



Automation, Customization, and Traumatic Brain Injury Trends in Motor Vehicle Crashes

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Acknowledgements:

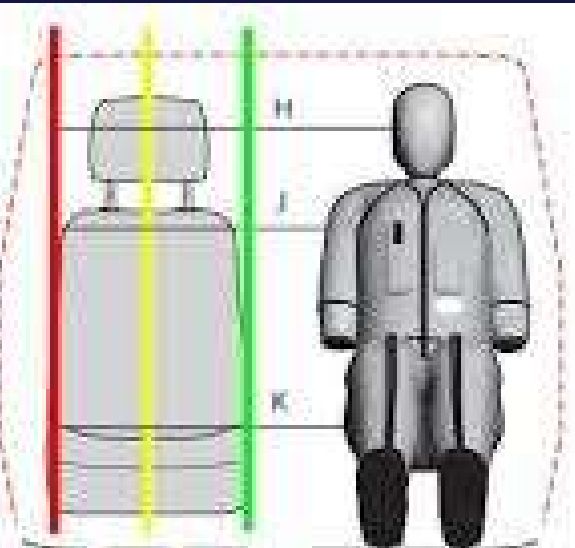
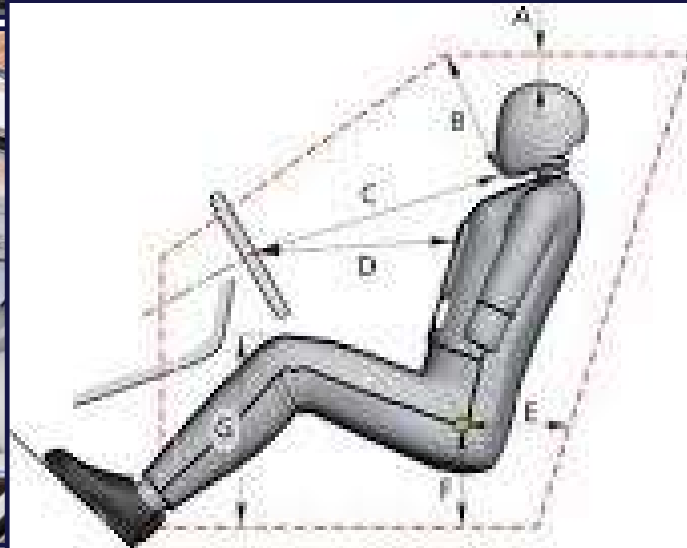
Jason Forman, PhD; Matt Panzer, PhD;
Francisco Lopez-Valdes, PhD; Sophie Tushak

Innovation Trends in Technology for Prevention, Treatment, and Management of TBI
Workshop National Academies of Science and Medicine, Washington, DC. April 15, 2024.

