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**IWG-DPPS/6/07**

and OICA

**Proposal for [Addendum 5 to Mutual Resolution No. 1 (M.R.1) of the 1958 and the 1998 Agreements]**

**Positioning of a Pedestrian Human Body Model**

# Preamble:

The technical content is based on the development of Euro NCAP to define boundary conditions for a pedestrian human body certification (Klug *et al.*, 2017; Klug *et al.*, 2019; Euro NCAP, 2019).

# Positioning

The target posture of the AM 50 model are specified within Table 1. The joint angles of the legs are based on SAE J2782 and the arm posture is based on a natural posture[[1]](#footnote-1).

The angles should be measured using the reference axis as defined in Annex A.

For the other statures reference measures describing the initial posture are described in Table 2.

The Head COG of the HBM must be positioned in line with the vehicle centreline (y=0 in the global coordinate system). The right side of the HBM is defined as the struck side. The z-direction is defined as the vertical axis, positive in inferior direction. The local HBM x-axis is the frontal axis, facing anterior.

A segment-based contact should be defined between the vehicle and the outer surface of the HBM. The static and dynamic coefficient of friction between the car and the HBM[[2]](#footnote-2) should be set to 0.3.

The friction value to be applied between the foot and the ground shall be 0.3

Table 1

Initial Posture AM 50.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Abbrev.** | **Measure** | **Ref.****Value** | **Tolerance (+/-)** | **Angle Definition** |
| Px | Heel to heel distance Longitudinal | 310 mm | 5.0% |  |
| Py | Heel to heel distance lateral | 185 mm | 15.0% |
| ACz[[3]](#footnote-3) | Height of AC relative to the ground level | 949 mm | 1.2% |
| K | Right Upper Leg Angle (around Y w.r.t. horizontal) | 89° | 3° |
| L | Left Upper Leg Angle (around Y w.r.t. the horizontal) | 106° | 5° |
| G | Right Knee flexion Angle (Y) | 164° | 3° |
| H | Left Knee flexion Angle (Y) | 175° | 5° |
| Ty | Right Upper Arm Angle (Y w.r.t. horizontal) | 98° | 3° |
| Uy | Left Upper Arm Angle (Y w.r.t. horizontal) | 70° | 3° |
| Tx | Right Upper Arm Angle (X w.r.t. horizontal) | 100° | 10° |
| Ux | Left Upper Arm Angle (X w.r.t. horizontal) | 100° | 10° |
| V | Right Elbow flexion Angle | 140° | 5° |
| W | Left Elbow flexion Angle Left | 160° | 10° |
| HCx | x-Position of HC relative to AC | 44 mm | 15 mm |
| HCz[[4]](#footnote-4) | Height of HC relative to the ground level | 1686 mm | 0.8% |

Table 2

Reference Posture of other pedestrian sizes.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Abbrev.** | **Unit** | **Reference** | **Tolerance** | **Reference** | **Reference** | **Tolerance** |
| **6YO[[5]](#footnote-5)** | **6YO** | **AF05** | **AM95** | **AF05 & AM95** |
| Px | mm | 199 | 5.0% | 243 | 340 | 5.0% |
| Py | mm | 152 | 15.0% | 164 | 265 | 15.0% |
| ACz | mm | 632 | 1.3%[[6]](#footnote-6) | 831 | 1043 | 2.0% |
| K | ° | 89° | 3° | 89° | 89° | 3° |
| L | ° | 106° | 5° | 106° | 106° | 5° |
| G | ° | 164° | 3° | 164° | 164° | 3° |
| H | ° | 175° | 5° | 175° | 175° | 5° |
| Ty | ° | 98° | 3° | 98° | 98° | 3° |
| Uy | ° | 70° | 3° | 70° | 70° | 3° |
| Tx | ° | 100° | 10° | 100° | 100° | 10° |
| Ux | ° | 100° | 10° | 100° | 100° | 10° |
| V | ° | 140° | 5° | 140° | 140° | 5° |
| W | ° | 160° | 10° | 160° | 160° | 10° |
| HCx | mm | 6.5 | 15 mm | 27 | 16 | 15 mm |
| HCz | mm | 1117.5 | 0.9%[[7]](#footnote-7) | 1468 | 1836 | 1.0% |
| Total weight | kg | 22.8 |  |  |  | [[8]](#footnote-8) |

# Calculation of Head Impact Time

The Head Impact Time (***HIT***) is defined as the time from the first increase of the bumper contact force (***C***) until the first increase of the contact force between head and generic vehicle (***H***) like shown in Figure 3. **Fehler! Verweisquelle konnte nicht gefunden werden.** describes the process of deriving ***HIT***.

H is defined as the time where the contact force starts to increase (first time where contact force is not zero anymore) and automatically derived in the provided template. If this is not clearly identifiable, the resultant and z acceleration of the head COG should be used additionally. If the upper extremities are stuck between the head and the vehicle and avoid that the head is contacting the vehicle, the contact between head and upper extremities should be disabled to enable a clear determination of H. The respective simulations have to be rerun with the disabled contact. For the determination of ***C,*** a first contact between upper extremities and bumper should be ignored.

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Figure 3: Example for calculation of HIT=H-C

## ANNEX A: HBM Reference Axis

The HBM reference coordinate system is defined as: The local HBM x-axis is the sagittal axis, facing anterior. The y-axis is the defined as the frontal axis and the z-direction is defined as the vertical axis, facing in inferior direction.

