Reclined Seating: Postural Variations and Associated Risks Assessed by Simulation

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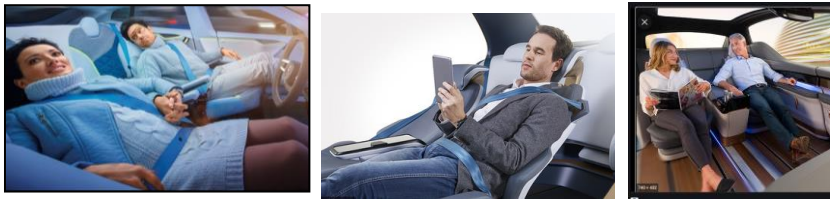
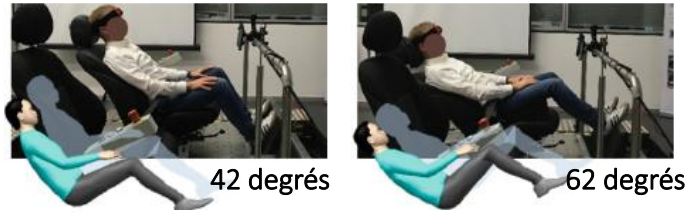
Introduction & objectives

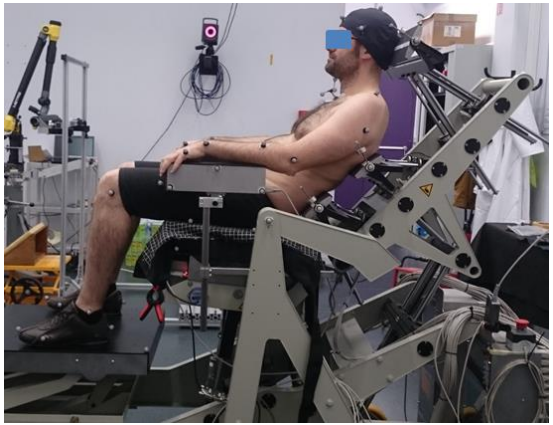
- **Automation: interest for reclined seating**
  - rest, relax = expected to be comfortable
    - Constraints on trunk / leg angle
    - Seat pan adjustment. e.g. Theodorakos et al., (2018, IEA Conf) comfort study @Univ Eiffel, airplane applications…
    - Pelvis could also be in relaxed, slouched position?
  - Could affect loading mechanisms change and performance of restraint systems… Assessment:
    - Dummies: a bit of work left
    - HBMs: various studies, limited focus on seat pan angle
- **Objectives of the work (2018-2021)**
  - Implement simulation-based methodology
    - HBM and emphasis on reproducibility
  - Study possible risks associated with new postures or seat adjustment for reclined configuration
    - Emphasis: seat pan angle, pelvis angle



Examples of concepts (Renault ; ZF ; Yanfeng; Tesla, Adient)



Bohrmann et al. 2019 (ISED Conf.)



Theodorakos et al., (2018, IEA Conf) study on multiadjustable seat

Methodology: loading and models

- **Loading: frontal only**
  - dimensioning in many cases?
    - rear or lateral impact not assessed here…
  - Two pulses: #1: used by reference studies #2: more severe EuroNCAP
- **Human model: GHBMC 50th male detailed (M50-O)**
  - v5.1 and v6.0 (many including lumbar spine)
  - Injury criteria: provided with model. Fracture enabled. Lumbar spine: backport some values of v6.0 to 5.1
- **Simplified, generic environment to allow for comparisons, etc.**
  - Adapted from Uriot et al (2015 Stapp), Trosseille et al. (2019 Stapp)
  - “Reasonably close from the state of the art”:
    - 3 point belt with pretensioners, load limiters, airbag (pre-inflated)
    - Semi rigid seat: articulated seat pan and anti-submarining ramp
  - Validation: comparison with Trosseille et al 2019 (Stapp)
  - Published in Open Source
  - Details in Grebonval et al. (2021, Plos One)