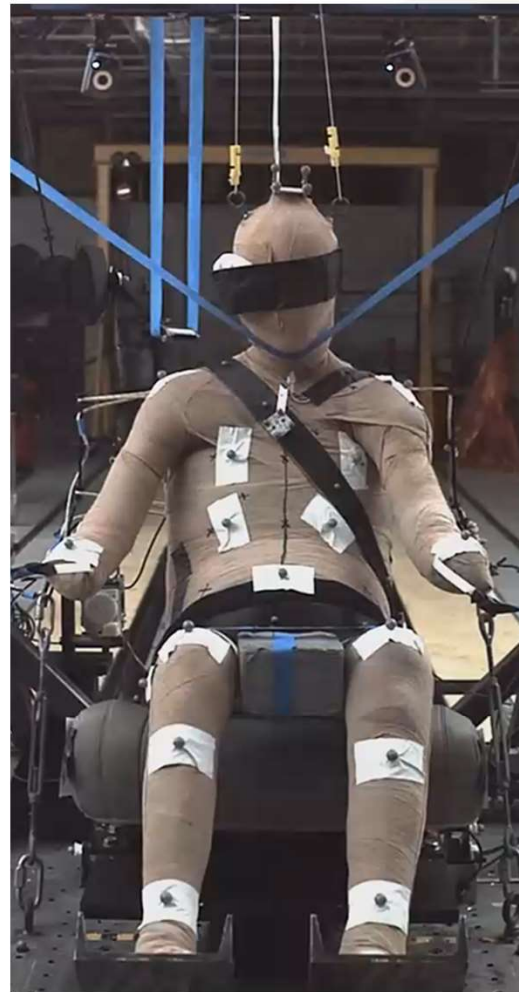
Brain Injury Biomechanics 101



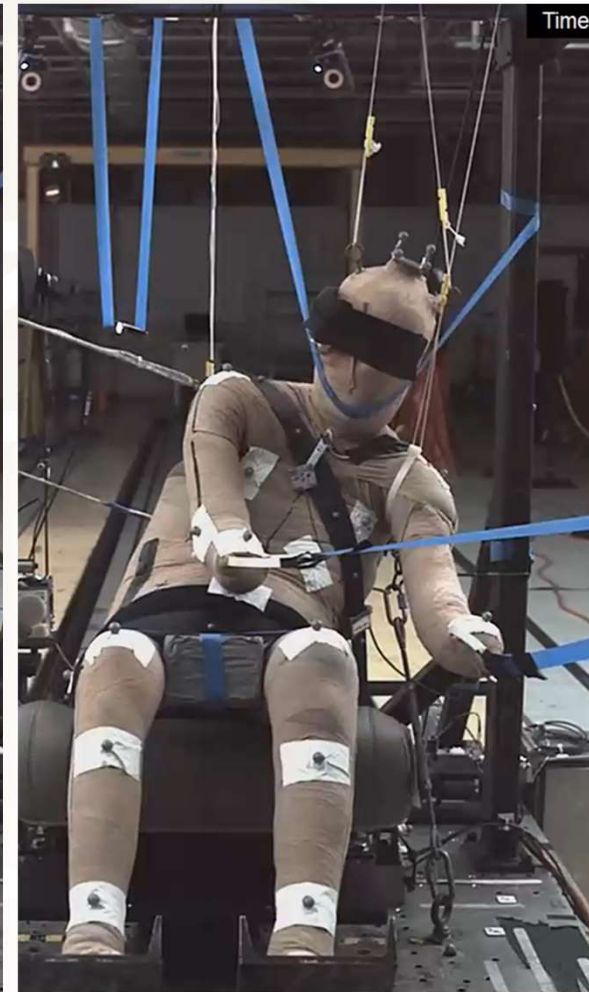


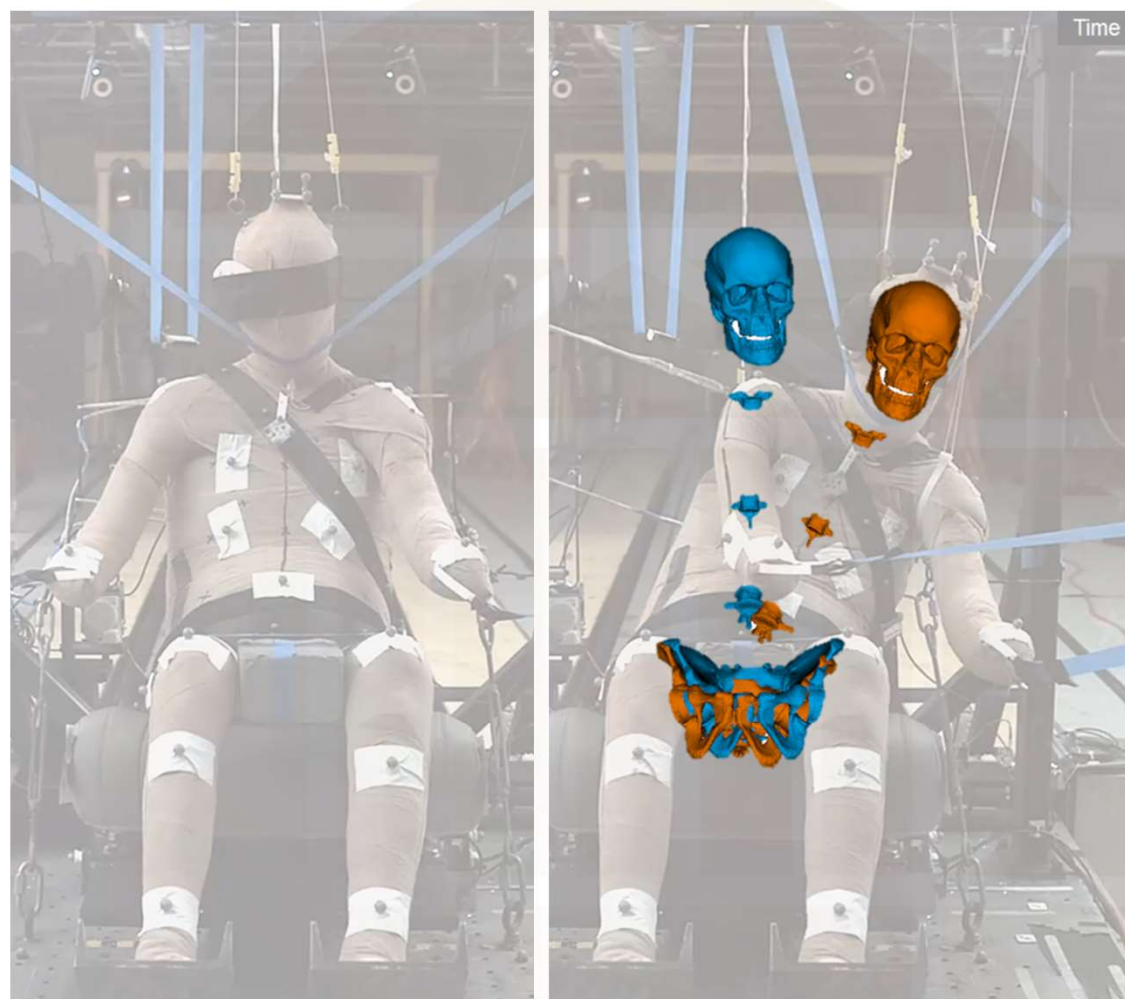


Neutral

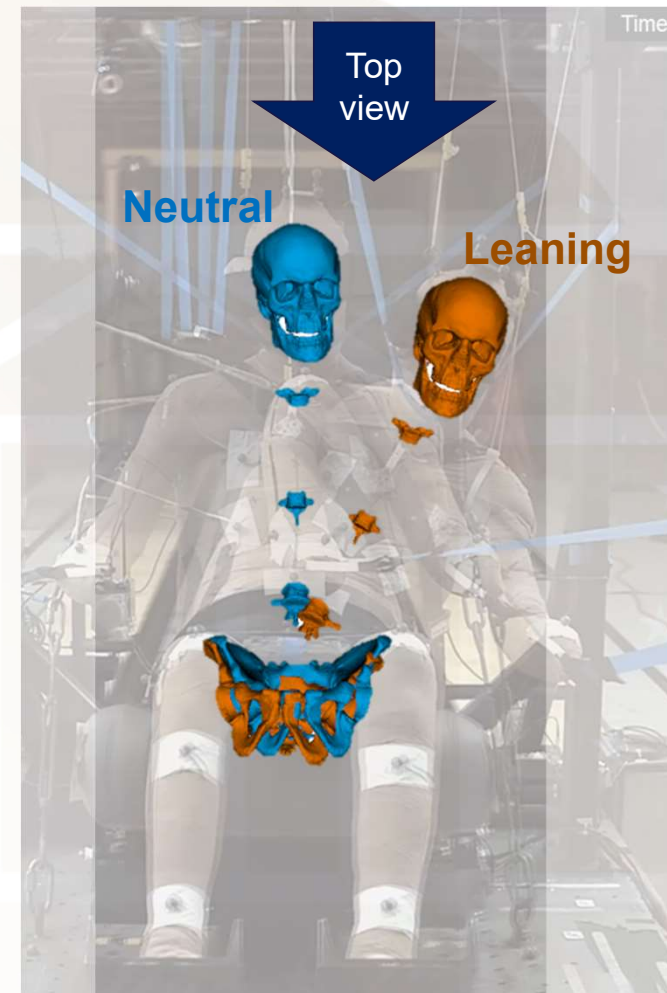
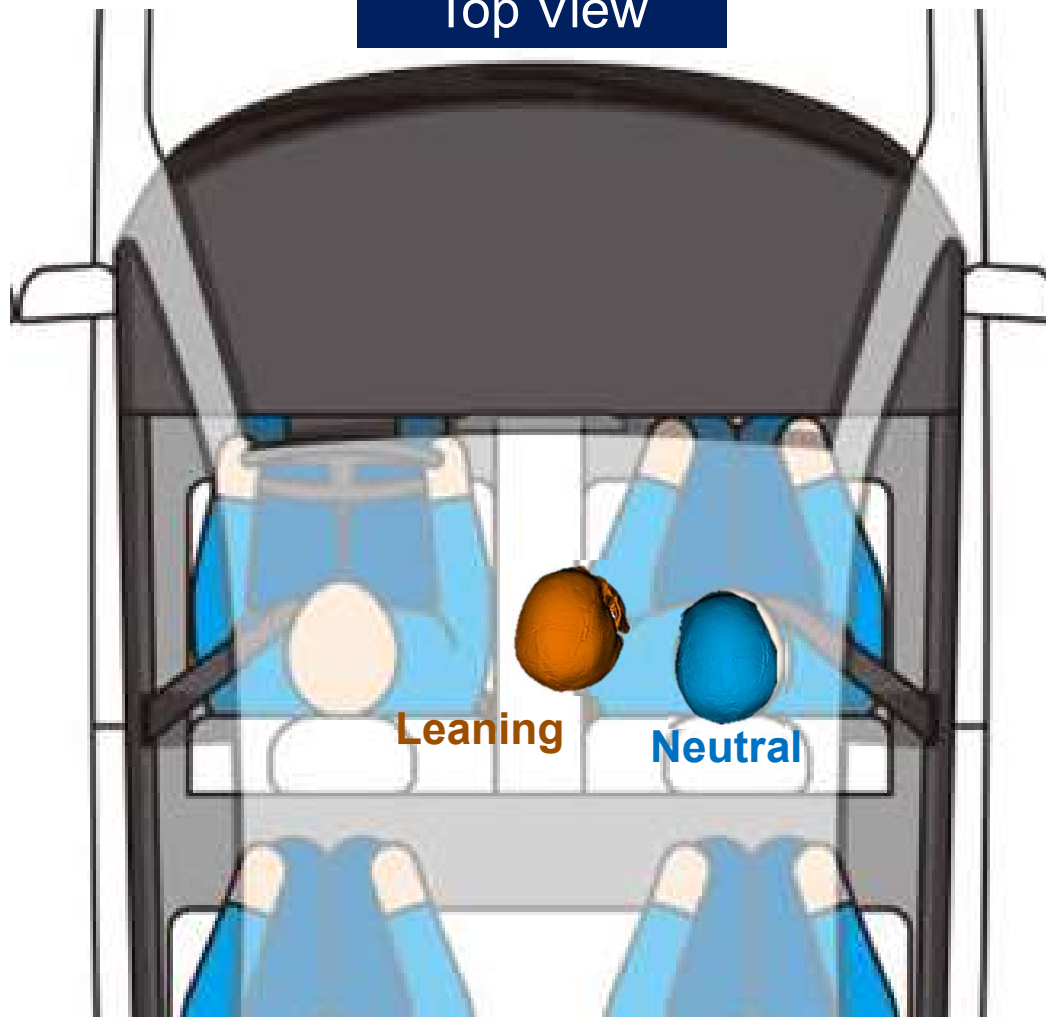


