Analysing Bicycle Accidents with Human Body Models

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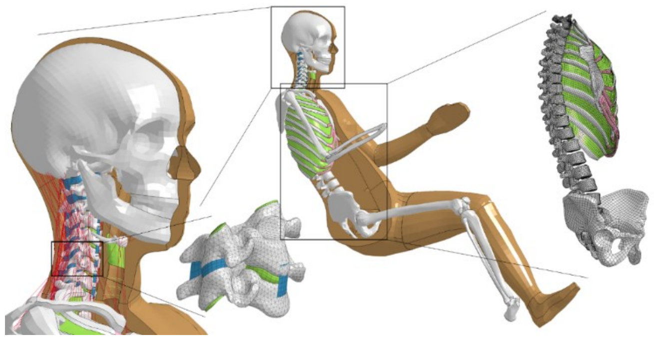
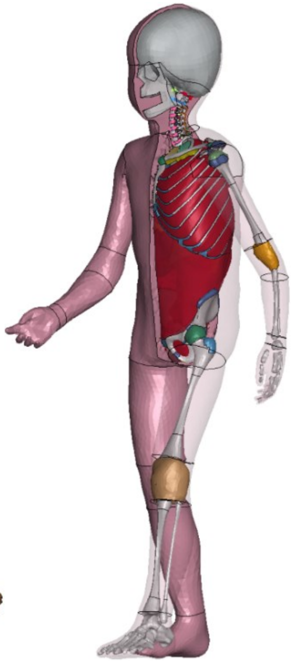
- Single-bicycle accidents most common
  - E.g. Sweden more than 70 % of all injuries
- Majority of fatalities from accident between bicycle and motor vehicles
- Relatively small portion neck injuries
  - Large risk of permanent medical impairment
- The Hövding
  - An inflatable head protection worn as a scarf around the neck
  - Can the airbag portion supporting the neck protect from injuries?

www.hovding.se

- Human Body Models (HBMs)
  - Developed during the past 20 years
  - Accepted tool in the automotive research and development
  - Used to represent the human response to impact loading
  - Many variation of HBMs
    - Children, adults, elderly, male, female, etc.

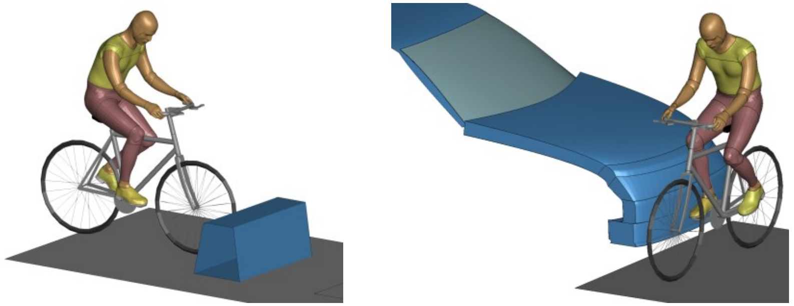





- Method for analysing bicycle accidents with HBMs
  - Funding by Skyltfonden

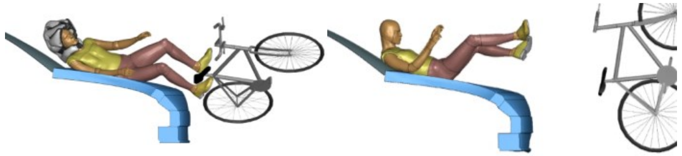
Projektet är genomfört med ekonomiskt stöd från Trafikverkets skyltfond. Ståndpunkter, slutsatser och arbetsmetoder i rapporten reflekterar författaren och överensstämmer inte med nödvändighet med Trafikverkets ståndpunkter, slutsatser och arbetsmetoder inom rapportens ämnesområde

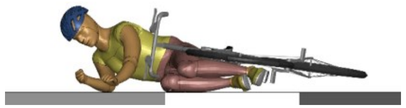
- Aim
  - Simulate multiple accident scenarios
  - Identify representative scenarios for evaluation of neck protection devices



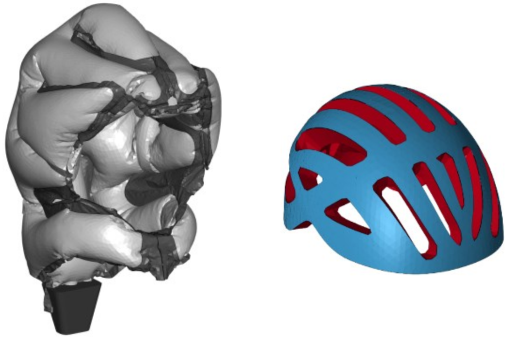
  - Use case: evaluate effect of Hövding on neck injury protection

- Positioning the HBM on a bicycle model



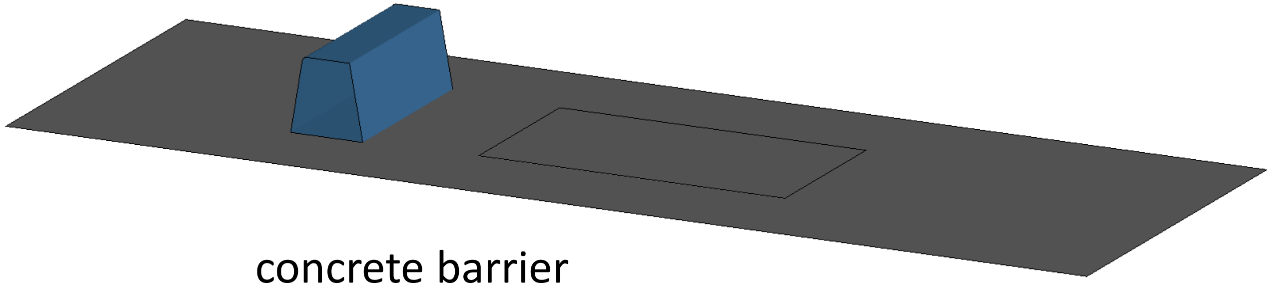


- Simulation of 20 accident scenarios
  - Comparison to 5 stunt person experiments
  - Assessment of neck and head injuries
  - Selection of 5 representative scenarios



- Use case: Evaluation of protective devices
  - A detailed Hövding model
  - A conventional helmet

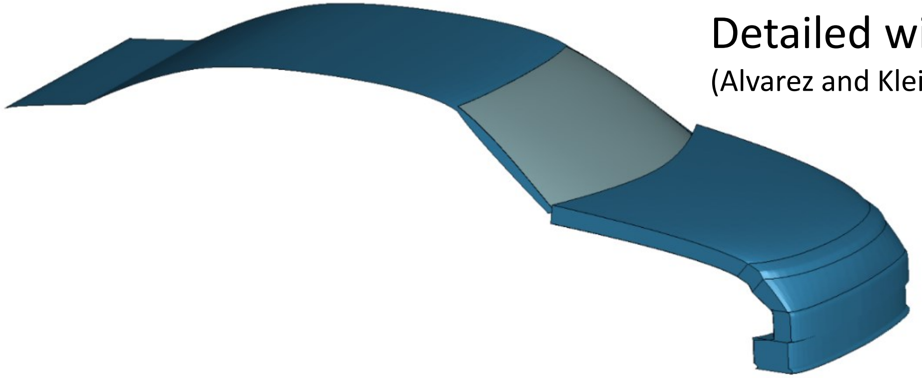
GHBMC M50-0 (Elemance LLC)



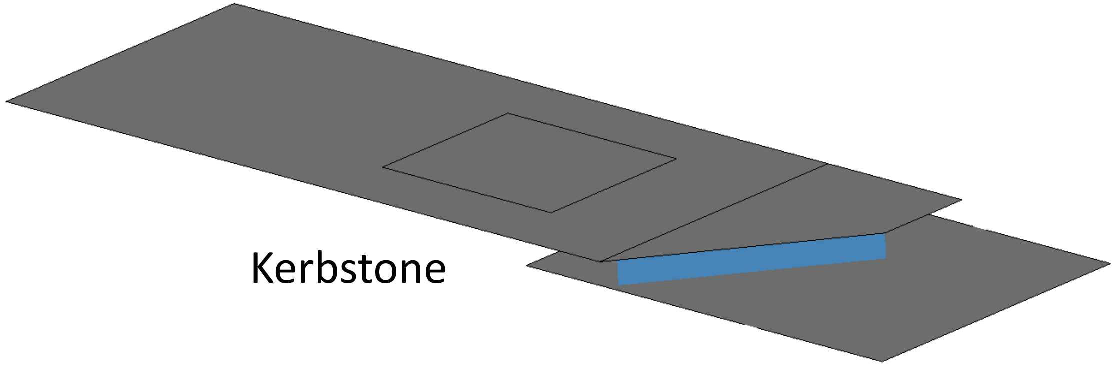
concrete barrier

EU project APROSYS

Euro NCAP (European New Car Assessment Programme)