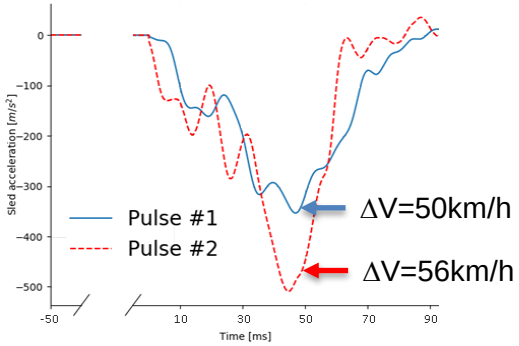
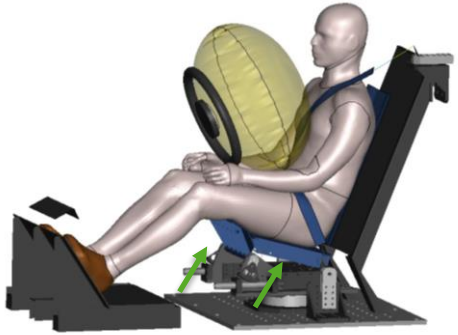
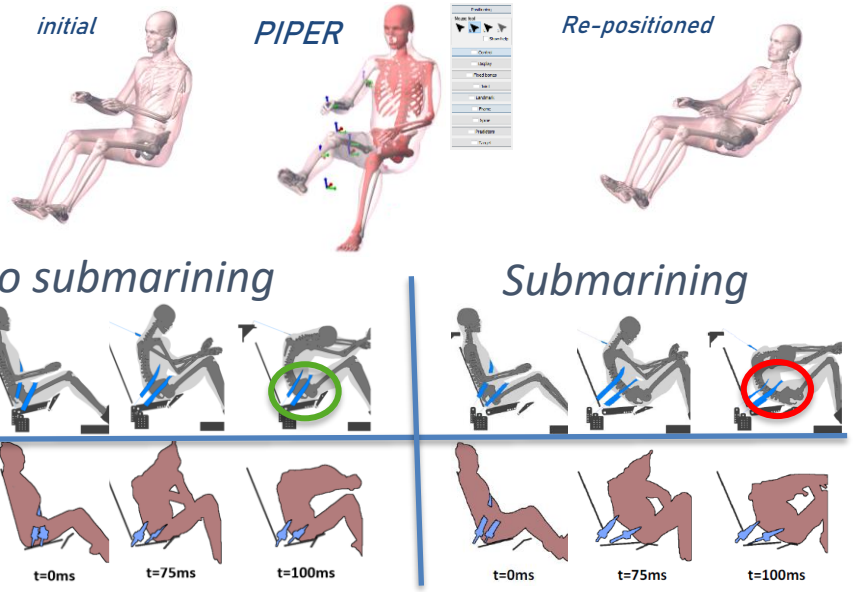


Illustration: Elemance.

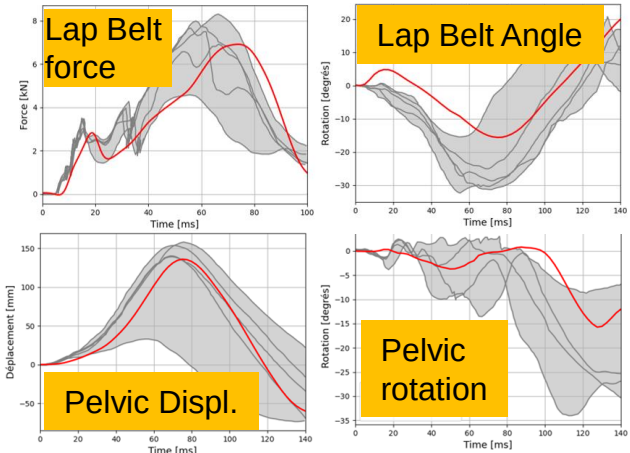


Methodology: positioning and validation

- **Positioning: PIPER tool**
  - Aim: help reproducibility, comparisons
  - **Metadata updated and published for M50-O v5.1 & v6.0**
- **Validation: 6 configurations added**
  - Submarining: Luet al (2012 Stapp), Uriot et al (2015)
  - First reclined tests (UVA, U of M)
  - ➔ Kinematics and restrain system loading approached
    - ➔ Yes it could be better,
    - ➔ Yes we computed CORA,
    - ➔ Not the focus of today's talk