Leaning 20° Inboard

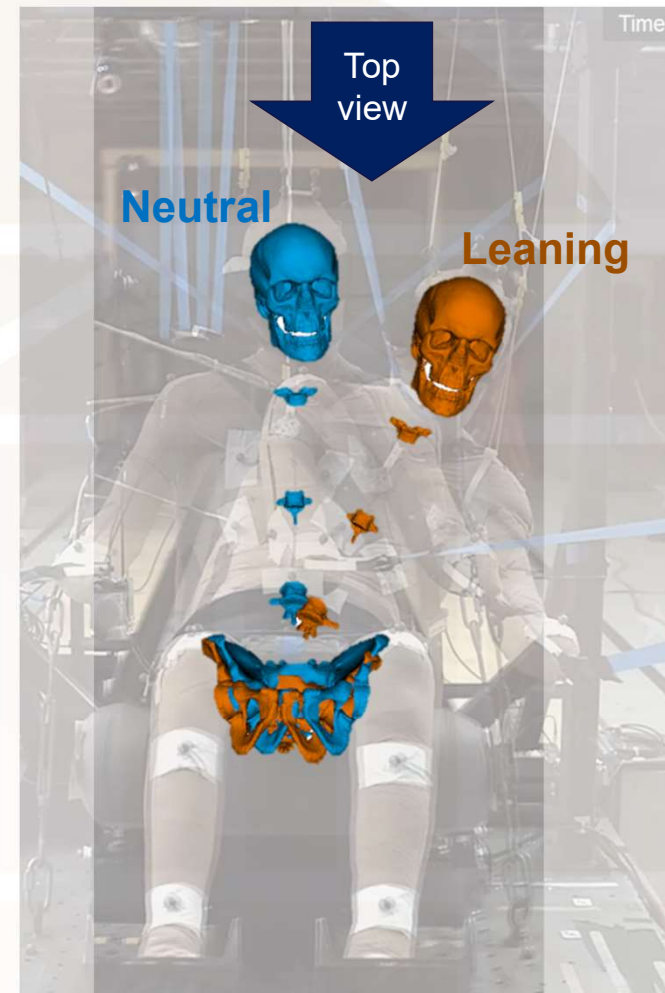
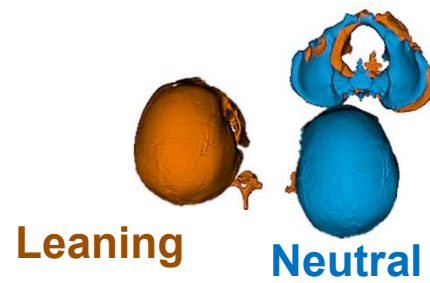




