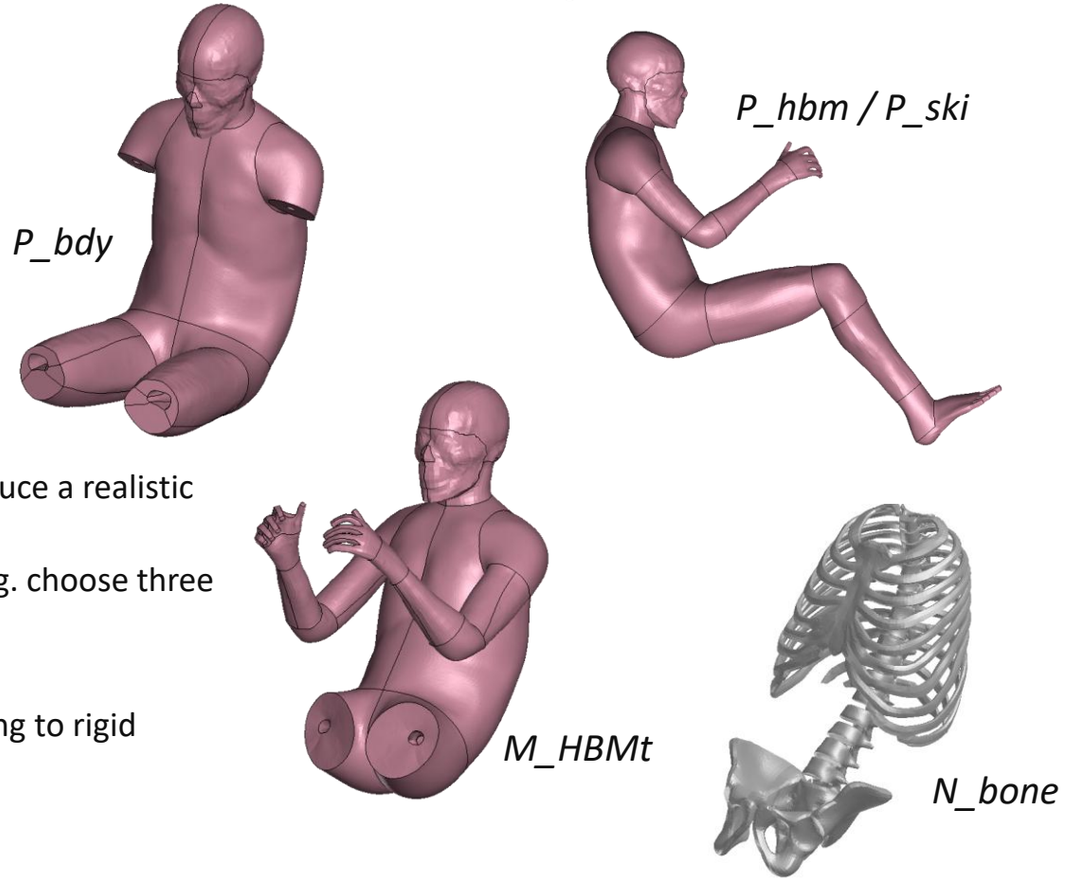
Define the node set including several nodes on the bones of the pelvis and the thorax (e.g. choose three nodes per bone, not all nodes of a bone are required to be constrained)

- 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 the HBM, set an ID offset for the HBM

- IDoff: default: 0.