Simulation vs. Richardson et al. (2020)



Methodologies: positioning and validation

- **Injuries & mechanisms: trends**
  - Relative trends ok, fractures underestimated, especially lumbar
    - Lumbar: baseline used (v6.0) ~ 53YO vs PMHS
    - Age targets available with model* ➔ run some simulations @75YO
- **Model not targeting specifically PMHS (age, geometry)**
  - Yes it could be refined
    - should be in the future?
  - Not the focus of this study

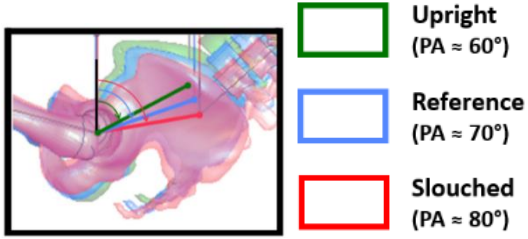
Lumbar baseline v6.0 ~ 53 YO target*

Test		Submar?	Thorax	Lumbar	Pelvis	Liver
Luet et al. 2012	PMHS	3/3	-	-	2/3 AIS2	-
	Simu.	Yes	-	-	None	-
Trosseille et al. 2019	PMHS	0/4	4/4 AIS3	2/4 AIS2	3/4 AIS2	1/4 AIS2+
	Simu.	No	AIS1	None	AIS2	< 5% AIS2+
Uriot et al. 2015 Front	PMHS	0/4	4/4 AIS4	3/4 AIS2	None	3/4 AIS2+
	Simu.	No	AIS3	None	AIS2	15% AIS2+
Uriot et al. 2015 Rear	PMHS	4/4	4/4 AIS4	2/4 AIS2	4/4 AIS2	1/4 AIS4
	Simu.	Oui	AIS4	None	AIS2	62% AIS2+
Richardson et al. 2020	PMHS	1/5	5/5 AIS2+	3/5 AIS2	4/5 AIS2	None
	Simu.	No	AIS2	None	AIS2	< 5% AIS2
Zasecket al. 2021 Standard	PMHS	?/3	3/3 AIS3+	None	1/3 AIS2	None
	Simu.	No	AIS2	None	AIS2	< 5% AIS2
Zasecket al. 2021 Reclined	PMHS	?/2	2/2 AIS4+	None	1/2 AIS2	None
	Simu.	No	AIS3	None	AIS2	< 5% AIS2

*Age targets derived from Brinckmann et al 1989
+dynamic scaling using Arun et al. 2017

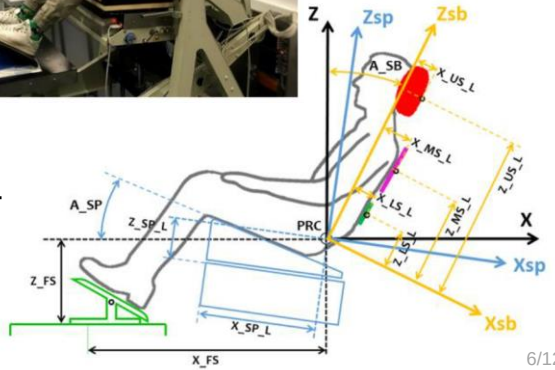
Methodology: postures

- **1st Simulation campaign: conditions are assumed**
  - Reference (22 degrees seat back, 15 seat pan)
  - 40 degrees reclined x3 seat pan angles
    - 5, 15, 25 deg , derived from Theodorakos et al. (2018)
  - 60 degrees reclined x3 seat pan angles
    - 25, 35, 45 deg , assumed
  - x3 pelvic angles
    - rotate with seatback (reference) ±10 degrees (variation range of Reed and Ebert 2018) = upright or slouched
- **2nd simulation campaign: experimental data**
  - use average pelvic angles for 3 seat pan angles
  - Grébonval et al. (2021) Comfort Congress 2021