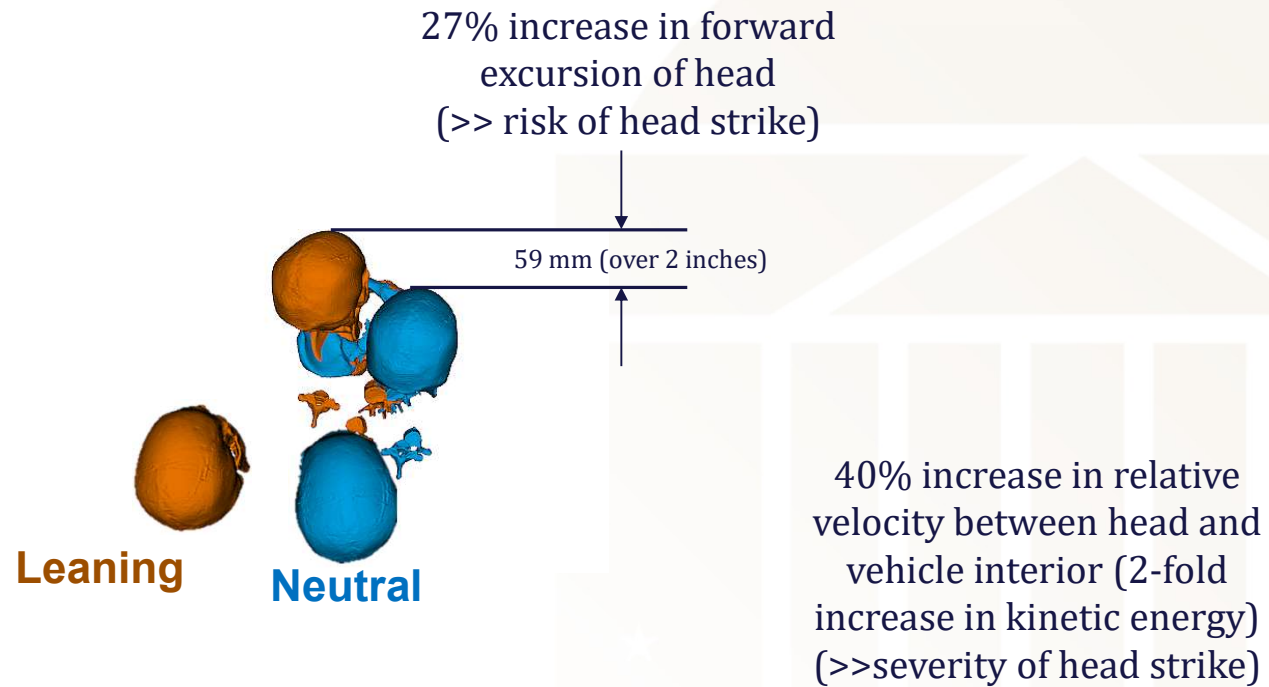
Top View

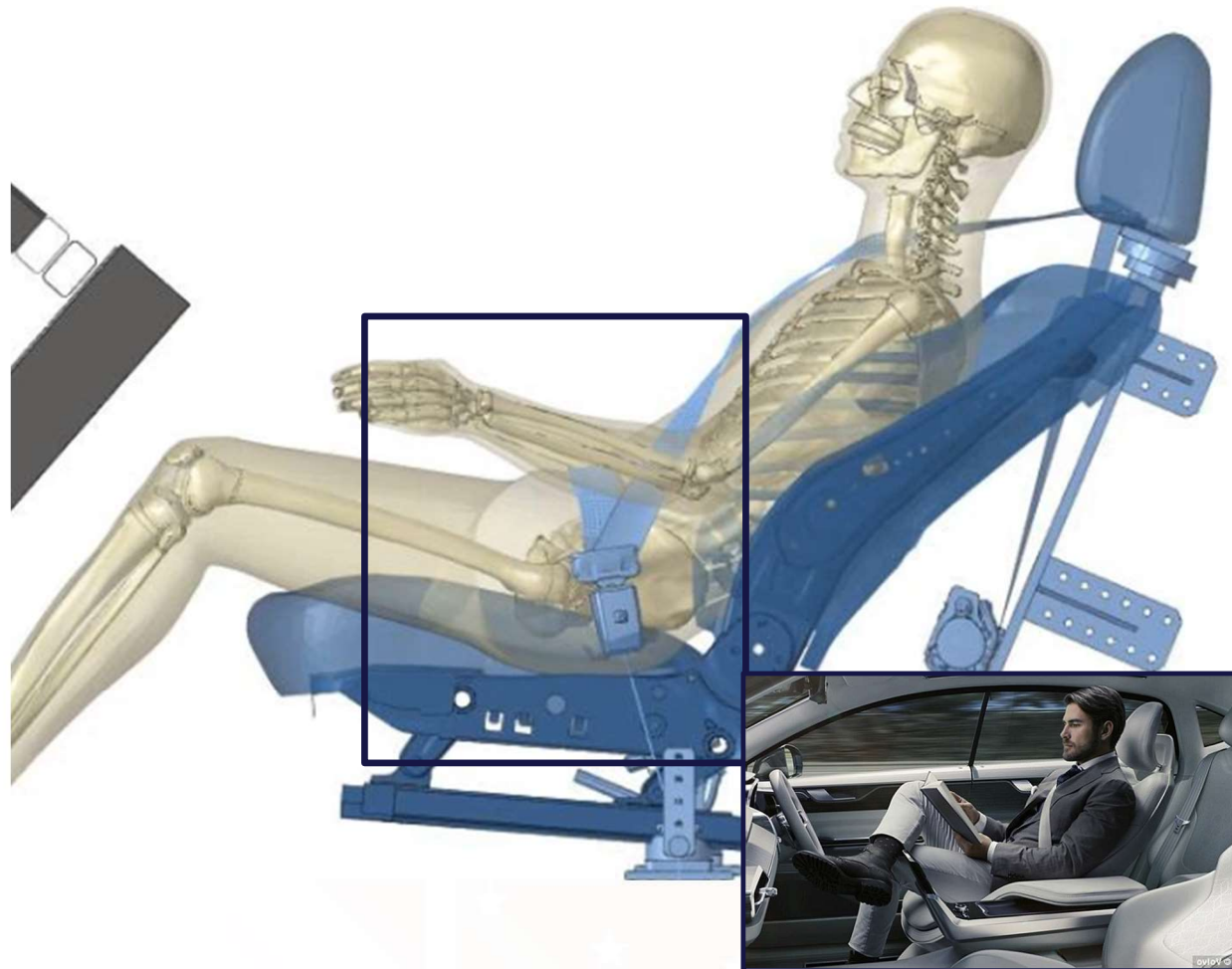
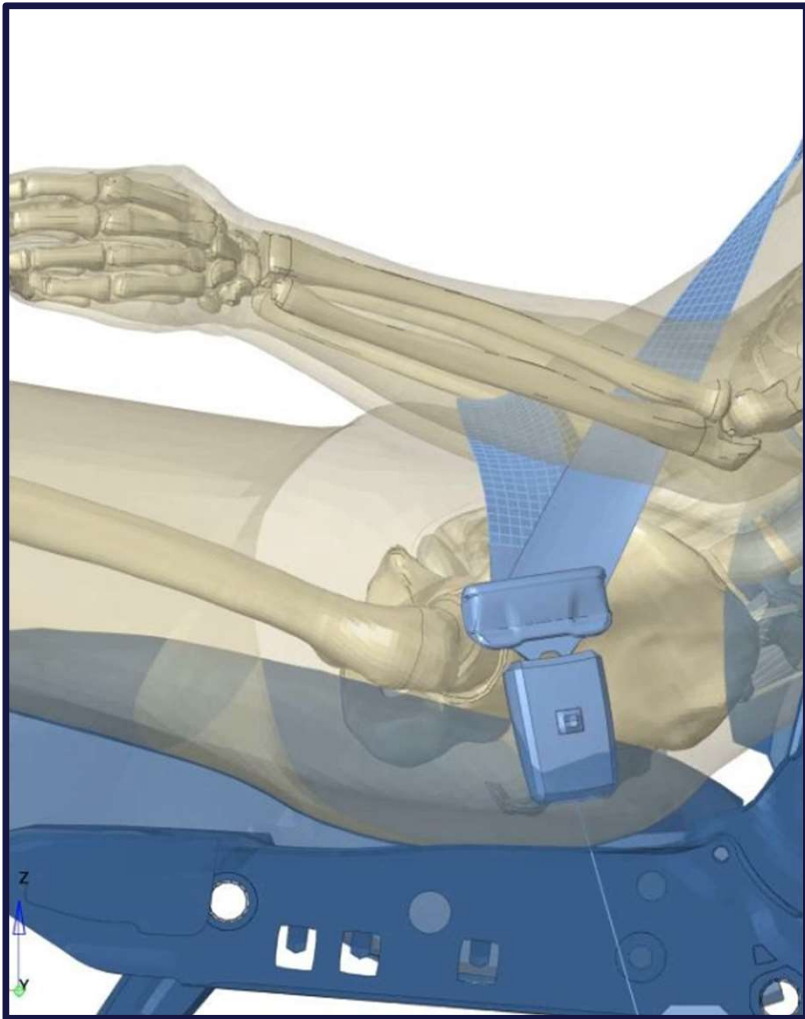