STEP 3
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

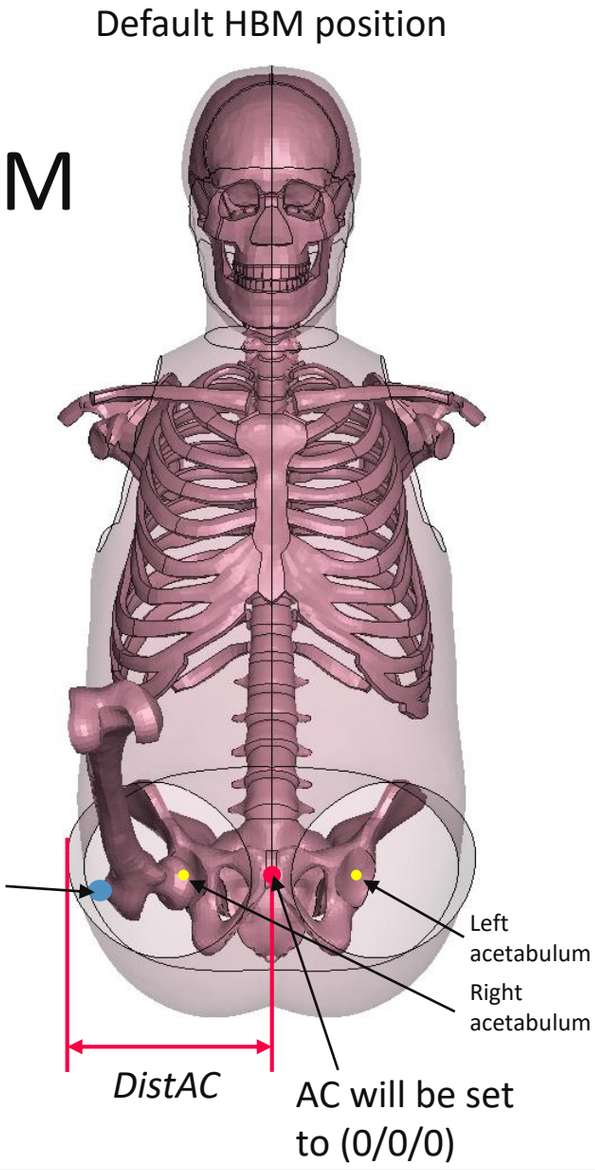
Define the x-coordinate of the location of the trochanter major

- *x_TM*: x-coordinate of trochanter major in the default HBM position with respect to the global coordinate system

Define the distance between the AC and the most anterior point on the pelvis

- *DistAC*: distance in medial direction

→ The hub (default positioned at 0/0/0) will be moved to the location of the trochanter major and transferred in anterior direction to avoid intersections with the HBM



STEP 4

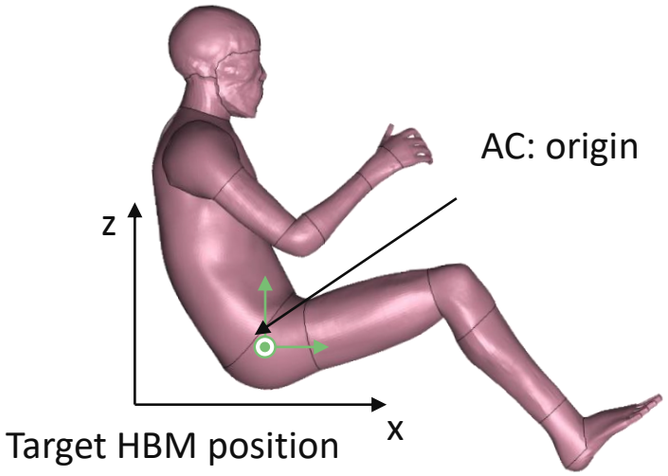
Definition of the HBM rotations in order to reach target orientation

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

Define the flag to 1 or -1 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

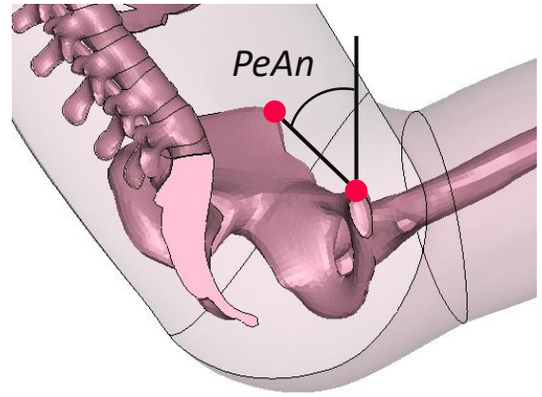
→ HBM will be rotated to reach target orientation



Define the angle of the pelvis measured between the pubic symphysis and the ASIS relative to the vertical plane