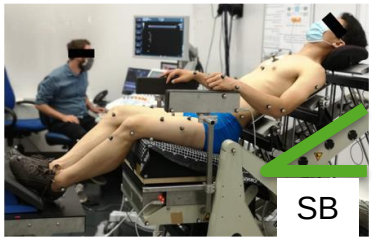
Pelvic tilt example

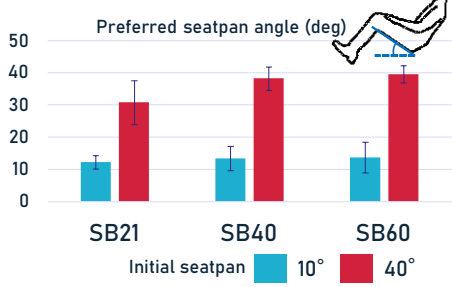
Experimental study with multi-adjustable seat 18 participants

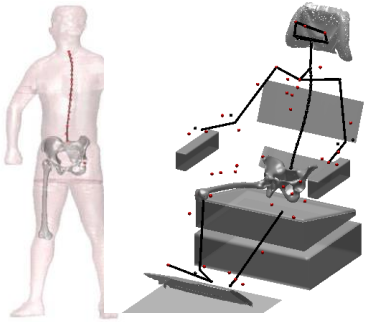


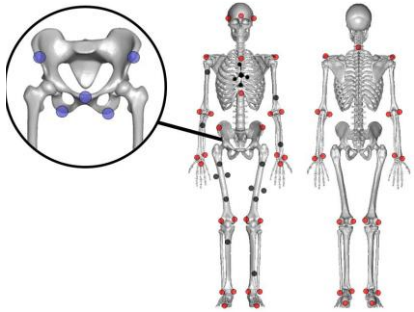
Methodology: postures

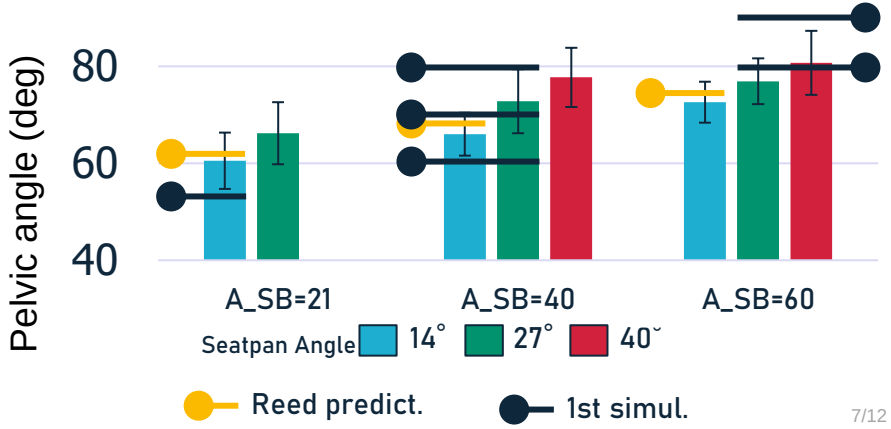
1. **Preferred seat pan angle for given seatback ?**
   - Wide range, **depends on initial setting**
   - Limitation: short duration, not in vehicle
2. **Detailed posture adopted by the participant**
   - New methodology: personalized model
     - stat shape model (pelvis, femur), anatomical points (palpation, ultrasound), regression (spine)
     - Positioned on seat using inverse kinematics, points (Vicon, palpation), pressure maps
   - Pelvic angle varies with seat back/seat pan
   - Subject to subject variability
   - 1st simulations is close ➔ combine results
   - Postural predictor ➔ reused in ENOP