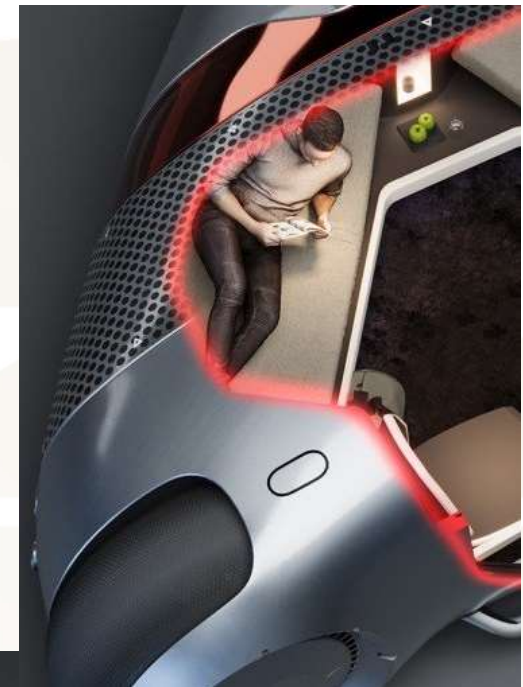
Top View



Top View





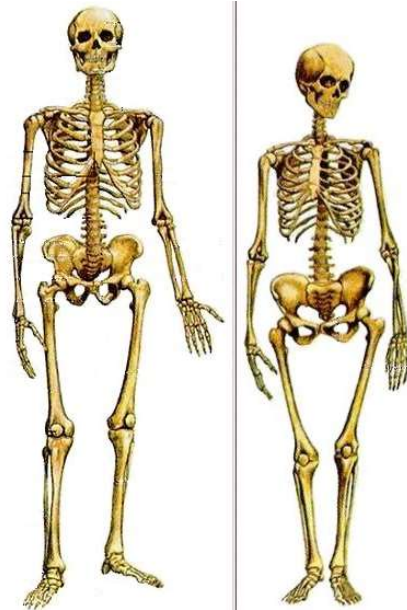


Customization and low-hanging fruit

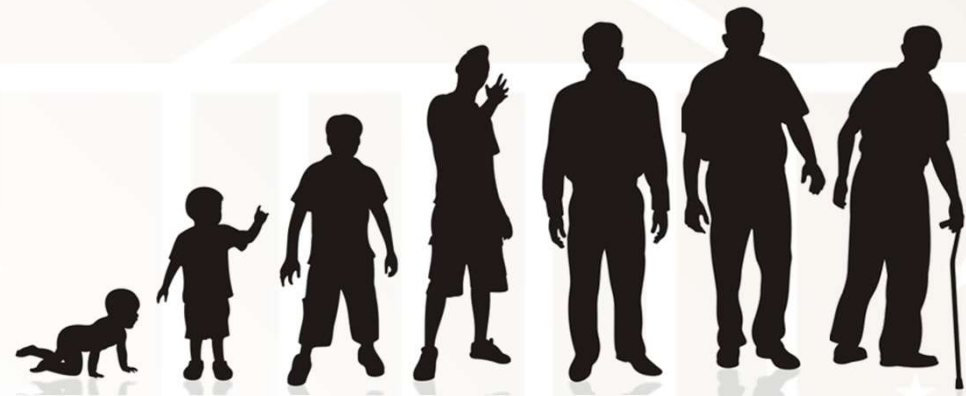
Body Shape



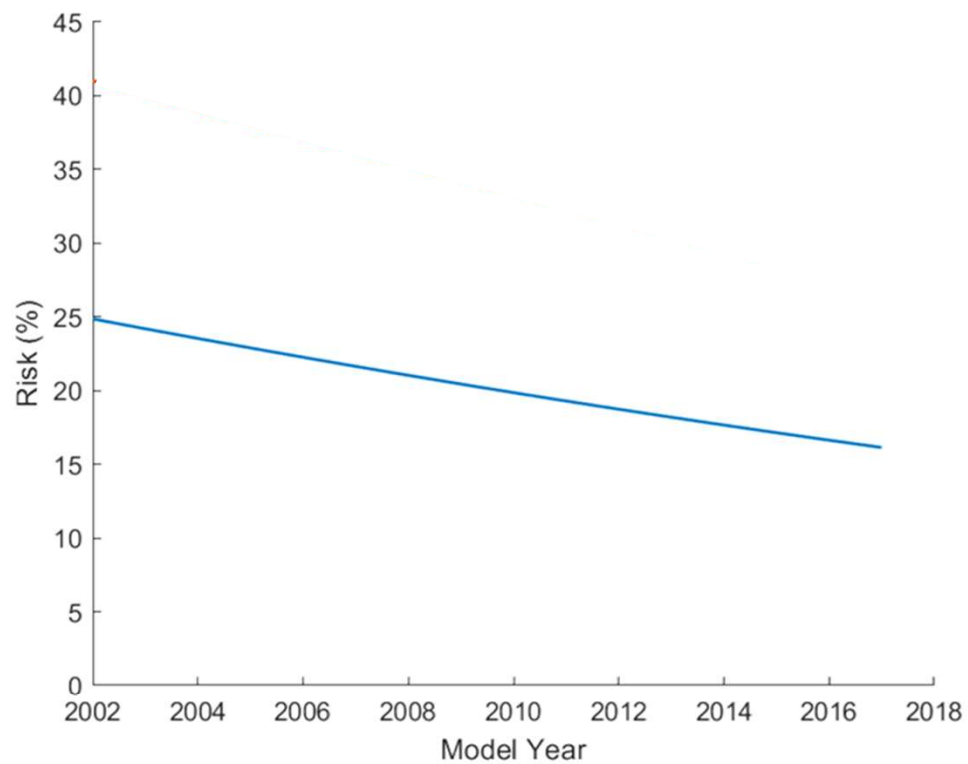
Sex



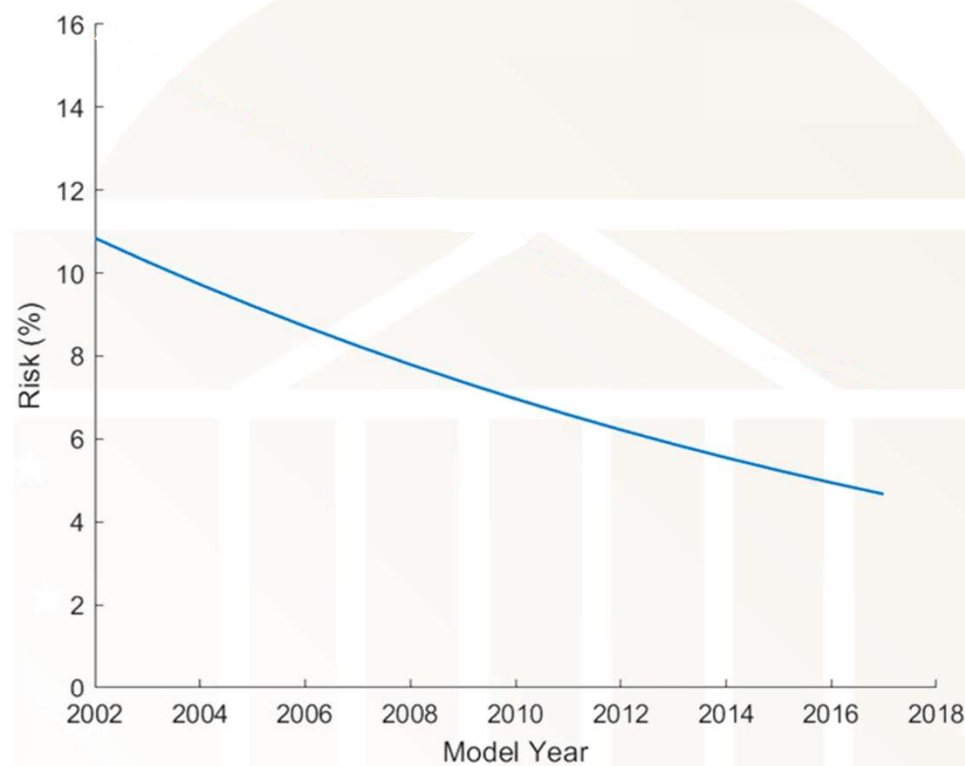
Age and condition



Risk of Moderate Injury

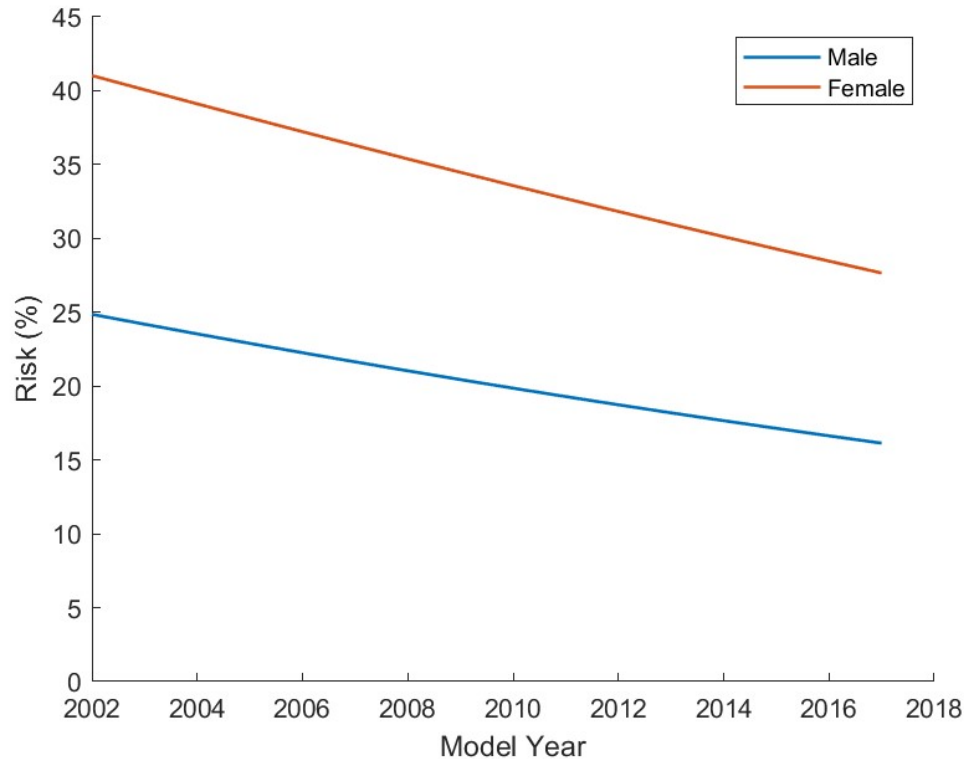


Risk of Severe Injury

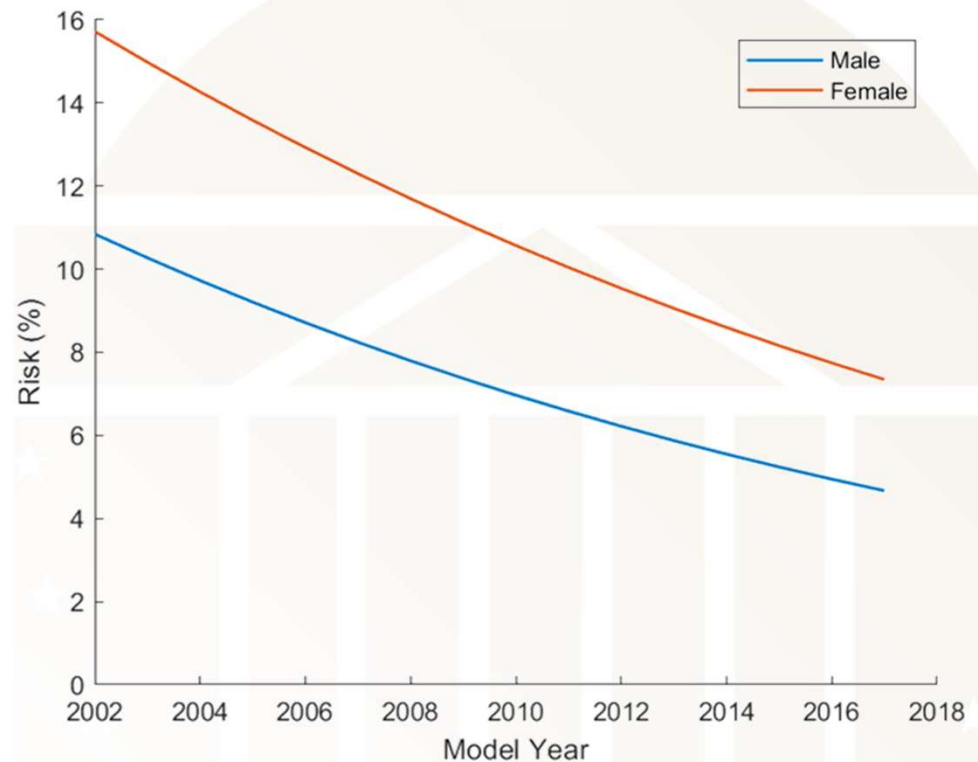


Frontal, belted, 56 km/h, 50 years old, male. Forman et al. (2019)

Risk of Moderate Injury



Risk of Severe Injury



Frontal, belted, 56 km/h, 50 years old, male and female. Forman et al. (2019)