- *PeAn*: pelvic angle

→ The HBM will be rotated to the target pelvis angle



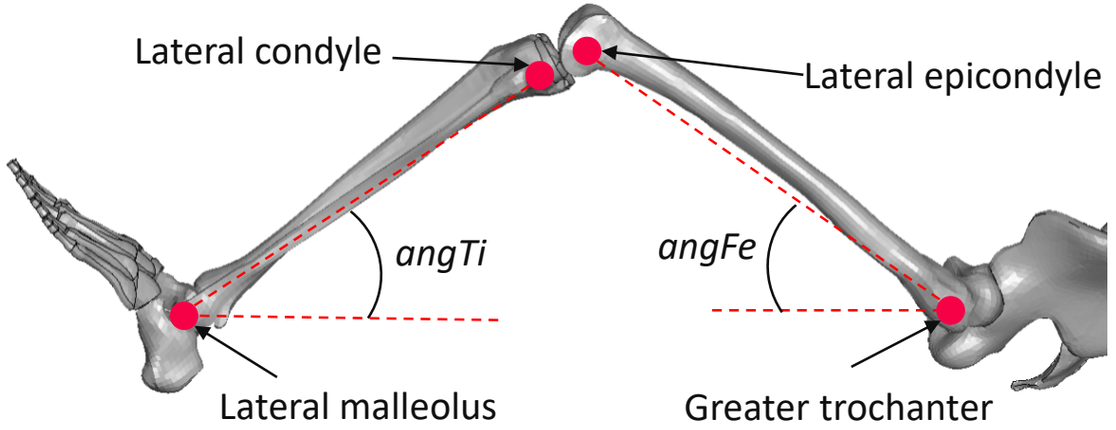
STEP 5
Measure initial angles

Save the file “00_Master_Hub.k” and open it in a pre-processor

Measure the femur and the tibia angle to the horizontal axis in the x-z plane in the positioned HBM

- *angFe*: femur angle defined as a positive value
- *angTi*: tibia angle defined as a positive value

→ The target positon of the knee and the ankle will be defined to archive a femur angle of 0° and a tibia angle of 40° to the horizontal plane



STEP 6
Define Nodouts and check for intersections of the HBM to the hub

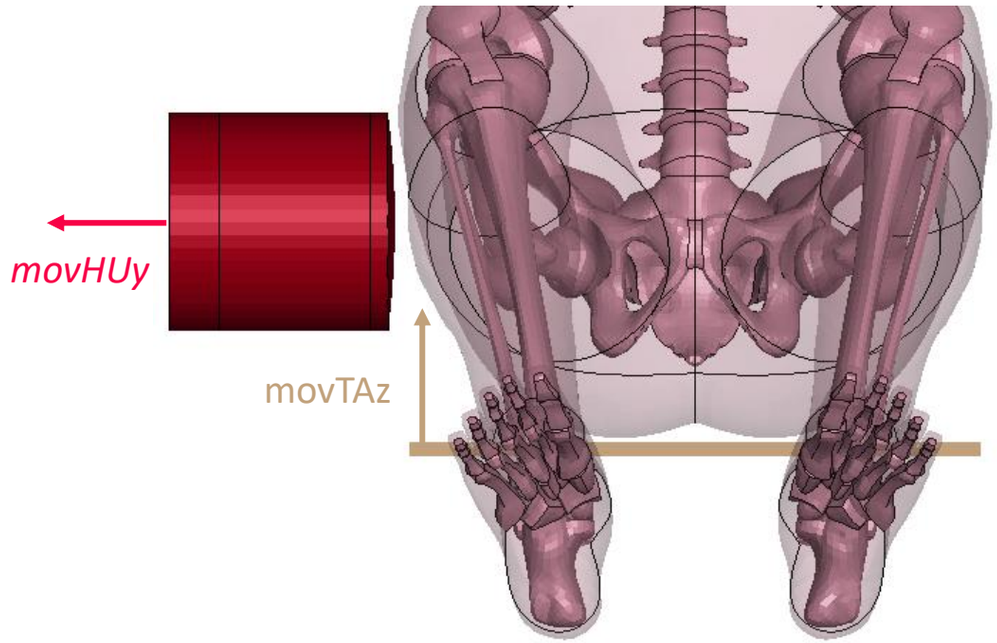
If the hub has intersections to the HBM, translate the hub in y direction.

- *movHUy*: distance in y (positive value: hub is moved away from HBM)

Note: Keep a clearance between hub and HBM of at least 20mm in the settled model to facilitate filtering of the force signal in the assessment notebook. Consider that the HBM hip may deform laterally when settling.