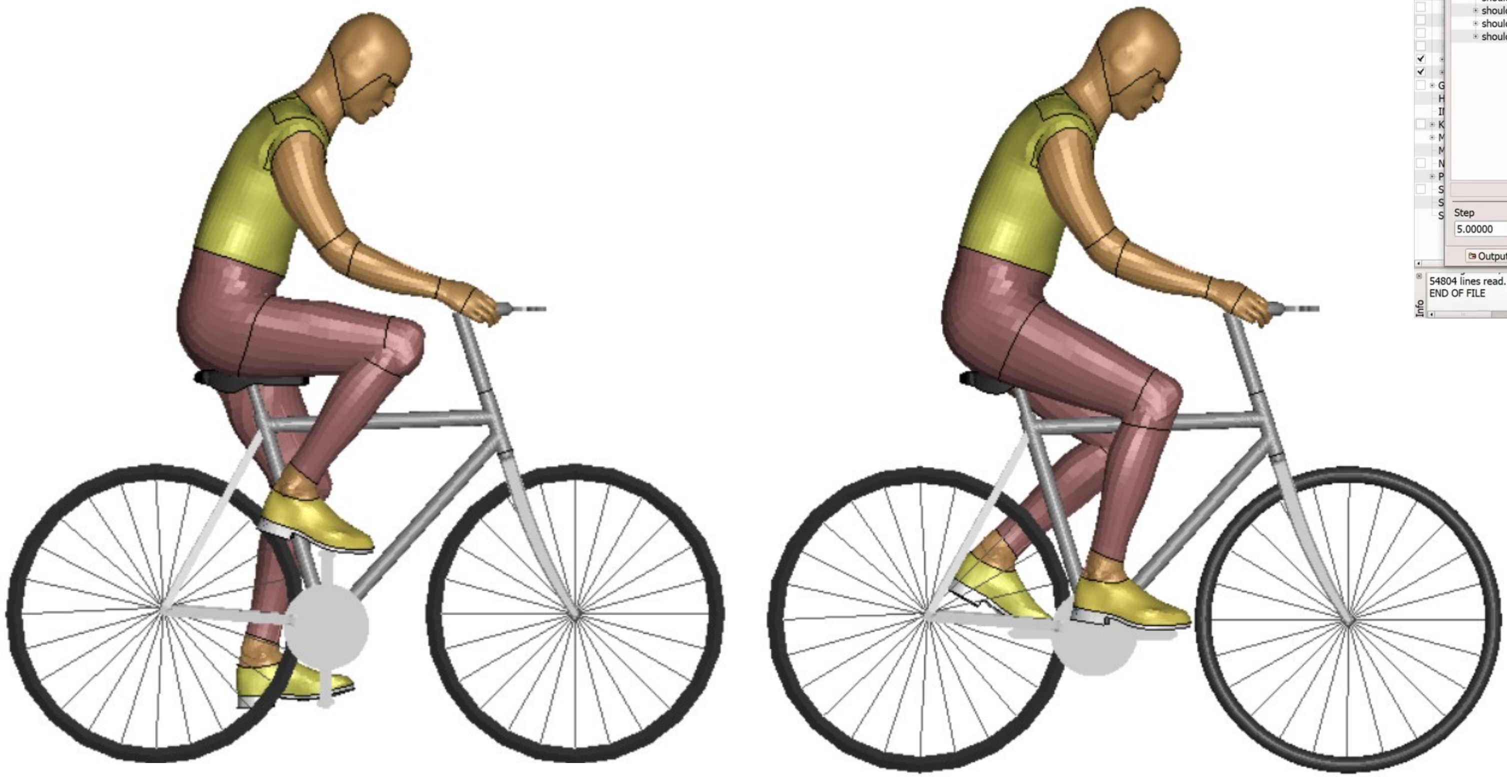


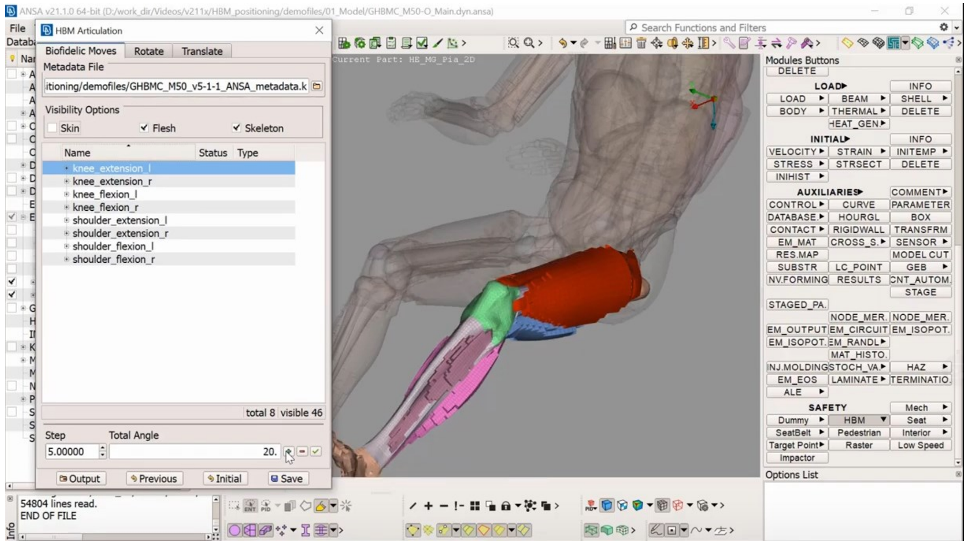
Detailed windscreen
(Alvarez and Kleiven, 2016)

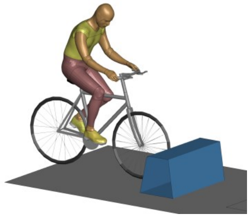


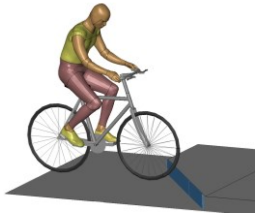
Kerbstone

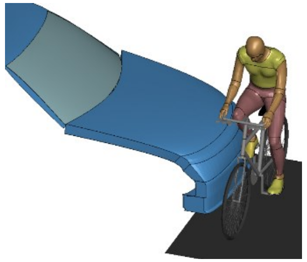
- GHBMC positioned using ANSA
  - Two pedal positions; vertical feet, horizontal feet
  - Additional deformation simulation of saddle