Disclaimer: the causes of this are multifaceted and poorly understood (men drive systematically heavier vehicles, women wear systematically different clothing, etc.), but....

Greatest sex disparity is in lower severity injuries in lower-speed crashes (both historically understudied)

Odds ratios for different head injuries

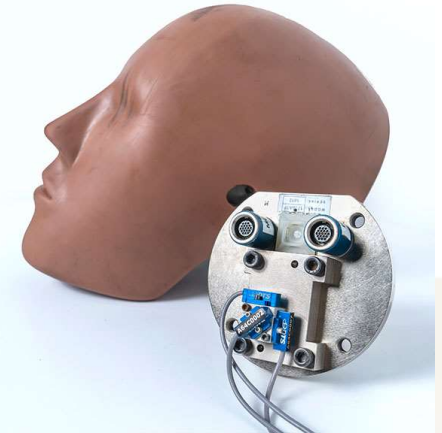
Body Region	Sex Female	
Skull AIS 2+	0.50	N.S.
Moderate Brain	1.72	p<0.05

Frontal impacts with belted occupants.
NASS-CDS/CISS 1998-2018.
Pre-publication findings; personal
communication, Forman et al. For
discussion only; do not cite.

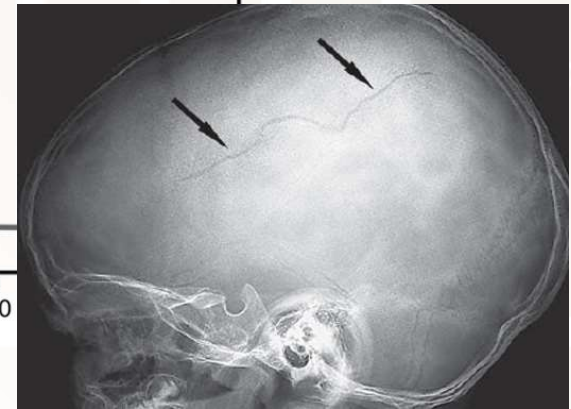
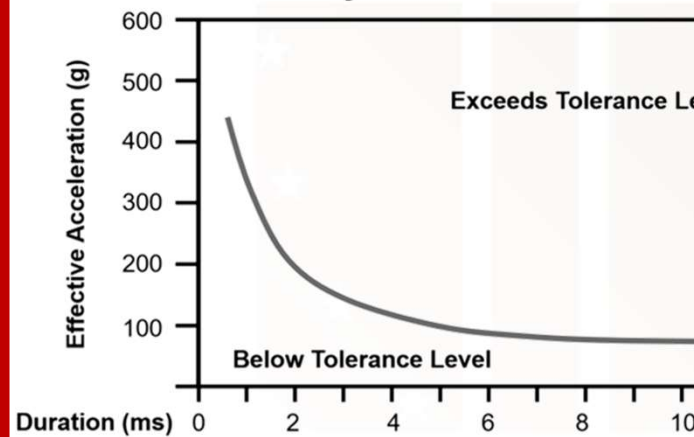


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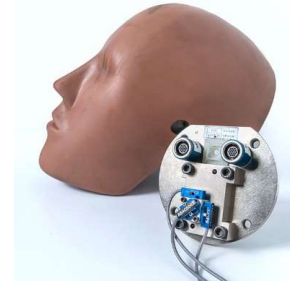