If the table has intersections to the HBM, translate the table in z direction

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

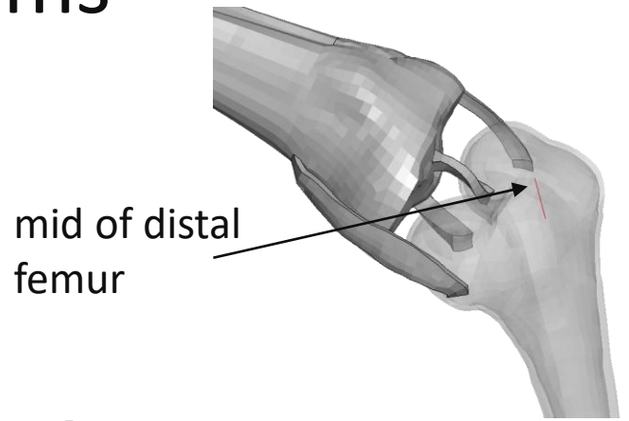


STEP 7
Define attachment nodes for positioning beams

Node IDs for the landmarks to be positioned

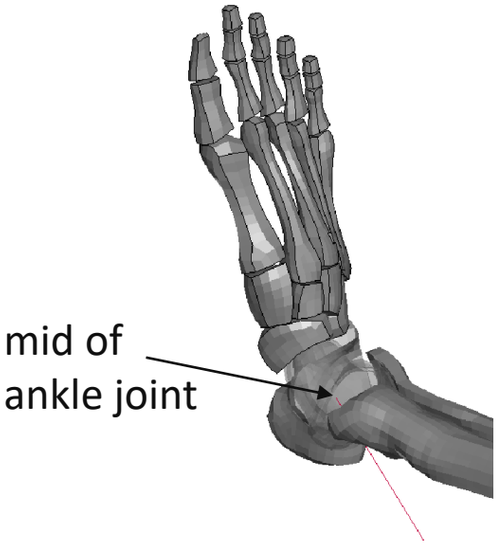
ri = right, le = left

- *N_feri/N_fele*: Node at mid of distal femur
- *N_anri/N_anle*: Node at mid of ankle joint



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

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



STEP 8
Run simulation and check results

Measure the distance between the lower edge of the hub and the upper surface to the seat in z-direction in the settled model (at tsetHBM)

IF the distance is not 24mm +/- 5mm, adjust the z-position of the hub

- *Hub_z*: distance in z (positive value: hub moves upwards)

IF the footrest has intersections to the HBM, move the footrest in z

- *FR_z*: distance in z (positive value: footrest moves upwards)

IF the settling phase for HBM is not long enough, change duration [ms]

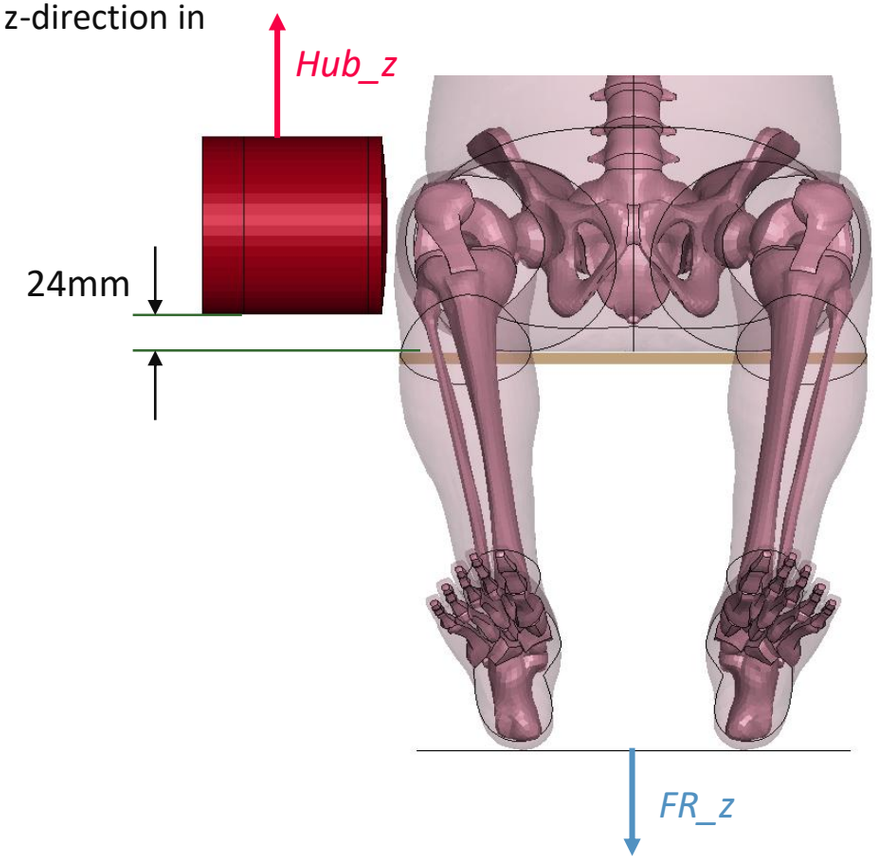
- *SetHBM*: duration of settling phase (default: 350ms)