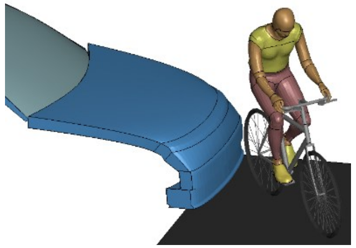


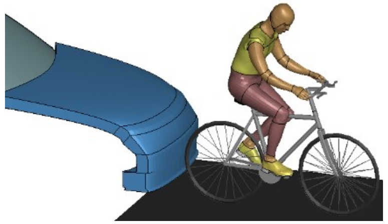






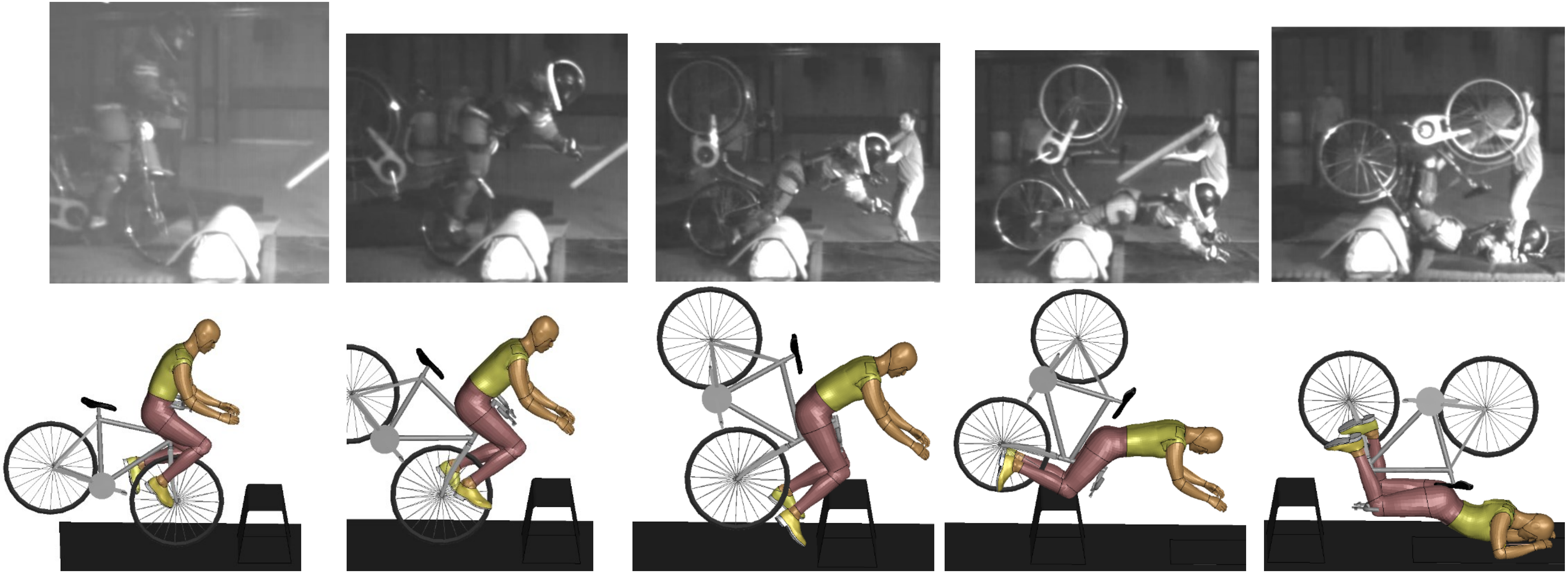




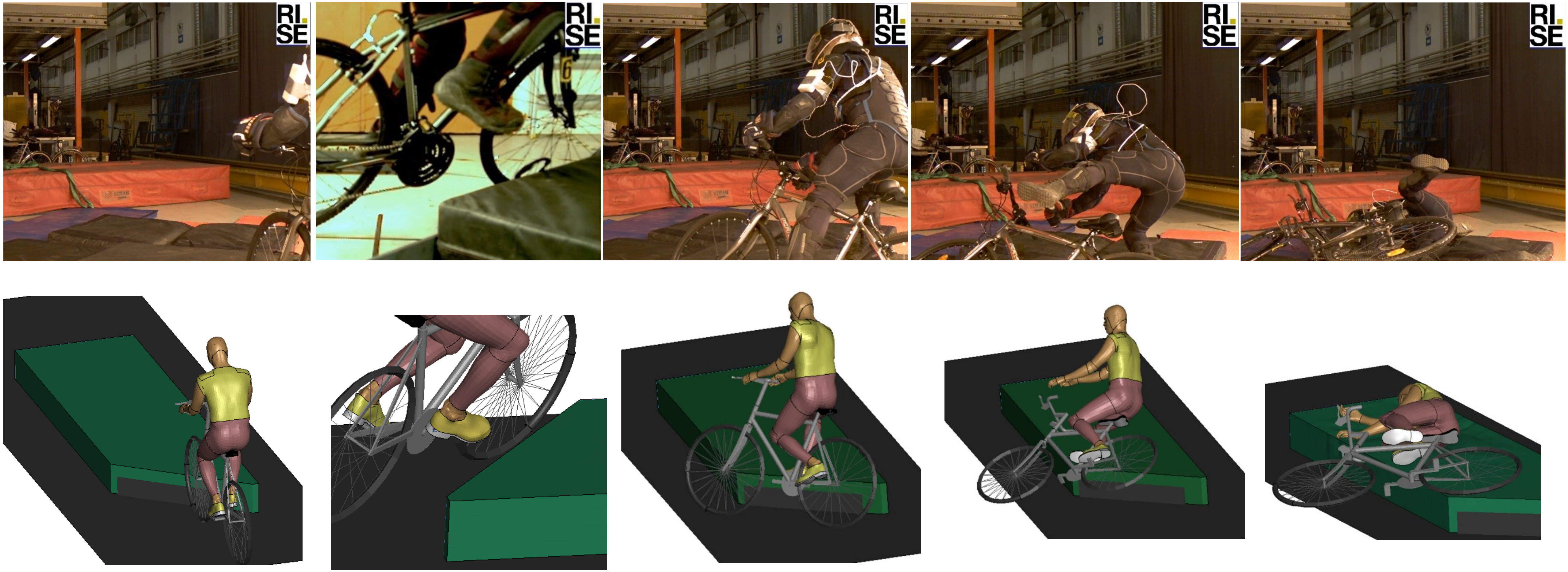


	10 km/h	20 km/h	30 km/h	40 km/h	50 km/h
Concrete barrier		Pedal position 1 & 2	Pedal position 2		
Kerbstone	Pedal position 2	Pedal position 2	Pedal position 2		
Car-to-bicycle collision: Side		Pedal position 1 & 2	Pedal position 1 & 2	Pedal position 2	Pedal position 1
Car-to-bicycle collision: Side rear/45 degrees	Pedal position 2	Pedal position 2	Pedal position 2	Pedal position 2	
Car-to-bicycle collision: Rear	Pedal position 2	Pedal position 2	Pedal position 2	Pedal position 2	Pedal position 2