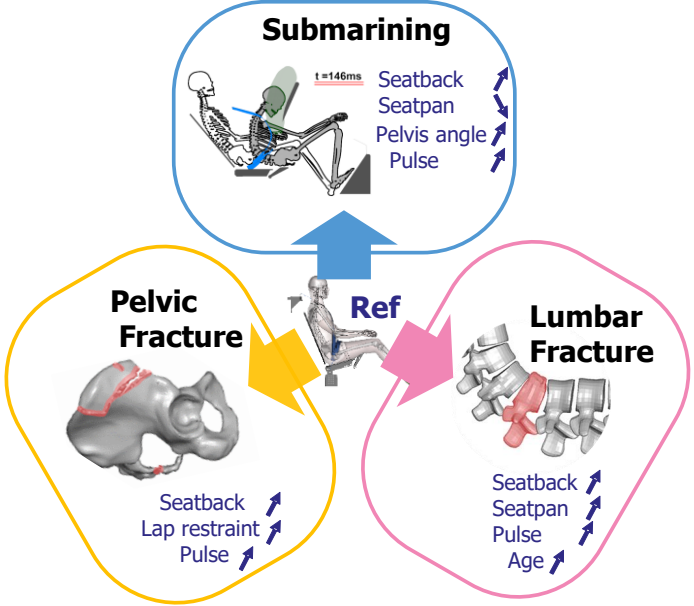




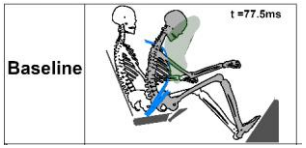


Results

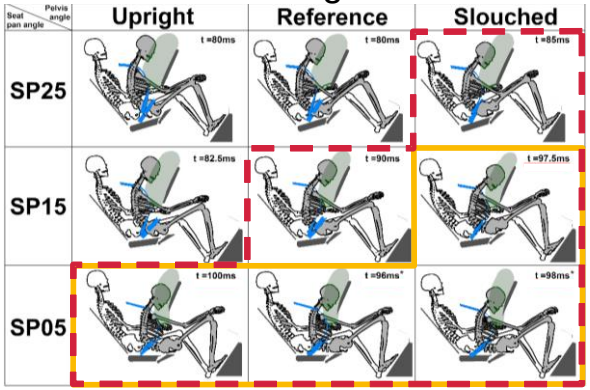
- **Simulations are coherent, incl. thresholds for discrete phenomena ➔ regions in the parameter space**
- **Changes in restraint mechanisms / balance**
  - Submarining vs Pelvic Fracture vs Lumbar Fracture
- **Illustration: submarining**
  - 1st simulation campaign; 40 deg = Plos One 2021