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

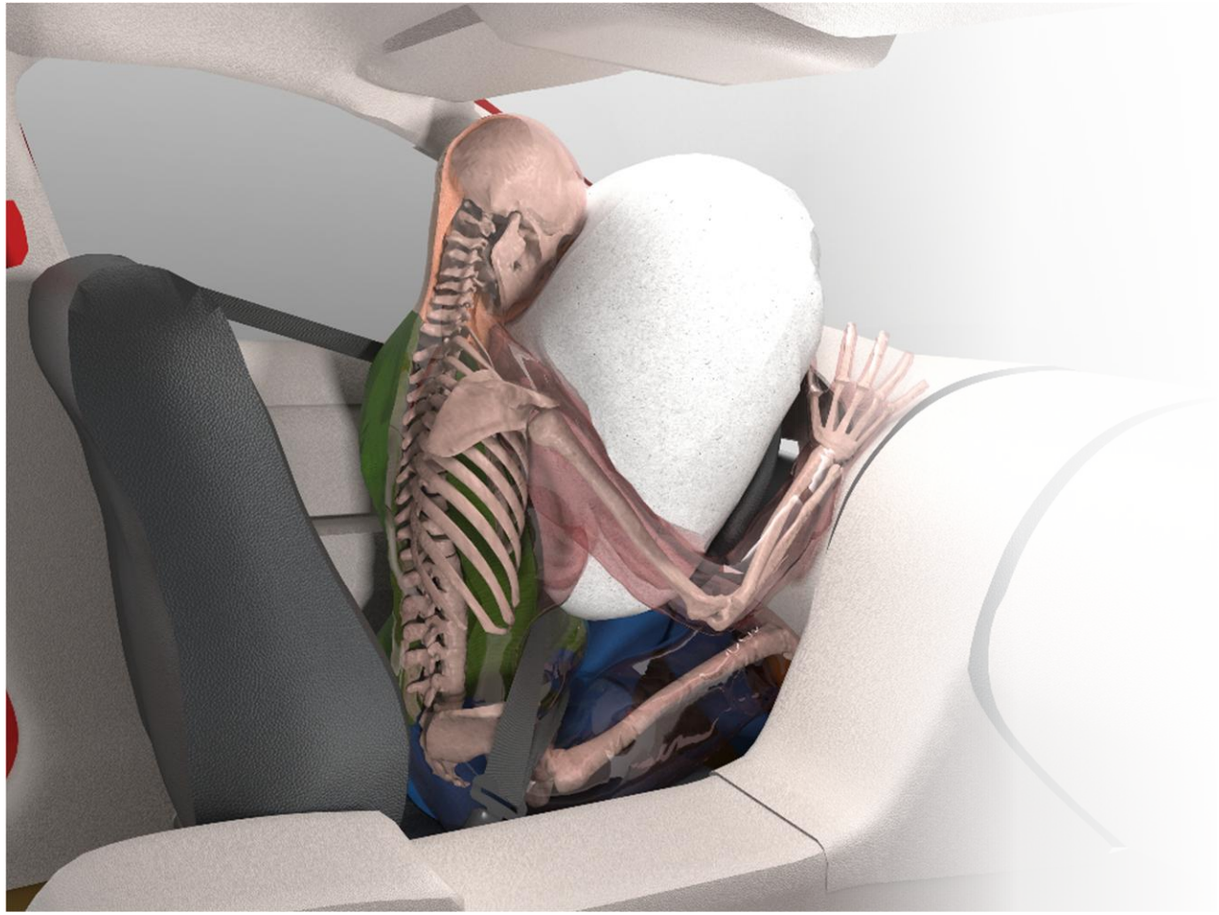
- *Depth*: default: 25



Final checks

Check following values in the settled model (@ tSetHBM)

- Distance between lower edge of hub and upper surface of seat: 24mm +/- 5mm
- No contact between the hub and the HBM must occur in the settling phase



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