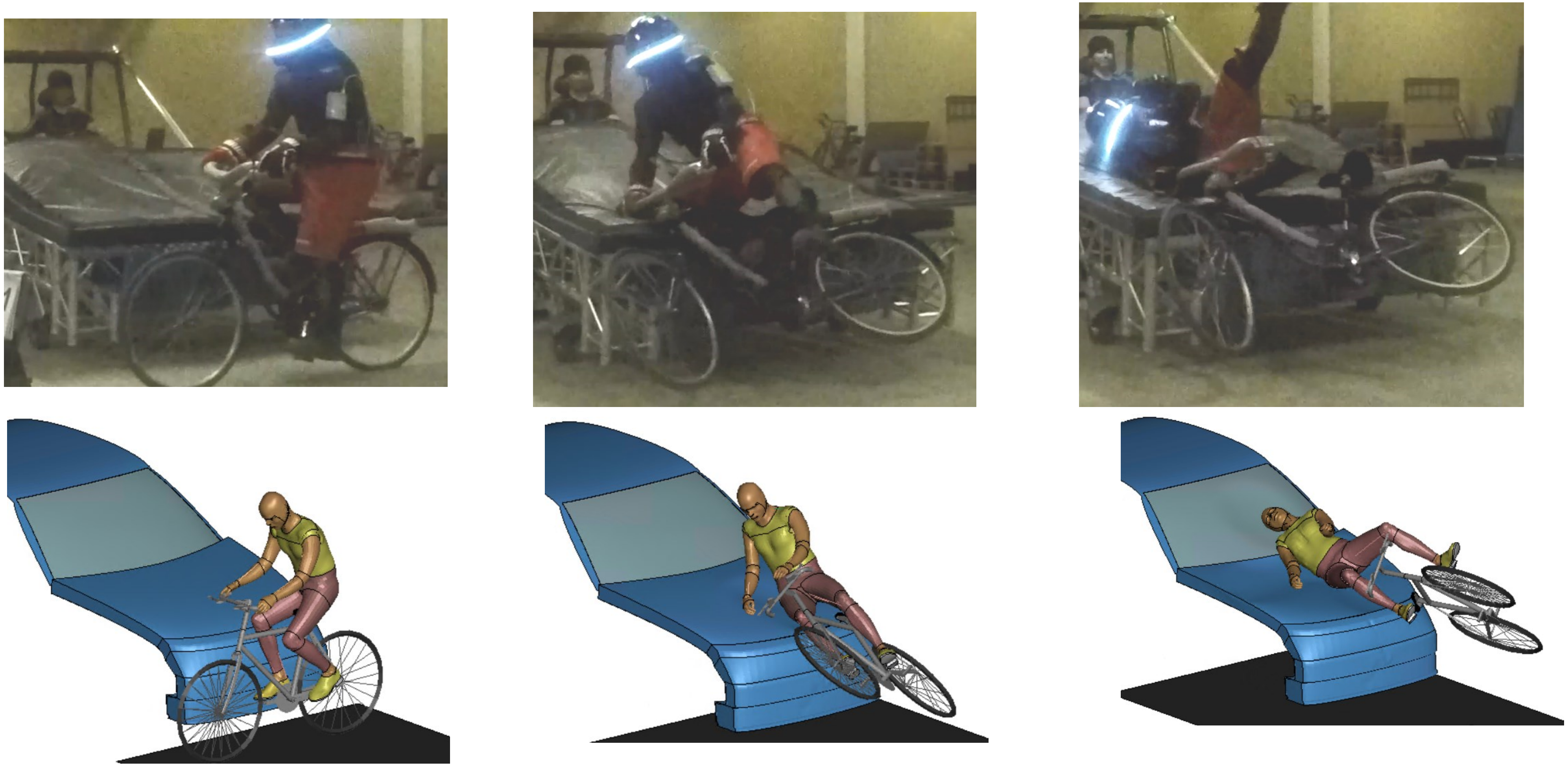
- Concrete barrier



- Kerbstone



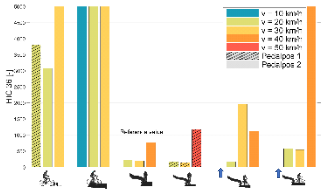
- Car-to-bicycle collision: Side



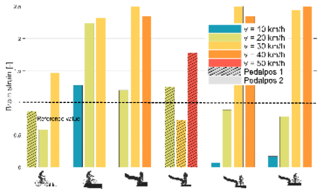
$v_c \approx 0$
$v = 17$

$v_c = 0$
$v = 20$

- Head injuries

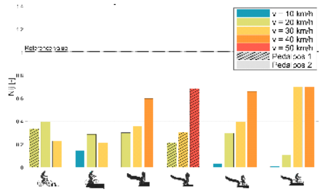


HIC - Function of linear acceleration

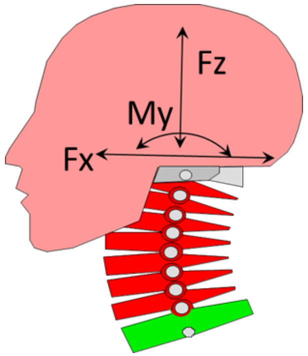


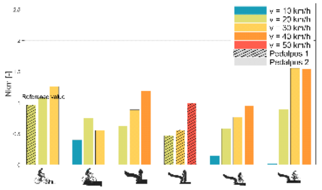
Brain tissue strain

- Neck injuries

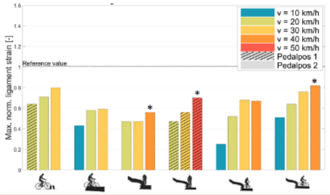


$$N_{km} = \frac{F_x}{F_{int}} + \frac{M_y}{M_{int}}$$



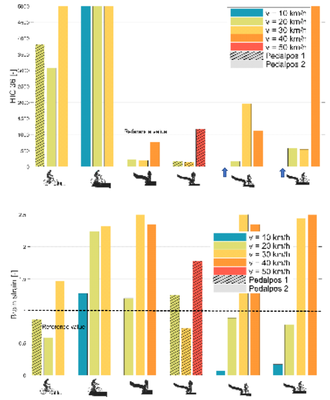


$$N_{ij} = \frac{F_z}{F_{int}} + \frac{M_y}{M_{int}}$$

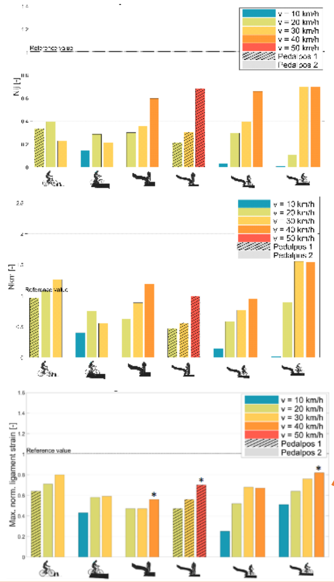


Ligament tension

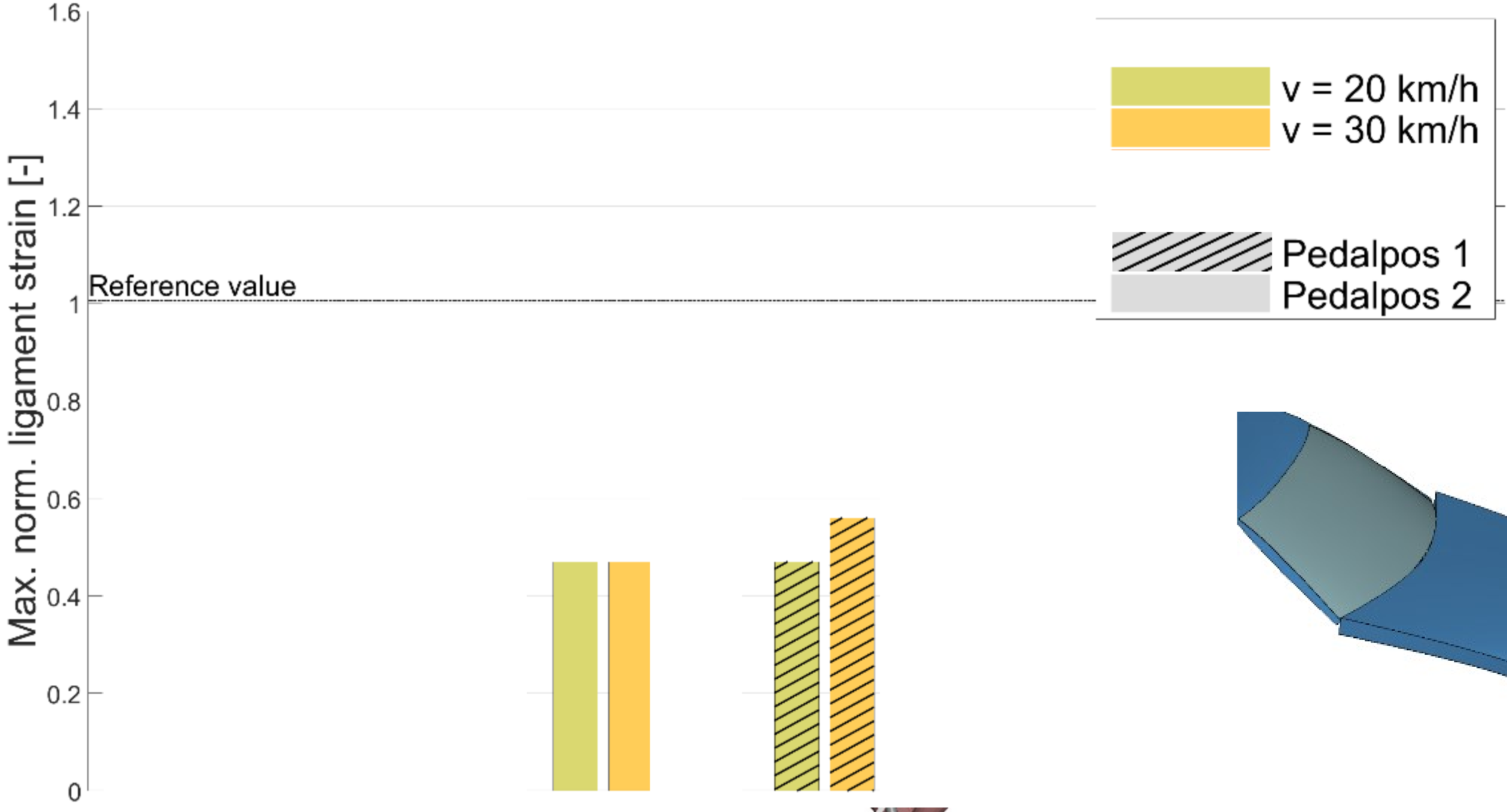
- Head injuries

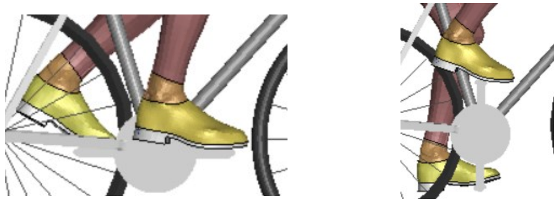


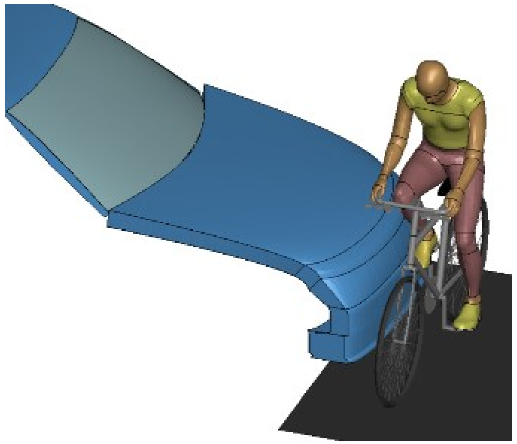