21 degrees



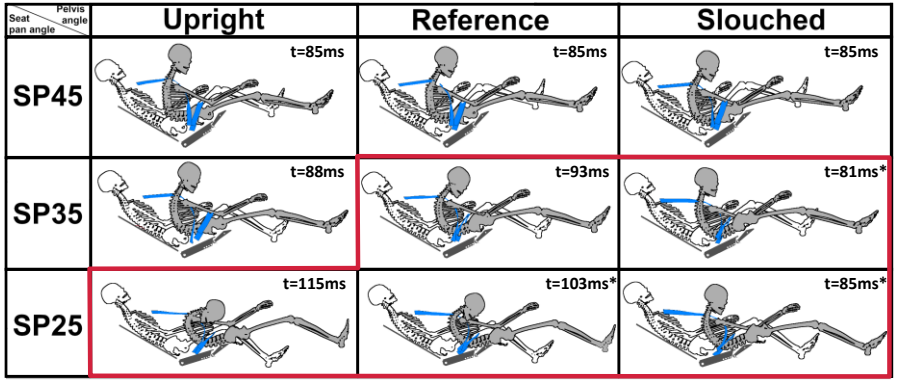
40 degrees



Submarining – 50km/h

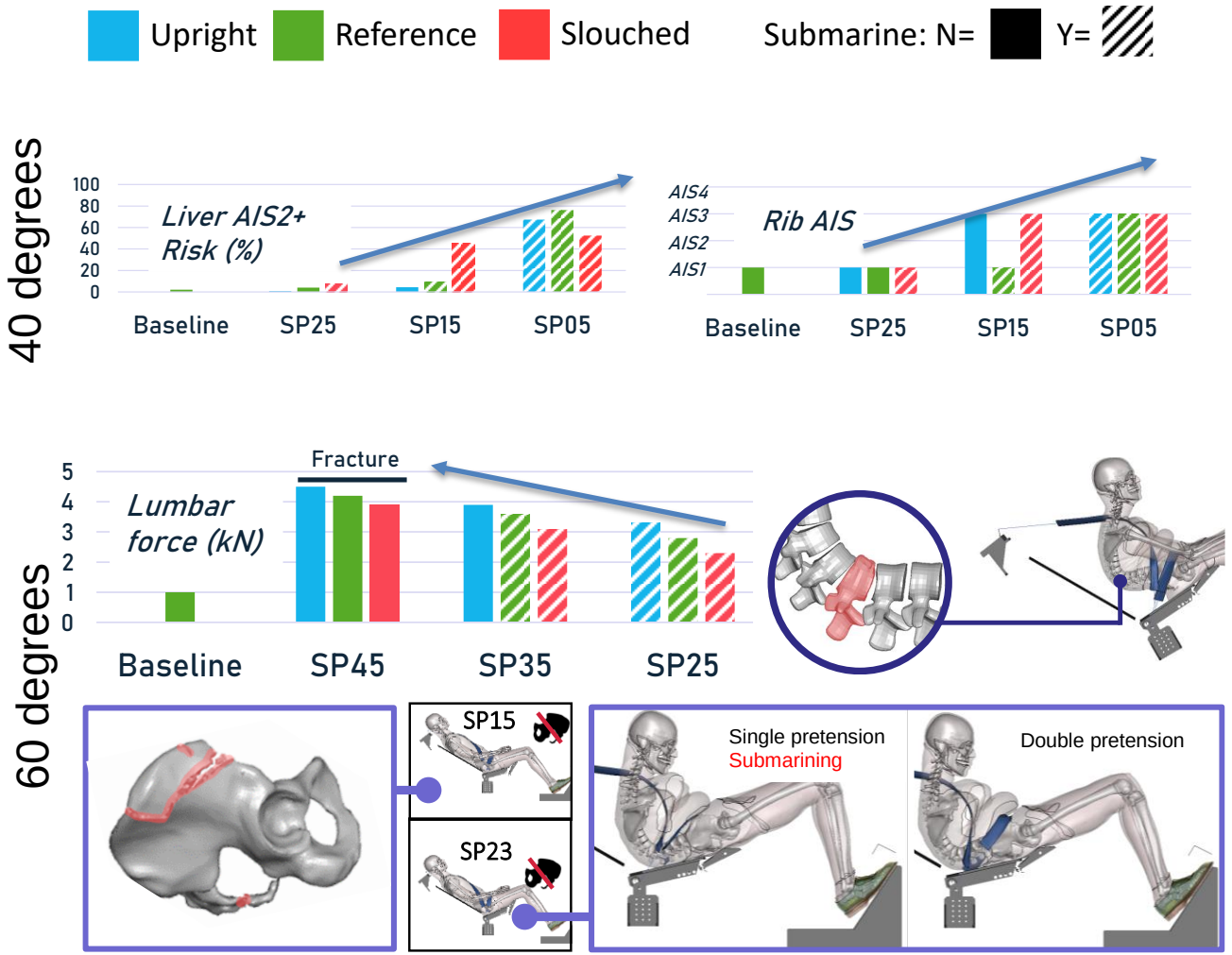
Submarining – 56km/h

60 degrees



Results:

- **Illustration: predicted injuries (Pulse #2)**
  - Submarining associated with liver and rib injuries
  - Seat pan angle: helps restrain the pelvis but generate lumbar fractures (60 degrees)
  - Double pretension can reduce submarining but can lead to pelvic fractures



