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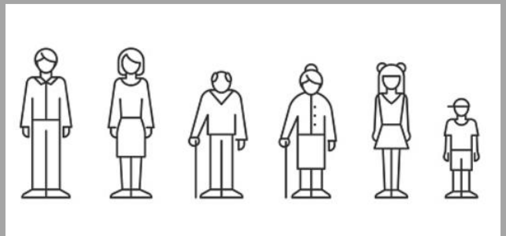
Relation of the topic to the TF Virtual Testing in the EqOP IWG

UNECE GRSP - TF UNECE R14

EqOP Approach

0.) Field data study

Identify which loading scenarios in the field cause <u>significant differences in injury risks for different groups of the population</u> and review how those are currently assessed in regulations



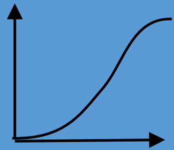
- gender
- age
- body height
- BMI / body weight

1.) Use available tools (already currently used in regulations) to address problems identified in 0.)

Change wordings in regulations

Change requirements in regulation with available tools:

a) Change what is required / voluntary?



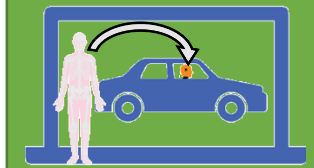
b) Change injury criteria

c) Change test conditions (speed, barrier, angle...)

2.) Use alternative test tools to address problems identified in 0.)

Which injury mechanisms can be predicted additionally compared to currently available tools, where problem in the field are observed?

Which alternative physical test tools are suitable for this?



What can be simulated what currently can‘t be tested?

EqOP Task forces

1. TF Drafting Team for the Report on equity issues: continue to work on the worktable and draft written report.
2. TF on rear impact seat assessment with focus on soft tissue neck injuries / whiplash associated disorders (Remark: presentations by NL and CLEPA at the next GRSP.)
3. TF on Virtual Crash Testing
4. TF on restraint system requirements.
   a. Geometric requirements for seatbelt
   b. Dynamic requirements / system performance
5. TF on extension of assessments towards currently not considered injury types with high frequency and risk of PMI.
   a. Lower extremity injuries in frontal and side impacts
   b. Upper extremity injuries in frontal and side impacts
   c. Brain injuries in frontal and side impacts
   d. Soft tissue neck injuries in frontal and side impacts

EqOP Task Force on Virtual Testing

2024	2025	2026	2027

„**Assess virtual crash testing as a method** in concerned regulations to improve equity in occupant protection further and define related requirements for the models and procedures, including how virtual testing can be validated with existing ATDs.“

Define requirements for virtual crash testing process

Proof of concepts

Draft process for virtual crash testing including different options

Status of Task force Virtual Crash Testing

- Virtual testing already possible in several regulations as alternative to physical tests or to determine worst case
- Opportunities, barriers and ideas, to overcome them to implement virtual testing for occupant safety assessments have been discussed
- Next step: Define ”proof of concept” loadcase to address relevant equity issue

Human Body Models for occupant assessments

Advantages:

+ overcome limitations of crash test dummies in terms of
  - Biofidelity (e.g. anatomical joints, „omnidirectional“ spine)
  - Available shapes and sizes
  - Assessment methods (i.e. tissue-based criteria)
  - Integrated safety assessment (consider precrash phase)

Disadvantages:

- No physical tests possible
  - New procedures / frameworks required to enable virtual testing without possibility for direct hardware test comparison
  - Virtual assessment is only useful if models of the vehicle and boundary conditions are capturing the real vehicle sufficiently enough to distinguish between safe and unsafe designs
- Qualification requirements currently not available

Activities on Virtual Testing

HBM4VT

2024 — 2025 — 2026 — 2027 — 2029

development of qualification requirements for HBMs
→ Euro NCAP TB

refine qualification requirements for HBM

translate into MR1?

define first protocol for HBM-based VT in frontal loadcase
→ Euro NCAP protocol

refine HBM protocols for frontal and far-side

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Status of the Validation of HBM for Extended Use (Reclined) Positions

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Overview on validations

- Focus of this presentation on THUMS, GHBMC and SAFER models
  - Only published studies considered
  - Focus on reclined positions
- Individual HBM validations (one HBM compared with PMHS setup(s))
- Comparison of different HBMs in the same validation setup
- Studies using validated HBMs to analyse sensitivities relevant for the discussed topic