- Neck injuries



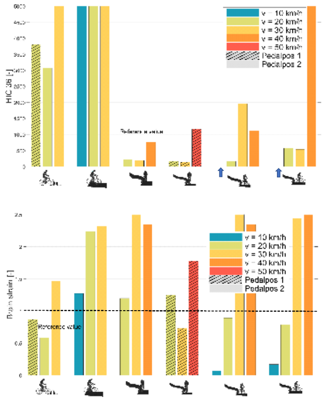
Effect of pedal position



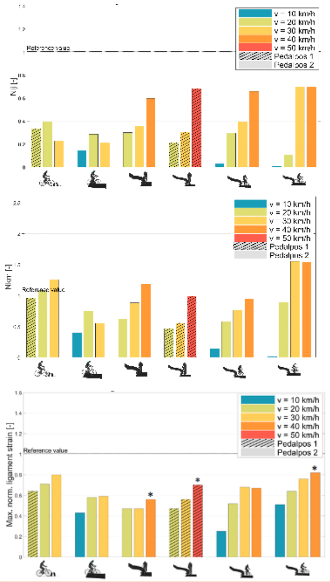




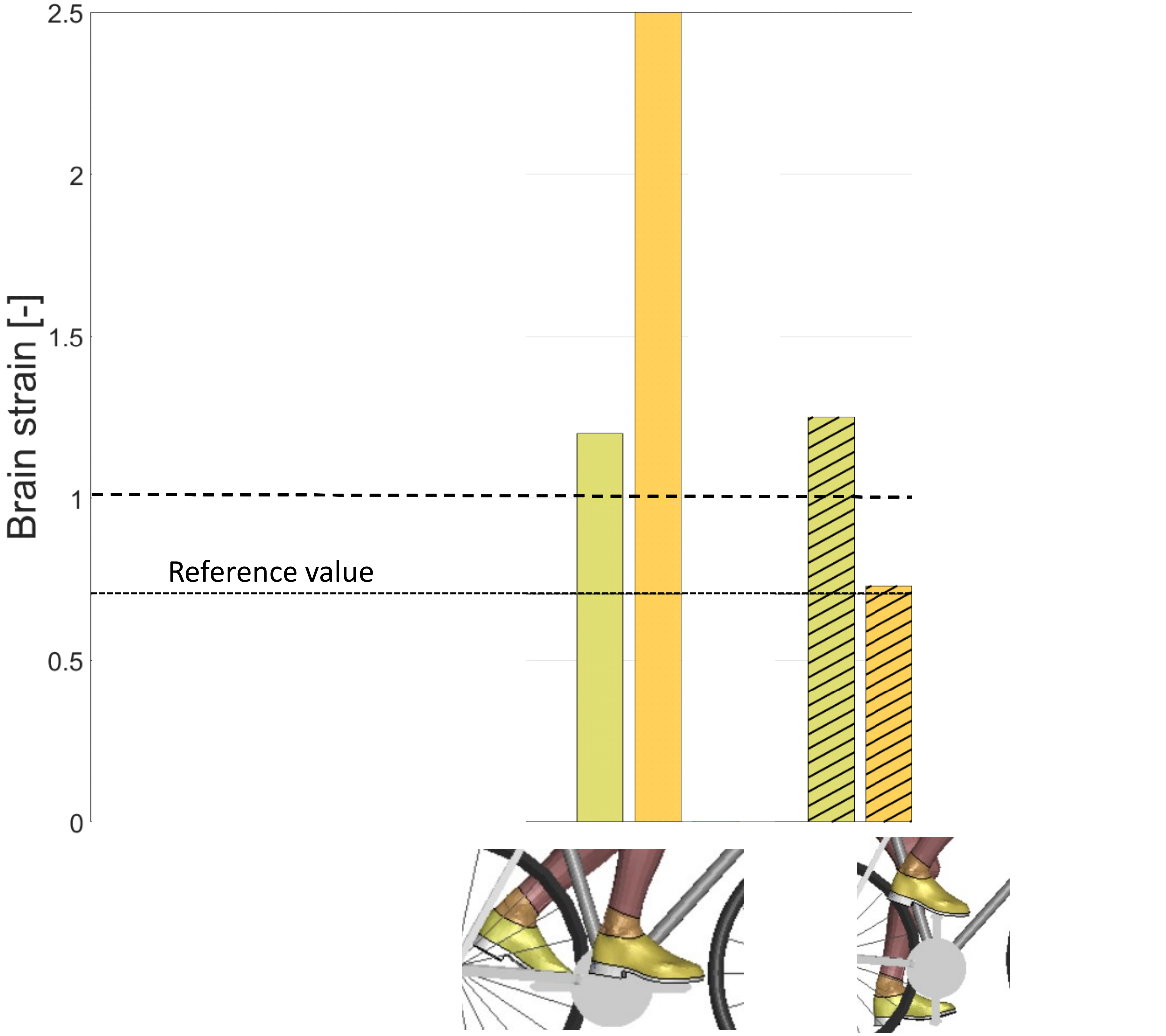
- # Head injuries

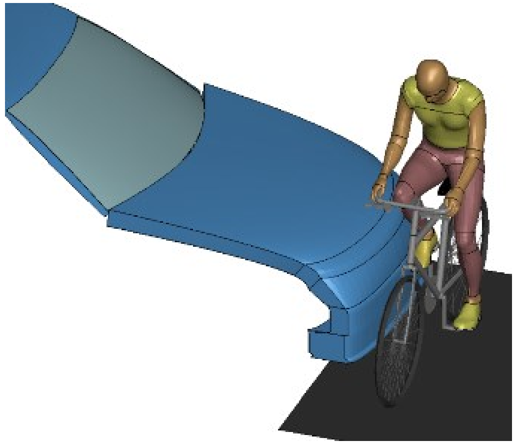


- # Neck injuries

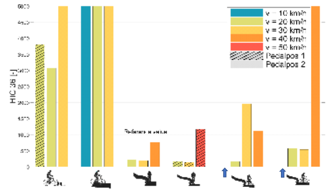


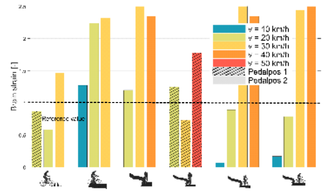
Effect of pedal position



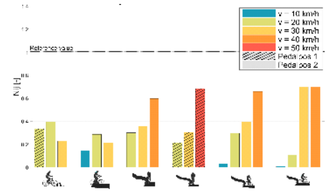


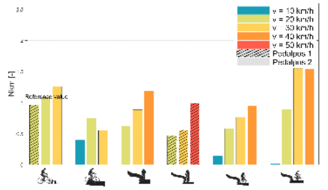
- Head injuries

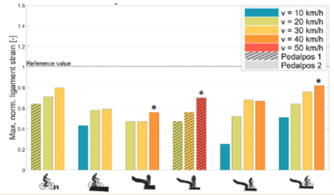




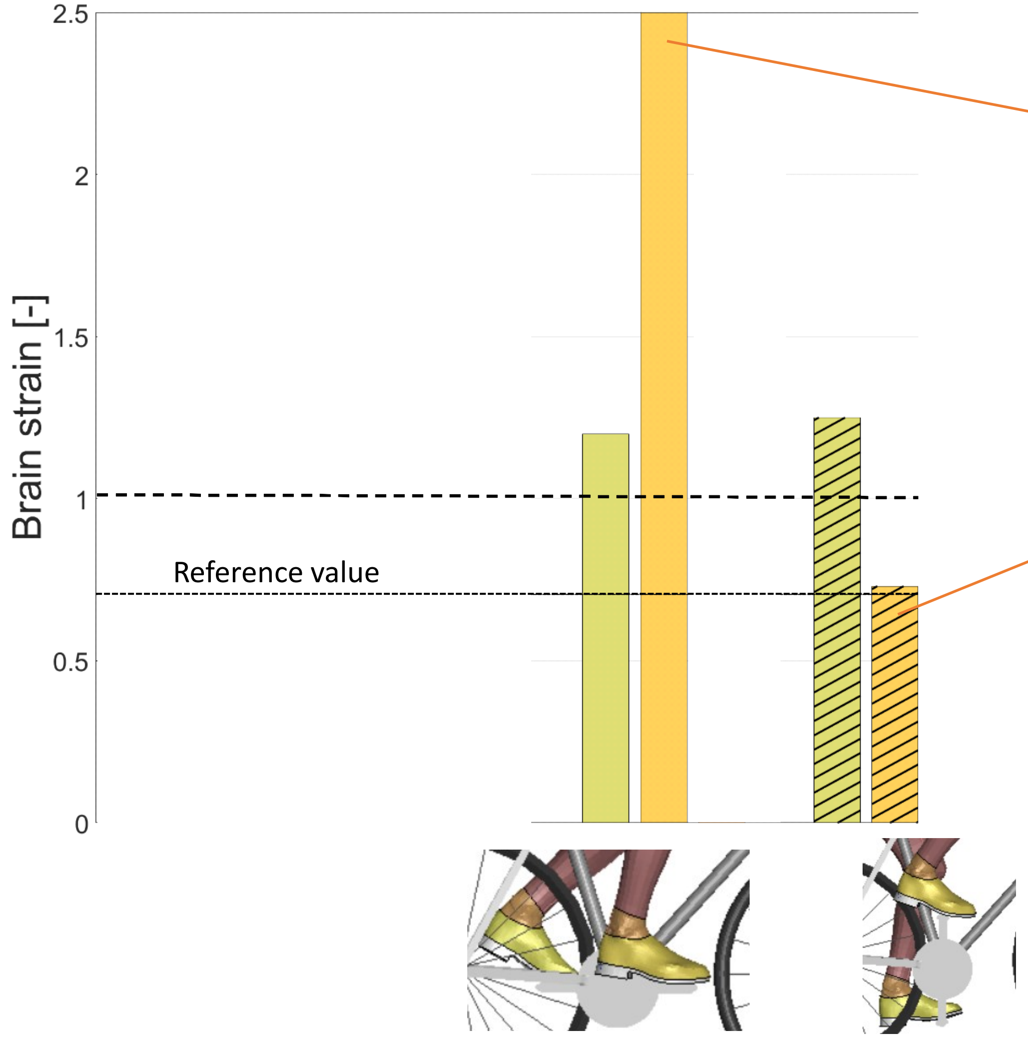
- Neck injuries



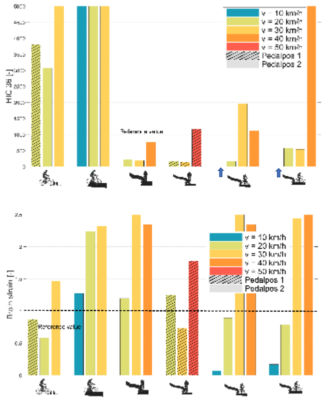




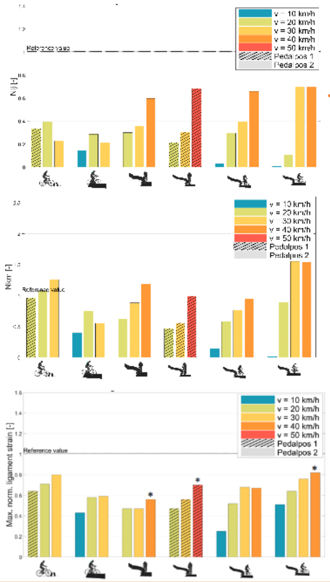
Effect of pedal position



- Head injuries



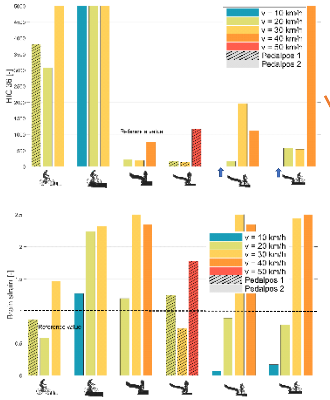
- Neck injuries



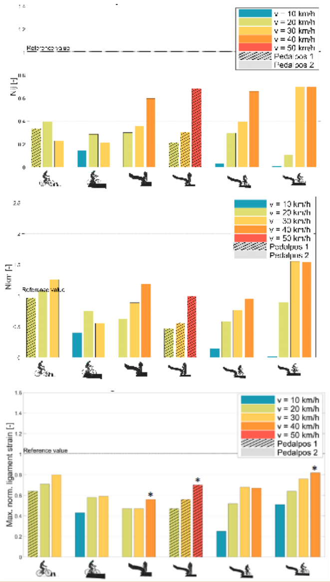
$$N_{ij} = \frac{F_z}{F_{int}} + \frac{M_y}{M_{int}}$$