Synthesis of Both campaigns

Legend
SP = Seatpan angle

Submarining – 50km/h

Submarining – 56km/h

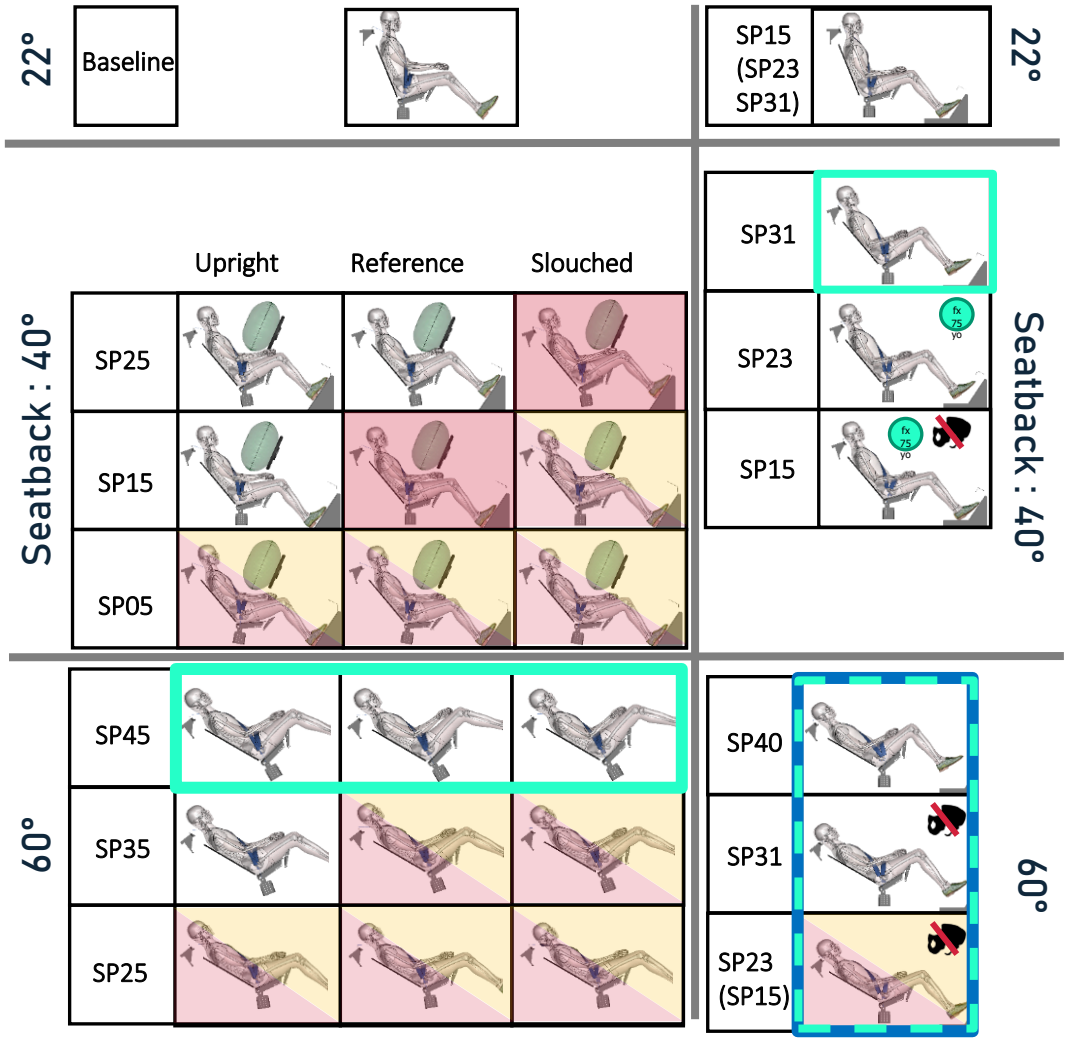
Lumbar Fracture – 56km/h

Lumbar Fracture – 56km/h, 75yo

Pelvis Fracture– 56km/h, double pretension

Lumbar Fracture – 50km/h

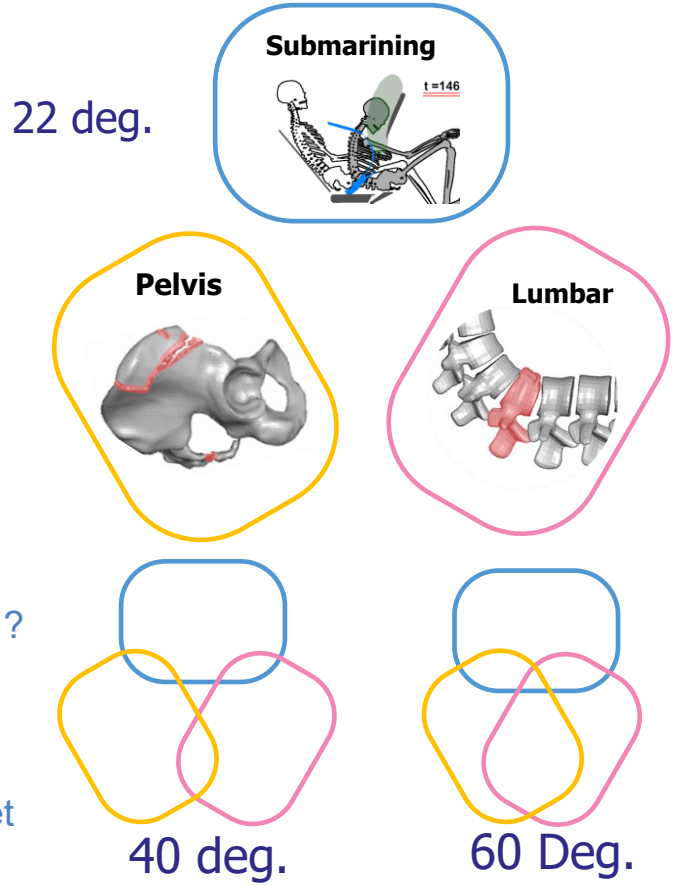
SIM1: seat pan & pelvis (GHBMC v5.1)



SIM2: seatpan, restraint, age (mean pelvis GHBMC v6.0)

Conclusion and perspectives

- **Methodology: Open source / data building blocks**
  - positioning, posture, environment ➔ could help with reproducibility…
- **Reclined: large effect, affects loading balance / injury**
  - Sensitivity to parameters, coherent response ➔ clear tendencies, “smooth surface response” (with “ridges” for discrete phenomenon)
    - 60 degrees: balance difficult ➔ need another restraint?
    - Affected by HBM, injury thresholds, population target… ?
  - Seems subtle ➔ remembering limitations and choices
    - HBM approximates response and injury trends
    - Need to refine (fracture, age…), define population target
    - Pelvic angle vs. protection: average, slouched ?
  - Risk varies within wide range of preferred seat pan angles ➔ set limits?



Trend: effect of seatback angle for the human and environment models used

Thank you

- **Funding: Surca collaborative project 2018-2022**

- Conferences and articles
  - Grébonval, C., Trosseille, X., Petit, P., Wang, X., and, Beillas P. 2021. Effects of seat pan and pelvis angles on the occupant response in a reclined position during a frontal crash. PLoS ONE.
  - Grébonval, C., Beillas, P., and Wang, X. Experimental investigation of preferred seating positions and postures in reclined seating configurations. Comfort Congress 2021, 2nd – 3rd September.
  - Grébonval, C., Trosseille, X., Petit, P, Wang, X., and Beillas, P. 2020 The Effects of Small Seat Swiveling Angles on Occupant Responses During a Frontal Impact. SAE Technical Paper No. 2020-01-0571.
- Additional material:
  - Environment: under Open Source license:
    https://gitlab.com/piper-project.org/misc_models/-/tree/master/Environment/SURCA_ENV
  - Parameters: postural parameters used for 1st campaign in Plos One
  - Postural predictor: not online yet (will be)
  - GHBMC M50-O v5.1 / v6.0 PIPER Metadata: www.piper-project.org