Individual HBM Validations – THUMS v7

Matsuda, T., Kobayashi, N., Fujita, N., & Kitagawa, Y. (2023). DEVELOPMENT OF A HUMAN BODY MODEL (THUMS VERSION 7) TO SIMULATE KINEMATICS AND INJURIES OF RECLINED OCCUPANTS IN FRONTAL COLLISIONS. In National Highway Traffic Safety Administration (Chair), *International Technical Conference on the Enhanced Safety of Vehicles,* Yokohama, Japan. Retrieved from https://www-esv.nhtsa.dot.gov/Proceedings/27/27ESV-000030.pdf

- Full scllae validation with publicly available NHTSA data (overall 0.72 ISO rating)
  - Reed, M. P., Zaseck, L., Hu, J. 2019. "Automated Vehicle Occupant Kinematics - Phase I: Task Implementation Plan." University of Michigan Transportation Research Institute
- Component validations for intraction of pelvis with lap belt, abdominal stiffness and lumbar spine FSU.

Individual HBM validations – GHBMC v5

- Grébonval, C., Trosseille, X., Petit, P., Wang, X., & Beillas, P. (2021). Effects of seat pan and pelvis angles on the occupant response in a reclined position during a frontal crash. *PLOS ONE*, *16*(9), e0257292. https://doi.org/10.1371/journal.pone.0257292
  - Comparison of HBM response with PMHS tests (CORA scores > 0.75 https://doi.org/10.1371/journal.pone.0257292.g005) from
    - Richardson R, Donlon JP, Jayathirtha M, Forman J, Shaw G, Gepner B, et al. 2020. Kinematic and Injury Response of Reclined PMHS in Frontal Impacts. Stapp Car Crash Journal, Vol. 64, pp 83–153. pmid:33636004
  - „the model and environment are able to capture the main trends observed in the experimental tests with correlation scores around 0.8."

Individual HBM Validations – SAFER HBM

- Mroz, K., Östling, M., Richardson, R., Kerrigan, J., Forman, J., Gepner, B., . . . Pipkorn, B. (2020). Effect of Seat and Seat Belt characteristics on the Lumbar Spine and Pelvis Loading of the SAFER Human Body Model in reclined Postures. In International Research Council on the Biomechanics of Injury (Ed.), *IRCOBI Conference Proceedings, 2020 IRCOBI Conference Proceedings*. IRCOBI. https://www.ircobi.org/wordpress/downloads/irc20/pdf-files/58.pdf
  - Comparison of SAFER HBM Version 9.0.1 50M response with PMHS tests from Richardsson et al. 2020
  - Total CORA rating of 0.81

Comparison of different HBMs in the same validation setup

- Gepner, B. D., Perez-Rapela, D., Forman, J. L., Östling, M., Pipkorn, B., & Kerrigan, J. R. (2022). Evaluation of GHBMC, THUMS and SAFER Human Body Models in Frontal Impacts in Reclined Postures. In International Research Council on the Biomechanics of Injury (Ed.), *IRCOBI Conference Proceedings, 2022 IRCOBI Conference Proceedings* (116-143). IRCOBI. https://www.ircobi.org/wordpress/downloads/irc22/pdf-files/2227.pdf
  - Reference PMHS tests:
    - Richardson, R., Jayathirtha, M., Donlon, J.P., Forman, J., Gepner, B., Ostling, M., Mroz, K., Pipkorn, B. and Kerrigan, J.R., 2020. Pelvis Kinematics and Injuries of Reclined Occupants in Frontal Impacts. In Proceedings of the International Research Conference on the Biomechanics of Impact, IRCOBI. IRC-20-60.
    - Richardson R, Donlon JP, Jayathirtha M, Forman J, Shaw G, Gepner B, et al. 2020. Kinematic and Injury Response of Reclined PMHS in Frontal Impacts. Stapp Car Crash Journal, Vol. 64, pp 83–153. pmid:33636004
  - Simulations with GHBMC v6, THUMS v6.1, SAFER HBM v10 50M models
  - Overall CORA Scores: 0.66-0.69
  - Good lap belt engagement and no submarining, Similar X-axis motion of the head, T1, and pelvis compared to the PMHS
  - Difference in pelvis motion (posterior rotation at maximum excurions), localised lumbar spine flexion and under-prediction of Z direction trajectories compared to PMHS