Single accident vs car collision

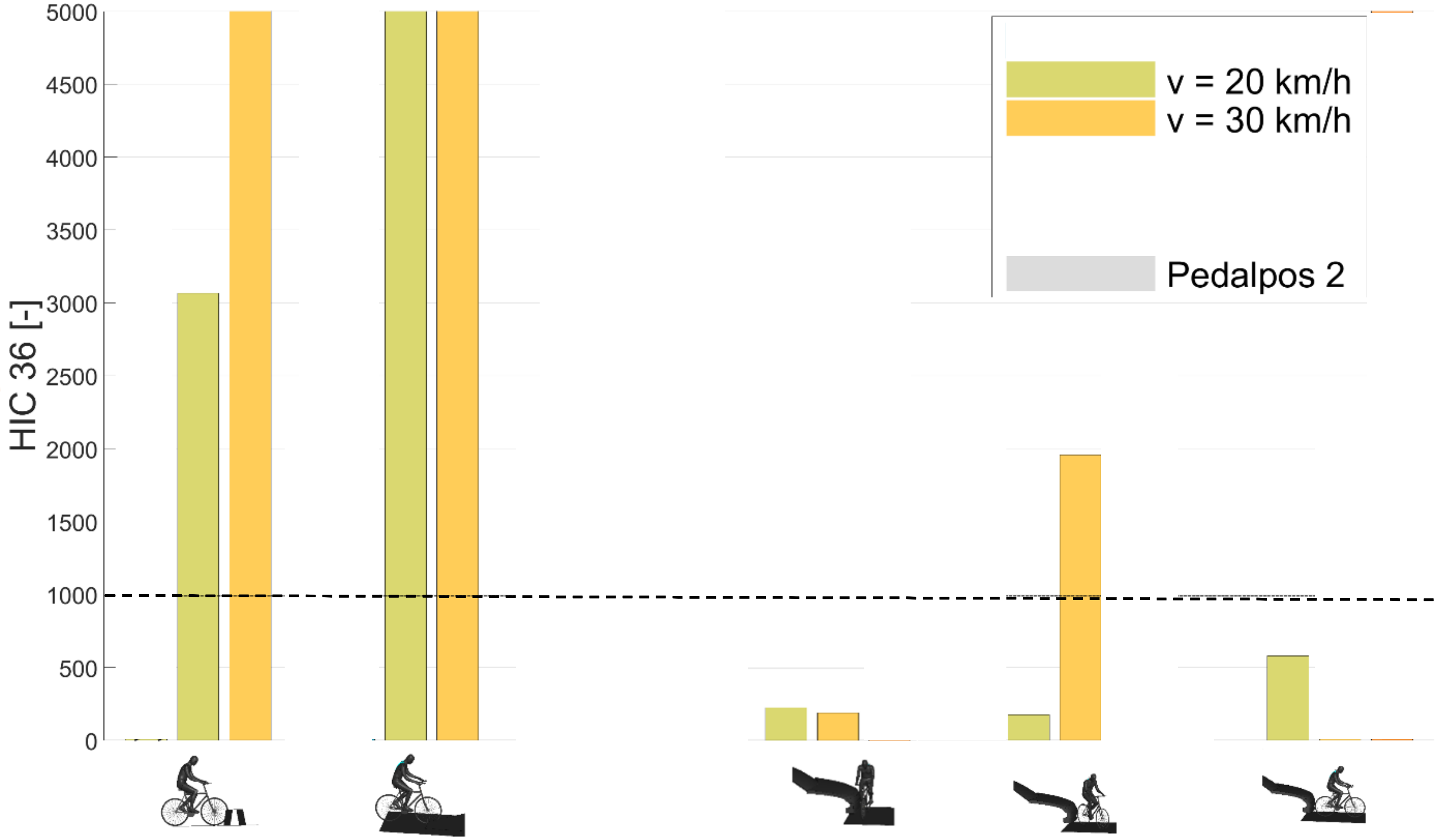
- Head injuries



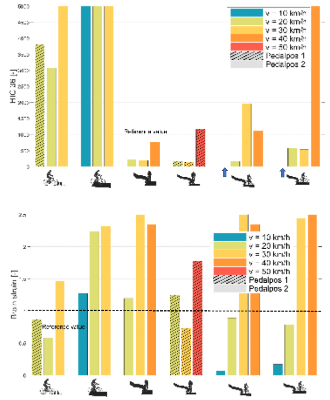
- Neck injuries



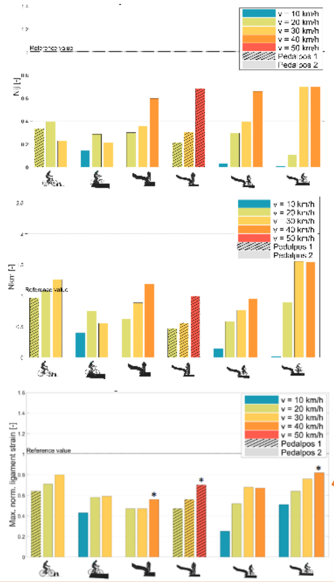
Single accident vs car collision



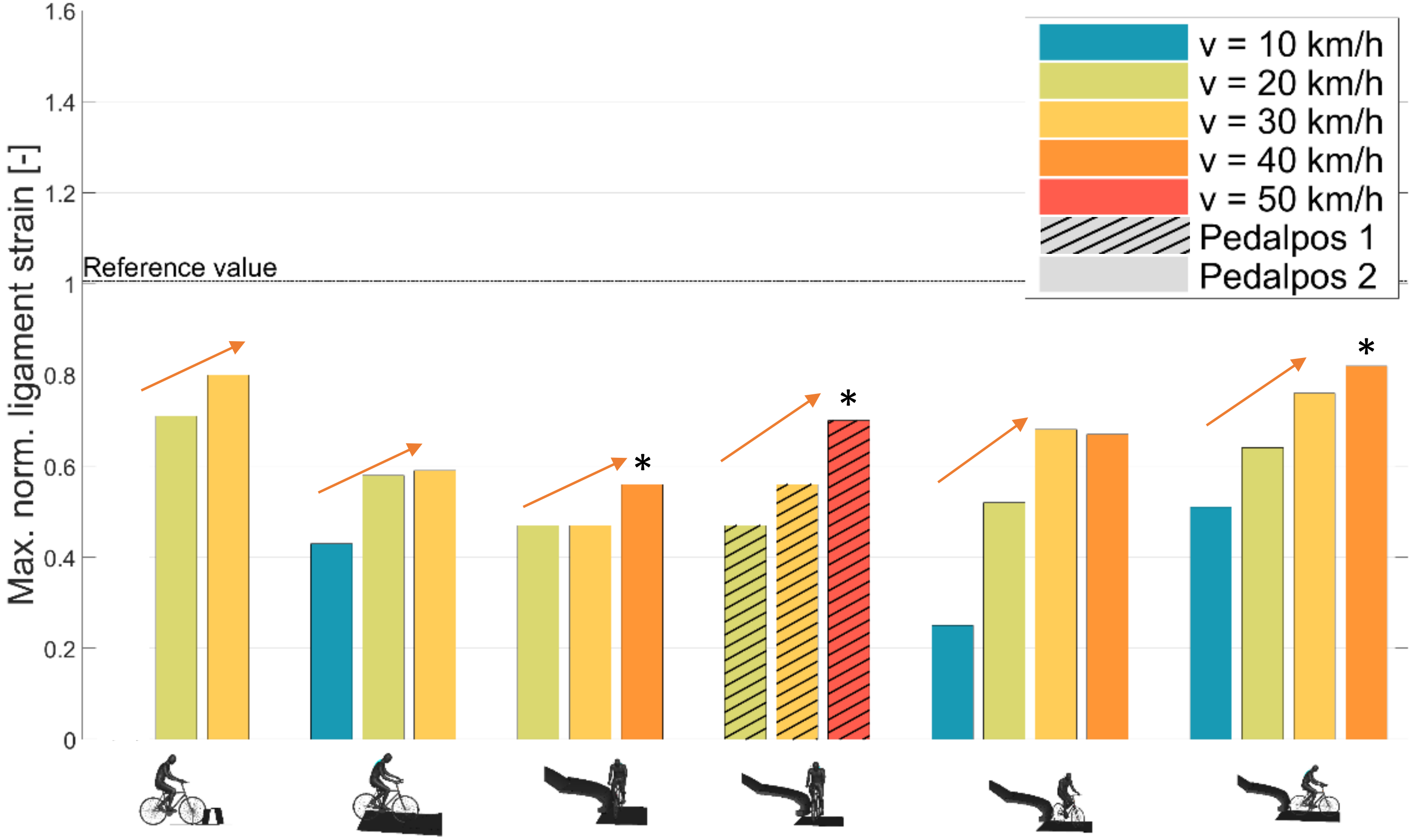
- Head injuries



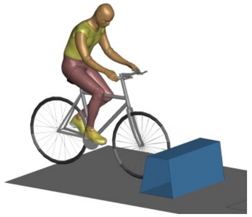
- Neck injuries

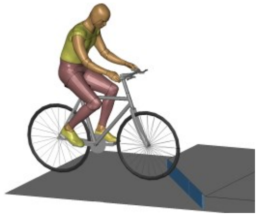


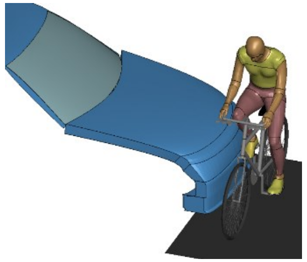
Effect of velocity

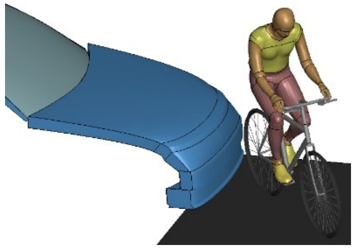


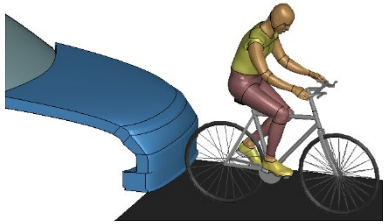
* *Eroded ligaments in model*







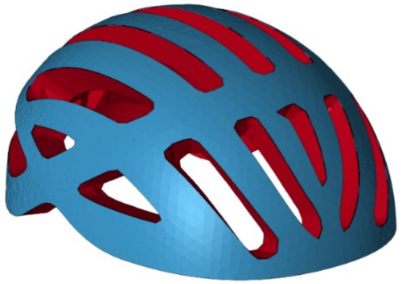


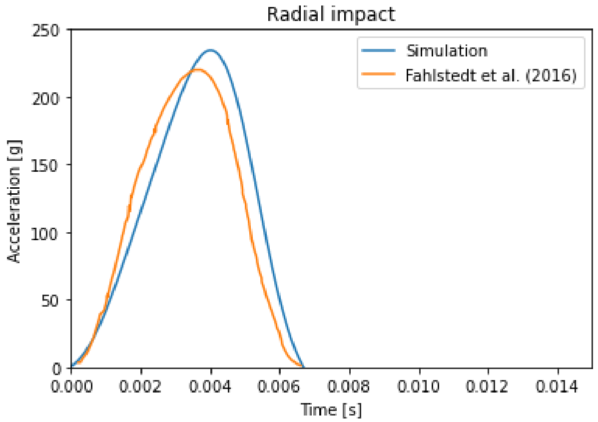


	10 km/h	20 km/h	30 km/h	40 km/h	50 km/h
Concrete barrier		Pedal position 2			
Kerbstone		Pedal position 2			
Car-to-bicycle collision: Side		Pedal position 2			
Car-to-bicycle collision: Side rear/45 degrees			Pedal position 2		
Car-to-bicycle collision: Rear			Pedal position 2		