Wayne State Tolerance Curve

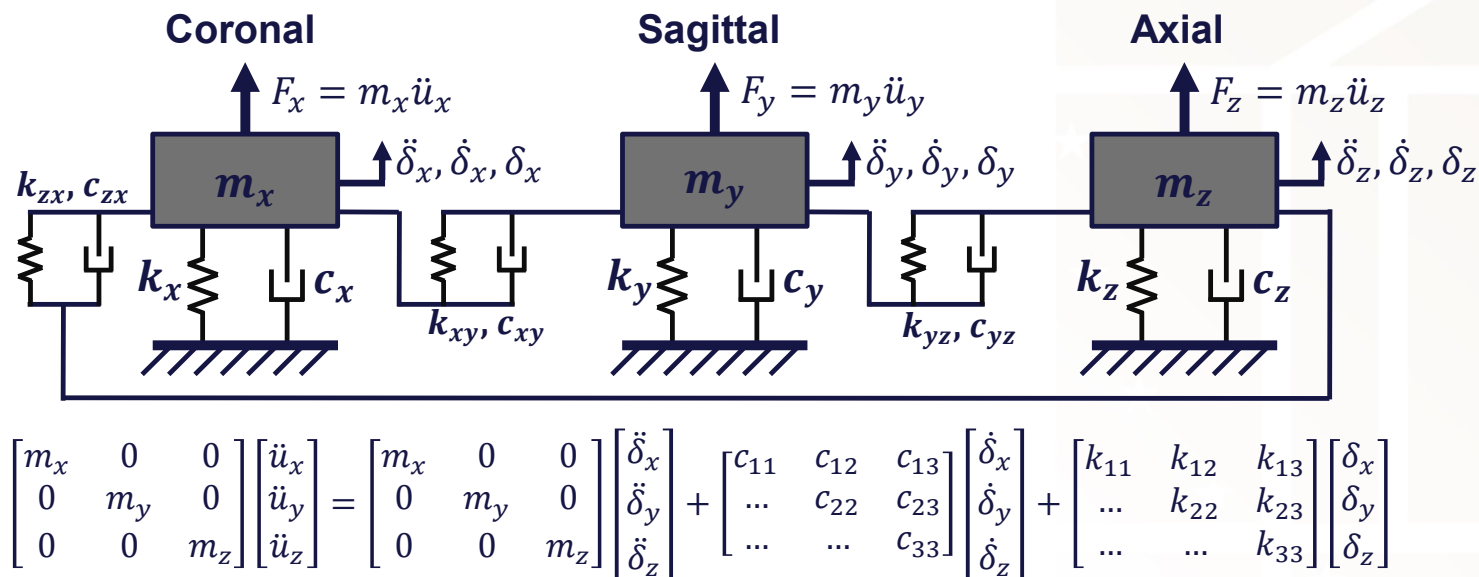


Frontal impacts with belted occupants.
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$$UBrIC = \left\{ \sum_i \left[\omega_i^* + (\alpha_i^* - \omega_i^*) e^{-\frac{\alpha_i^*}{\omega_i^*}} \right]^2 \right\}^{\frac{1}{2}}$$

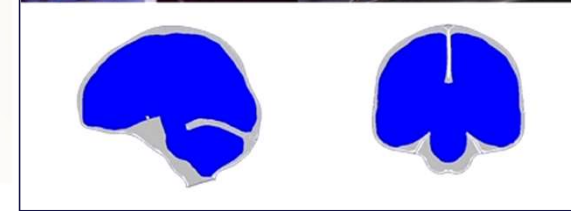
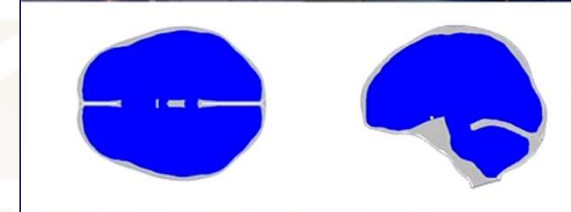
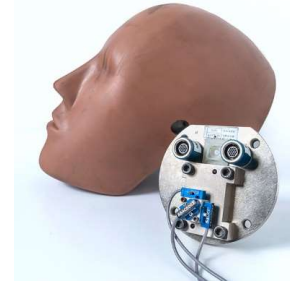


DAMAGE: *Diffuse Axonal, Multi Axis, General Evaluation*

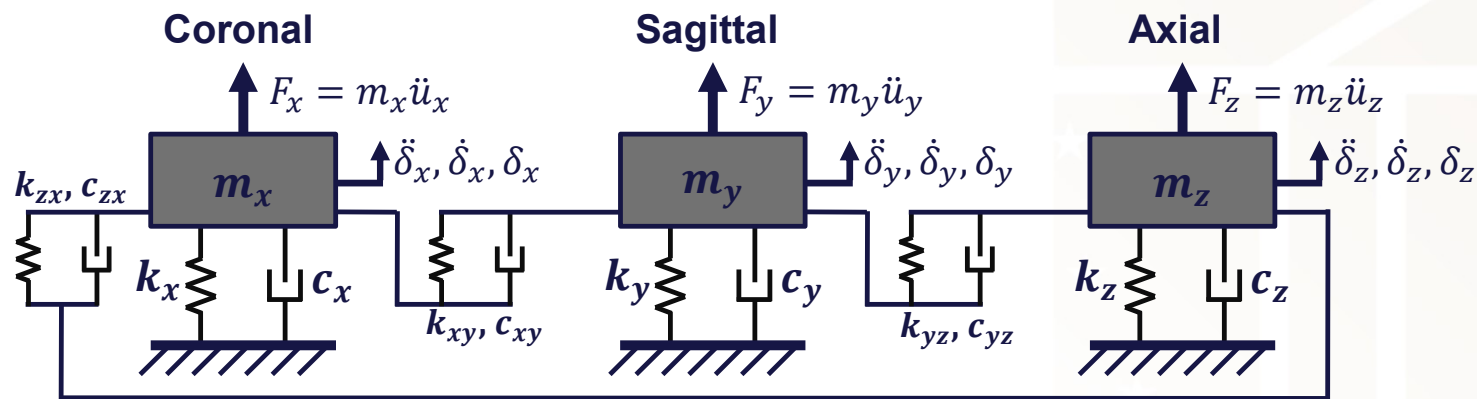


Gabler et al., 2018; Gabler et al., 2019

$$UBrIC = \left\{ \sum_i \left[\omega_i^* + (\alpha_i^* - \omega_i^*) e^{-\frac{\alpha_i^*}{\omega_i^*}} \right]^2 \right\}^{\frac{1}{2}}$$