Comparison of different HBMs in the same validation setup

- Autonomous Vehicle Occupant Safety Consortium (2023). Investigation of the biofidelity of human body models and atd models in sled test conditions. In National Highway Traffic Safety Administration (Chair), *International Technical Conference on the Enhanced Safety of Vehicles,* Yokohama, Japan. Retrieved from https://www-esv.nhtsa.dot.gov/Proceedings/27/27ESV-000288.pdf

  - Comparison of GHBMC (v.5.1.), THUMS (v6.1), THOR (v.1.8.1) and THOR AV (v0.6) in the same PMHS setups in upright and reclined seatback
  - For the UMTRI 45° test* configuration HBMs did show an average Biofidelity Rank Score of 1.28-1.45; THOR AV of 1.12 and THOR 1.36 in terms of dummy kinematcis. All models showed BRS >2 for the restraint systems.
  - UMTRI 45° tests used:
    - Wang Z.J., Zaseck L.W., Reed M.P., THOR-AV 50 th percentile male biofidelity evaluation in 25 and 45 seatback angle test conditions with a semi-rigid seat, IRCOBI conference, Porto, Portugal, September 14-16, 2022.

Example for Finding from HBM Studies

Takeuchi, Y., Tanaka, Y., Azuma, T., Zhao, Y., Mizuno, K., Yamada, M., . . . Jinzaki, M. (2024). Predictive modeling of submarining risk in car occupants based on pelvis angle and lap belt positioning. *Traffic Injury Prevention*, *25*(2), 147–155. https://doi.org/10.1080/15389588.2023.2278419

- Simulation study using THUMS v7 to develop a prediction model for submarining
- Small belt-ASIS overlap and a rearward-tilted pelvis angle led to high submarining risk.
- Belt-pelvis angle and belt-ASIS overlap were statistically significant to influence the submarining risk

Examples of Findings from HBM studies

- Östling, M., Lundgren, C., Lubbe, N., & Pipkorn, B. (2022). Reducing Lumbar Spine Vertebra Fracture Risk With an Adaptive Seat Track Load Limiter. *Frontiers in Future Transportation*, *3*. https://doi.org/10.3389/ffutr.2022.890117
  - „The risk for lumbar vertebra fracture increased with crash pulse severity, while HBM size had no effect on risk. "
  - "For all conditions, the passive seat track load limiter reduced injury risks compared to the fixed seat, and the adaptive seat track load limiter reduced risk even further."

→An example to show that it is not the belt position alone which is of interest

Some remarks on appropiate occupant models

- Occupant models need to
  - be representative and human-like enough
  - be applicable to distinguish between safe and unsafe designs
  - capture sensitivities sufficiently
  - ensure equitable occupant protection
    - Exemplary study on this topic: Shin, J., Donlon, J. P., Richardson, R., Espelien, C., Gallaher, M., Luong, V., . . . Kerrigan, J. (2023). Comparison of Pelvis Kinematics and Injuries in Reclined Frontal Impact Sled Tests Between Mid-Size Adult Male and Female PMHS. In International Research Council on the Biomechanics of Injury (Ed.), *IRCOBI Conference Proceedings, 2023 IRCOBI Conference Proceedings* (pp. 266–284). IRCOBI. Retrieved from http://www.ircobi.org/wordpress/downloads/irc23/pdf-files/2335.pdf: "Due to variations in pelvis geometry compared to male subjects, the H-point positioning target for female subjects needed to be translated forward relative to that of the male subjects to fit the female subjects in the seat. Lap belt anchor points were also moved forward to avoid potential differences in belt–pelvis interaction"

- Currently identified gaps/challenges for the usage of HBM in reclined seating positions:
  - Validation data needed to validate sensitivity of the models within reclined posture (cases with/without submarining or with / without lumbar spine injury)
  - Missing specification of spine posture (i.e. vertebrae orientation) in reclined posture
  - Harmonised validation & injury assessment methods (e.g. lumbar spine)

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