The reference axis for the skeleton are based on the recommendations of the international society of biomechanics (ISB) using anatomic landmarks (Wu et al. 2002)[[9]](#footnote-9). All axis describing the initial posture with the corresponding landmarks are shown in Figure A.2 (small capital r stands for right and l for left side of the body)

For humanoid models the connection of the joint centres shall be used instead of the axis. After that they should be overlaid with at least one HBM in reference posture or the IP free skeleton to fine adjust the position until the outer surface of the models are as close as possible.



Figure A.2: HBM Reference Axis for angle definitions

* The **Upper Leg Angle** is defined as the angle around Y between the femur reference axis and the horizontal.
* The femur reference axis is defined as the connection between the centre of the nodes of the acetabulum and the midpoint (**F**) between Epicondylus femoralis medialis (FEM) and Epicondylus femoralis lateralis (FEL). If FEM and FEL are not clearly identifiable the approach shown in Figure A.3 can be used[[10]](#footnote-10):
* The femur has to be positioned such that the lateral and medial epicondyle are overlaying as much as possible. A section cut normal to the view plan should be created. Create a circle from the contour of femoral condyle. The midpoint of the circle can be used as reference for FEM and FEL which should be placed with an offset normal to the view plane. Turn the femoral bone 90 degrees around and identify the most lateral and the most medial point in line with the centre of the circle created at the previous step.



Figure A.3: Construction of FEL and FEM

* The **Knee Flexion Angle** should be measured between the femur reference axis and the connection between the midpoint of the femoral epicondyles and the inter-malleolar point (**M**) located midway between the tip of the medial malleolus (MM) and tip of the lateral malleolus (LM).



Figure A.4: The right inter-malleolar point (MR) located midway
between MM and LM

* The **Upper Arm Angle** is defined as angle around the Y axis between the horizontal plane and the humerus reference axis. **The humerus reference** axis is defined as the connection between the midpoint (**SC**) of AA (the most laterodorsal point of the Angulus Acromialis) and PC (the most ventral point of processus coracoideus) and the midpoint (**HM**) of EL (the most caudal-lateral point on lateral epicondyle) and EM (the most caudal-medial point on medial epicondyle).
* The **Elbow Flexion Angle** is defined as angle between the humerus reference axis and the connection between the midpoint of EM and EL and the most caudal-medial point on the ulnar styloid (**US**).

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Figure A.5: Anatomic Landmarks of upper extremities

* The **Heel to Heel** distance is defined as the distance between the centre of all nodes of the right and the left calcaneus. If this can’t be determined the distance between the most posterior node of the left heel to the most posterior node of the right heel of the shoe sole.

References

Euro NCAP (2019), *Pedestrian Human Model Certification* No. TB 024, Version 2.0, TB 024, 1-35, available at: https://cdn.euroncap.com/media/56949/tb-024-pedestrian-human-model-certification-v20.pdf.

Klug, C., Feist, F., Raffler, M., Sinz, W., Petit, P., Ellway, J. and van Ratingen, M. (2017), “Development of a Procedure to Compare Kinematics of Human Body Models for Pedestrian Simulations”, *2017 IRCOBI Conference Proceedings, Antwerp, Belgium, 13.-15.9.2017*, IRCOBI, pp. 509–530, available at: http://www.ircobi.org/wordpress/downloads/irc17/pdf-files/64.pdf.

Klug, C., Feist, F., Schneider, B., Sinz, W., Ellway, J. and van Ratingen, M. (2019), “Development of a Certification Procedure for Numerical Pedestrian Models”, *The 26th ESV Conference Proceedings, Eindhoven, Netherlands, 10-13 June*, NHTSA, Paper No.19-0310-O, available at: http://indexsmart.mirasmart.com/26esv/PDFfiles/26ESV-000310.pdf.

1. Referring to 50% Position described in Untaroiu et al. (2009) (based on Perry (1992)). [↑](#footnote-ref-1)
2. A sensitivity study (Klug et al. (2017)) showed that the coefficient of friction between HBM and car has a remarkable effect on trajectories and Head Impact Time and was therefore set to 0.3 which is accordance with several studies (e.g. Crocetta et al. (2015), Mizuno and Ishikawa (2001); Simms and Wood (2006)). [↑](#footnote-ref-2)
3. The tolerance for ACz was adjusted to be aligned with the updated corridors at t0 (938-960 mm) [↑](#footnote-ref-3)
4. The tolerance HCz was adjusted to be aligned with the updated corridors at t0 (1673-1699 mm) [↑](#footnote-ref-4)
5. It is planned that the reference values for ACz and HCz will be adjusted by 2022 for the 6yo and the tolerance for ACz will be narrowed down to 1%. [↑](#footnote-ref-5)
6. The tolerance for ACz was adjusted to be aligned with the updated corridors at t0 and the reference models. [↑](#footnote-ref-6)
7. The tolerance for HCz was adjusted to be aligned with the updated corridors at t0 and the reference models. [↑](#footnote-ref-7)
8. Will be set to 1.5% from 2022 onwards. The reference mass is based on the average of male and female 6yo children as reported in CDC,2012 https://www.cdc.gov/nchs/data/series/sr\_11/sr11\_252.pdf [↑](#footnote-ref-8)
9. Wu et al. (2005), Wu and Cavanagh (1995); Wu et al. (2002) [↑](#footnote-ref-9)
10. Based on Churchill et al. (1998) [↑](#footnote-ref-10)