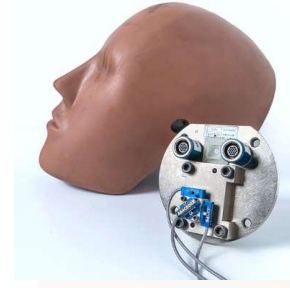


DAMAGE: Diffuse Axonal, Multi Axis, General Evaluation

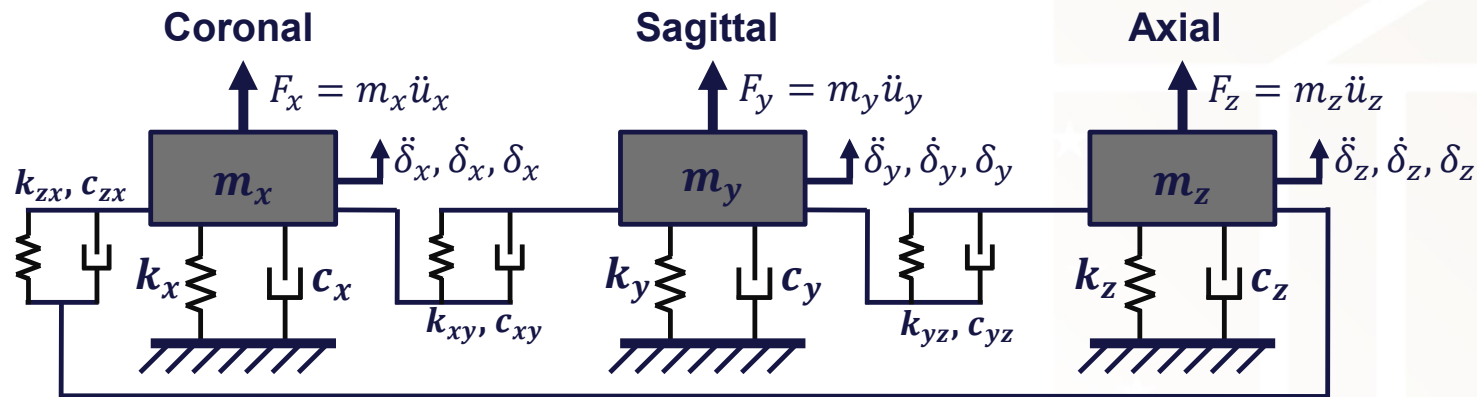


$$\begin{bmatrix} m_x & 0 & 0 \\ 0 & m_y & 0 \\ 0 & 0 & m_z \end{bmatrix} \begin{bmatrix} \ddot{u}_x \\ \ddot{u}_y \\ \ddot{u}_z \end{bmatrix} = \begin{bmatrix} m_x & 0 & 0 \\ 0 & m_y & 0 \\ 0 & 0 & m_z \end{bmatrix} \begin{bmatrix} \ddot{\delta}_x \\ \ddot{\delta}_y \\ \ddot{\delta}_z \end{bmatrix} + \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ \dots & c_{22} & c_{23} \\ \dots & \dots & c_{33} \end{bmatrix} \begin{bmatrix} \dot{\delta}_x \\ \dot{\delta}_y \\ \dot{\delta}_z \end{bmatrix} + \begin{bmatrix} k_{11} & k_{12} & k_{13} \\ \dots & k_{22} & k_{23} \\ \dots & \dots & k_{33} \end{bmatrix} \begin{bmatrix} \delta_x \\ \delta_y \\ \delta_z \end{bmatrix}$$

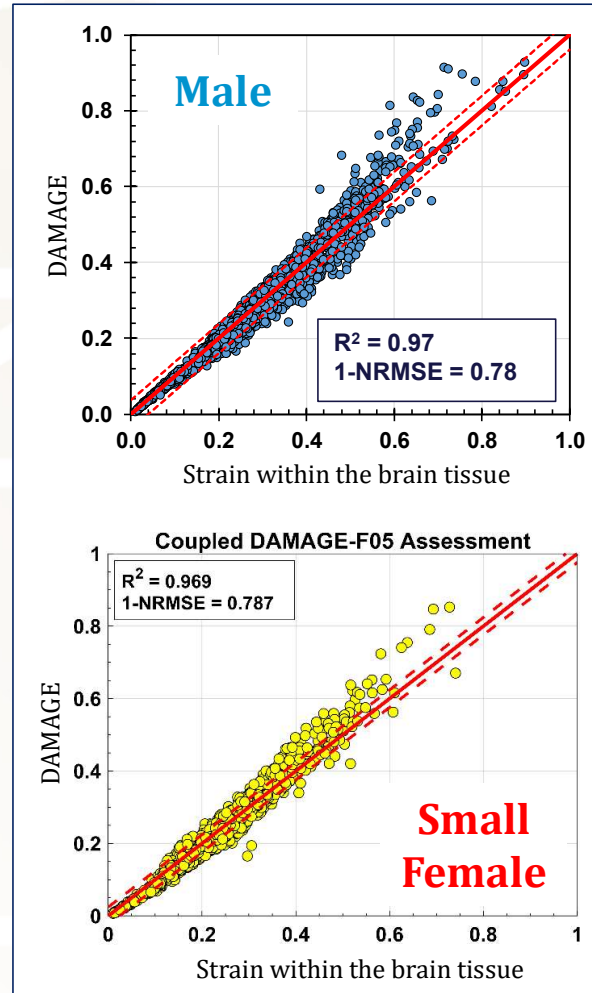
$$UBrIC = \left\{ \sum_i \left[\omega_i^* + (\alpha_i^* - \omega_i^*) e^{-\frac{\alpha_i^*}{\omega_i^*}} \right]^2 \right\}^{\frac{1}{2}}$$



DAMAGE: Diffuse Axonal, Multi Axis, General Evaluation

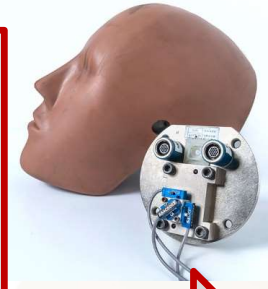


$$\begin{bmatrix} m_x & 0 & 0 \\ 0 & m_y & 0 \\ 0 & 0 & m_z \end{bmatrix} \begin{bmatrix} \ddot{u}_x \\ \ddot{u}_y \\ \ddot{u}_z \end{bmatrix} = \begin{bmatrix} m_x & 0 & 0 \\ 0 & m_y & 0 \\ 0 & 0 & m_z \end{bmatrix} \begin{bmatrix} \ddot{\delta}_x \\ \ddot{\delta}_y \\ \ddot{\delta}_z \end{bmatrix} + \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ \dots & c_{22} & c_{23} \\ \dots & \dots & c_{33} \end{bmatrix} \begin{bmatrix} \dot{\delta}_x \\ \dot{\delta}_y \\ \dot{\delta}_z \end{bmatrix} + \begin{bmatrix} k_{11} & k_{12} & k_{13} \\ \dots & k_{22} & k_{23} \\ \dots & \dots & k_{33} \end{bmatrix} \begin{bmatrix} \delta_x \\ \delta_y \\ \delta_z \end{bmatrix}$$

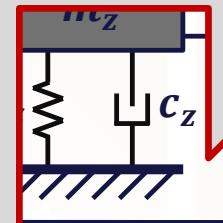


DAMAGE is already measured by EuroNCAP in their new car assessments (“5-star crash rating”)

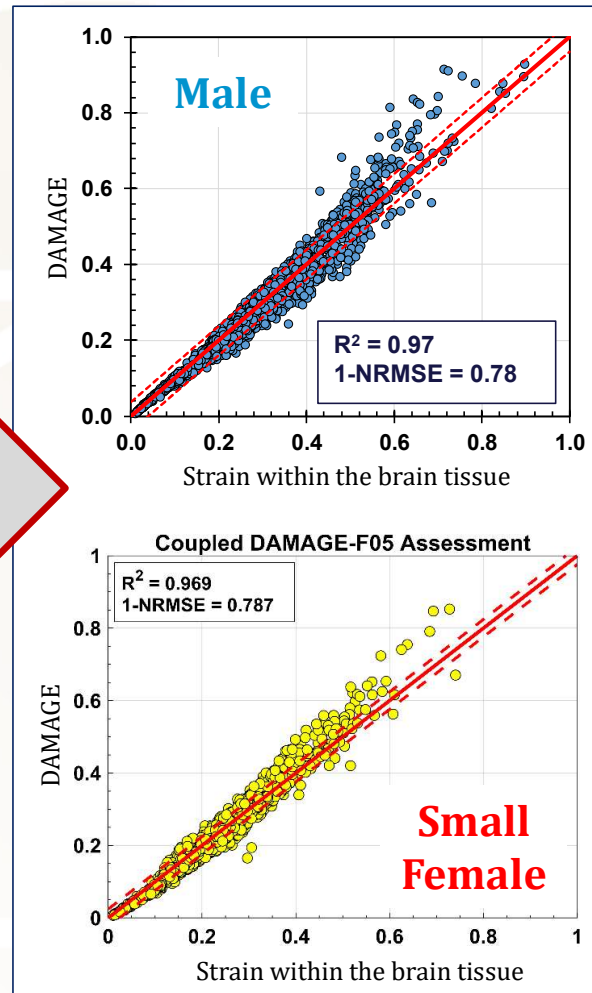
Small-female DAMAGE was developed in collaboration with the Insurance Institute for Highway Safety, who publishes one of the most influential vehicle rating systems (“IIHS Top Safety Pick”)



al Evaluation



$$\begin{bmatrix} 1 & k_{12} & k_{13} \\ & k_{22} & k_{23} \\ & \dots & k_{33} \end{bmatrix} \begin{bmatrix} \delta_x \\ \delta_y \\ \delta_z \end{bmatrix}$$





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