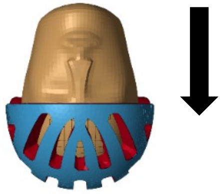
• Evaluation of protective devices

• Conventional helmet

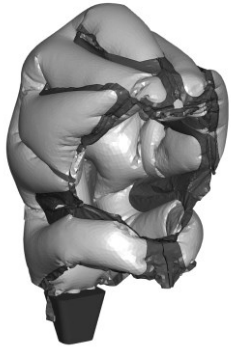




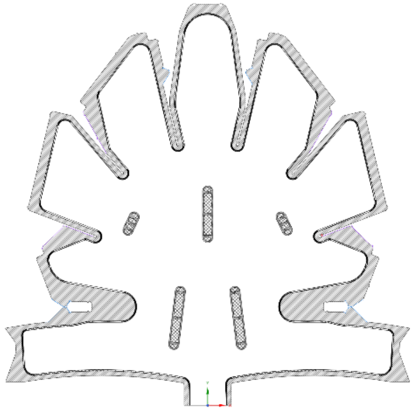
5.4 ms/s



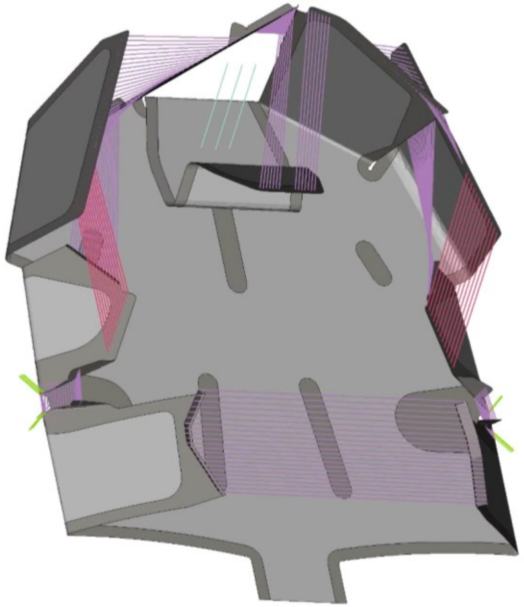
• Hövding



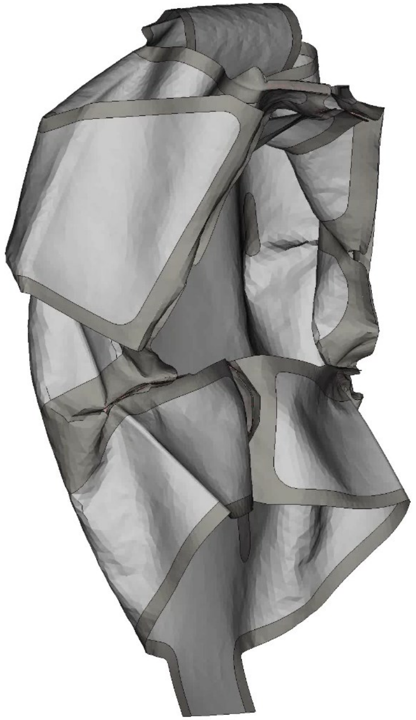
- Hövding



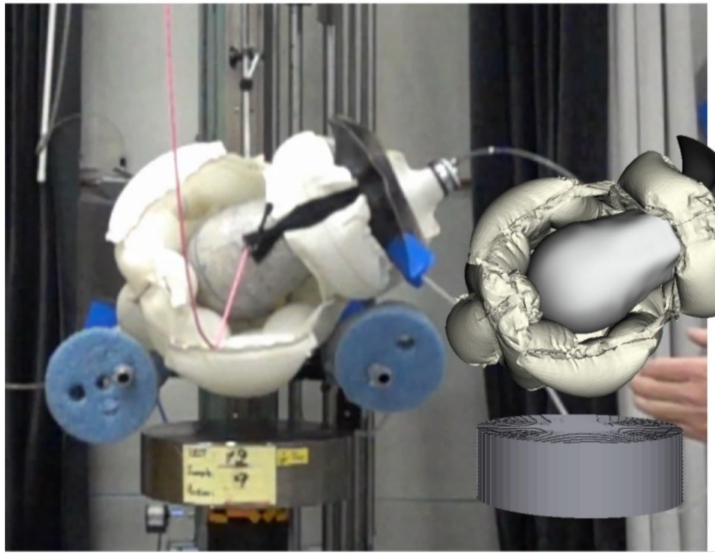
Planar drawing

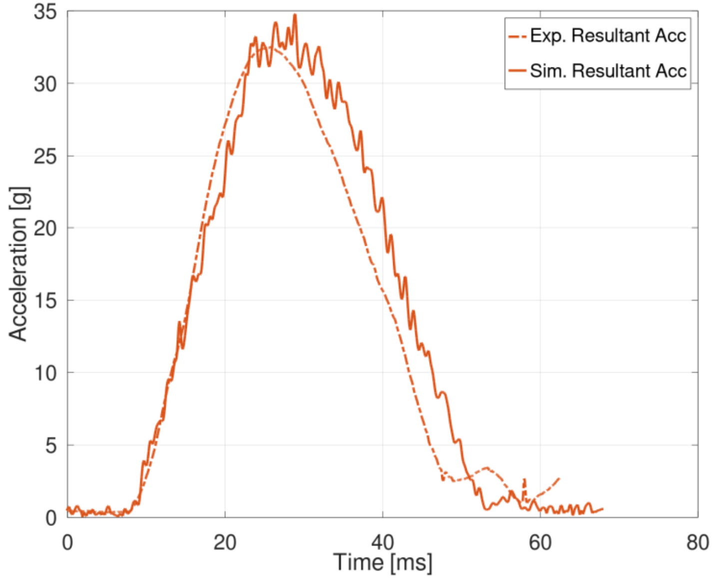


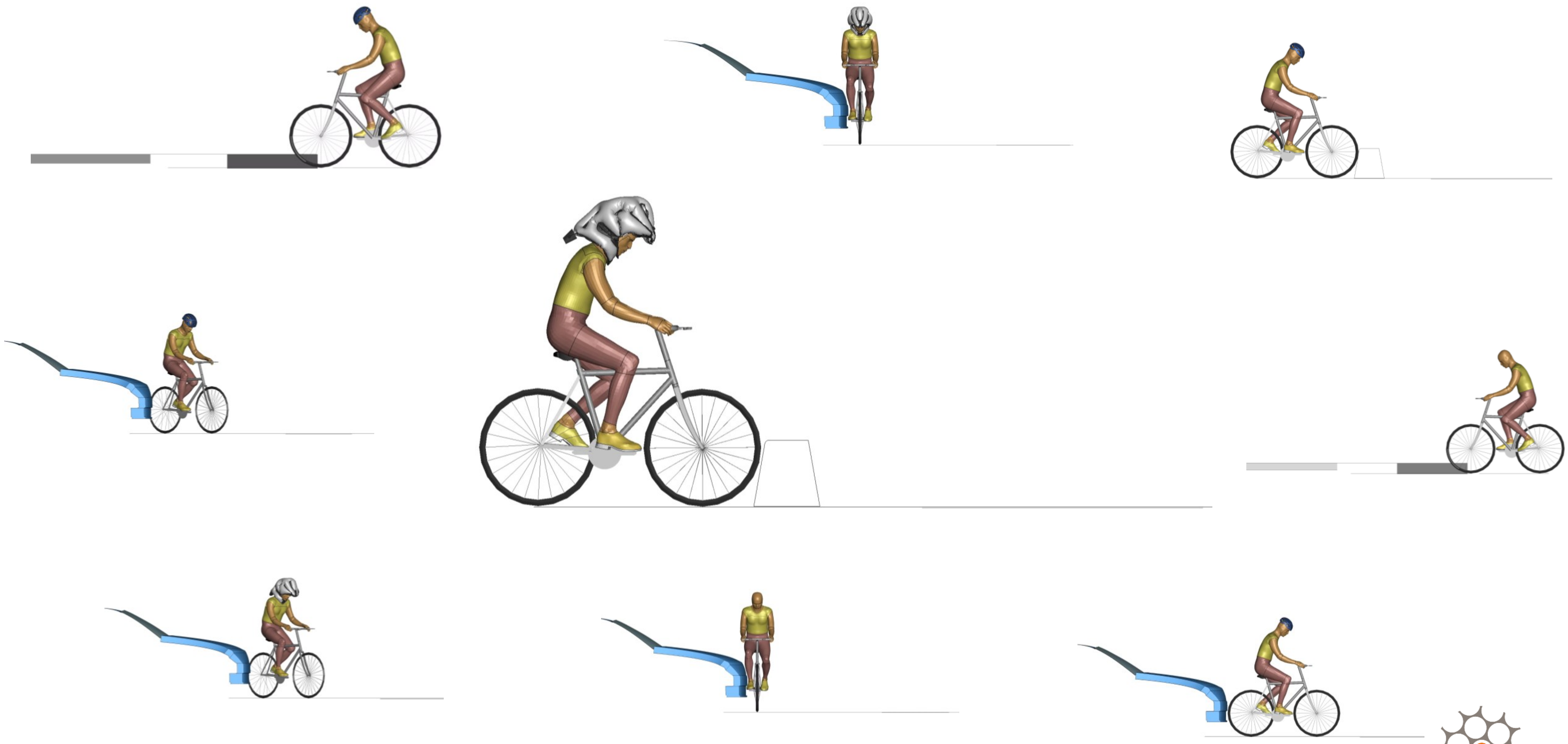
Simulation of seems contraction



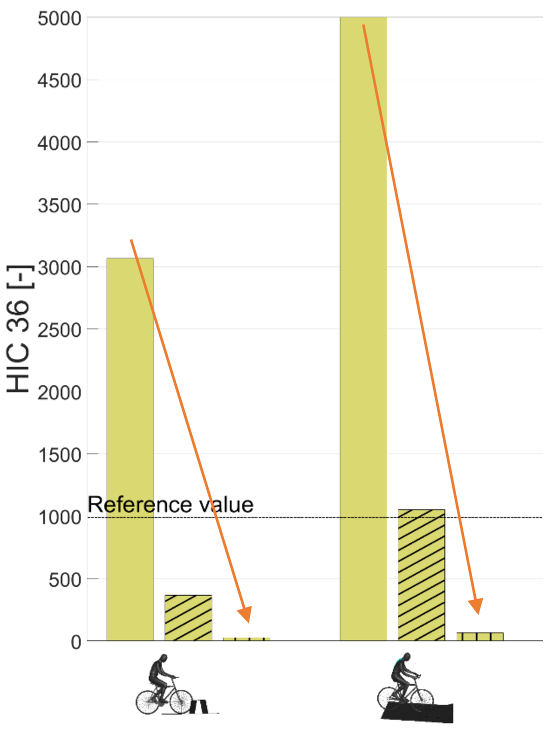
Constant pressure airbag

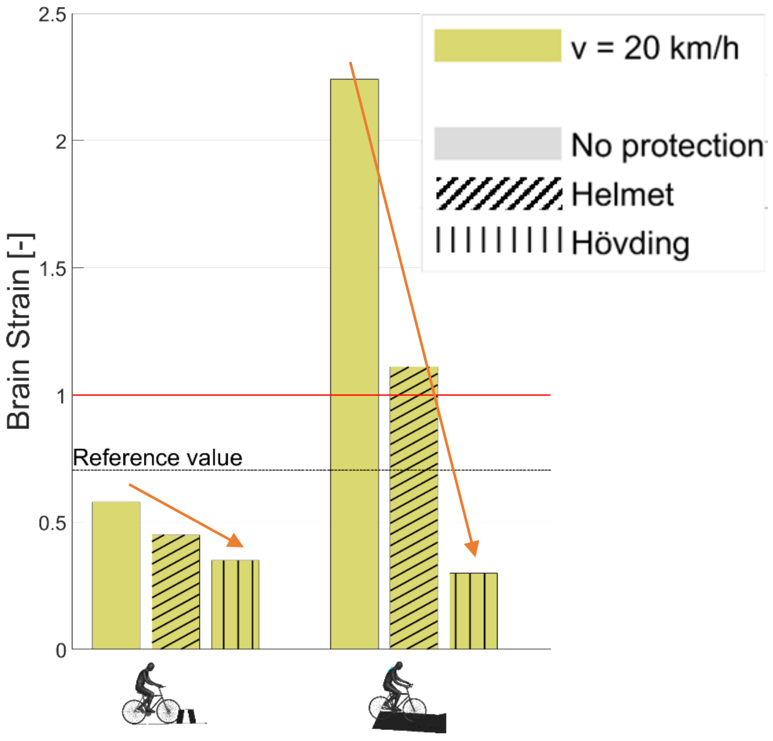


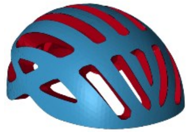


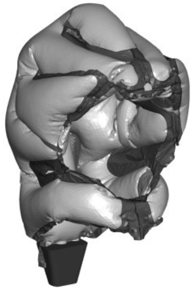


- Head injuries

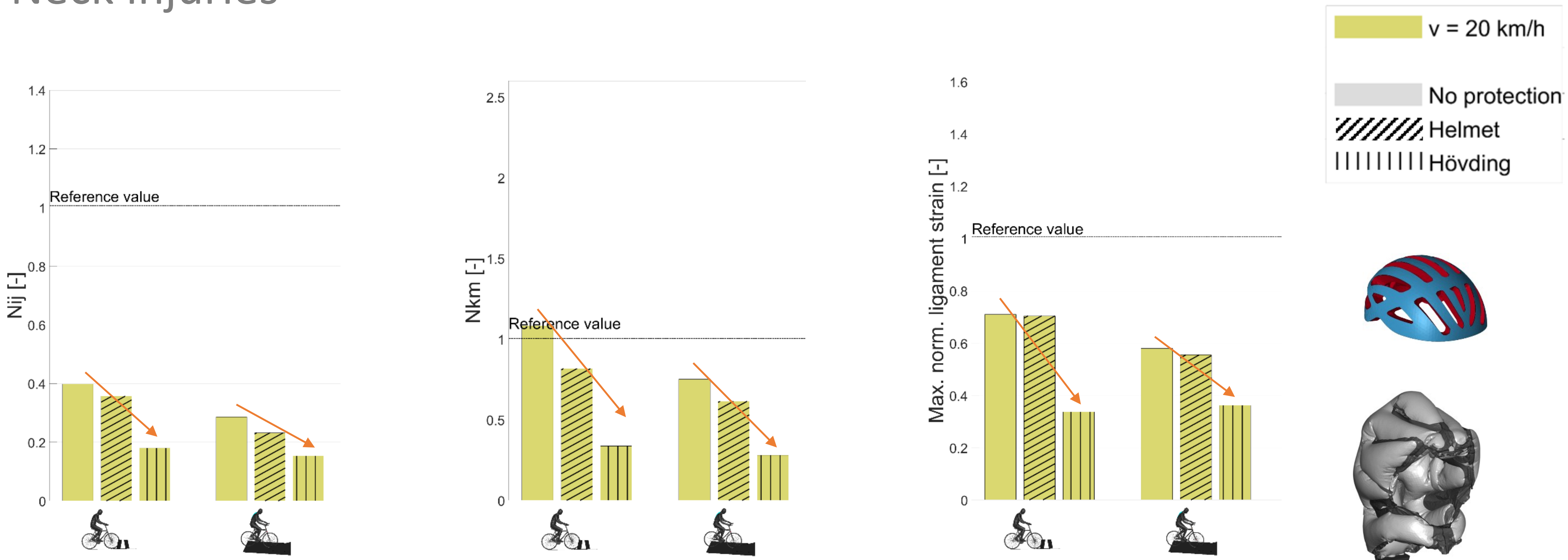








- Neck injuries



- Good agreement of kinematics between model and stunt tests
- Higher skull fracture risk in single accidents compared to car collisions
  - Due to harder impact surface
- Use case: Hövding markedly reduces injury values
  - Up to 50% more than a conventional helmet in many cases
- Promising method for evaluation of cycling injury protection devices!

Thank you for listening!

- Alvarez V, Kleiven S (2016). Importance of Windscreen Modelling Approach for Head Injury Prediction. In: Proceedings of IRCOBI Conference. Malaga, Spain, pp. 459–478.
- Fahlstedt M, Halldin P, and Kleiven S, (2016). The Protective Effect of a Helmet in Three Bicycle Accidents - A Finite Element Study. Accid. Anal. Prev. 91:135–143