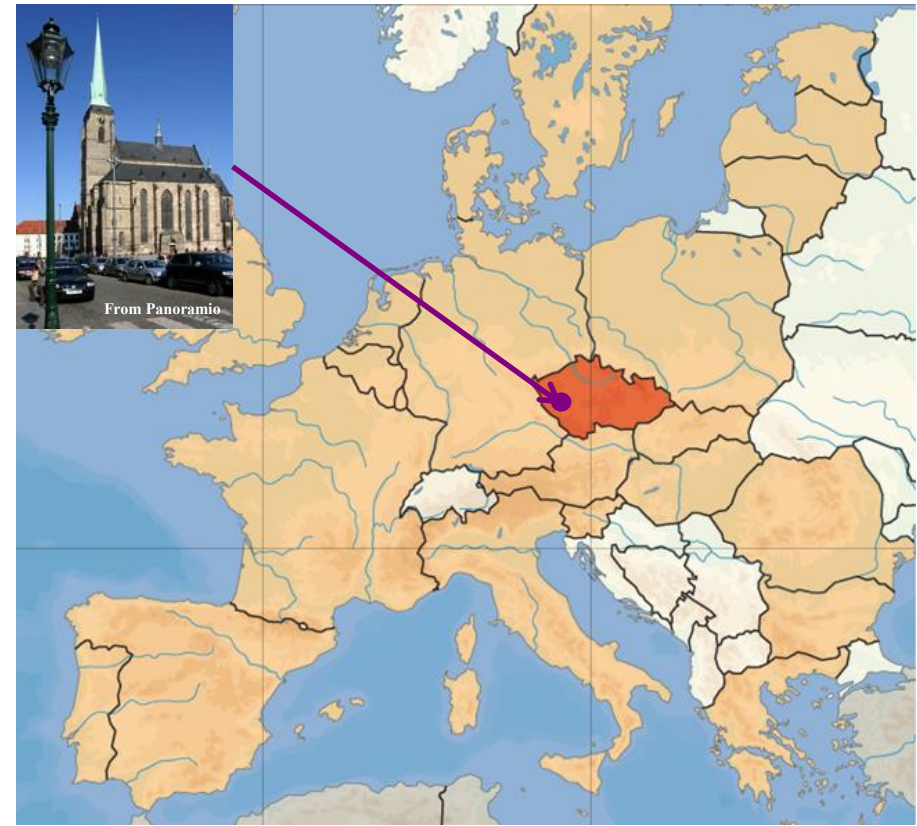




VIRTUAL HUMAN BODY MODELS FOR SAFETY ASSESSMENT AND MEDICAL APPLICATIONS

Biomechanical Human Body Models
New Technologies – Research Centre
University of West Bohemia

Assoc. Prof. Luděk Hynčík, Ph.D.



- ▶ Founded in 1991 (engineering since 1949)
- ▶ Faculty of Applied Sciences
- ▶ Ladislav Sutnar Faculty of Design and Art
- ▶ Faculty of Economics
- ▶ Faculty of Electrical Engineering
- ▶ Faculty of Arts
- ▶ Faculty of Education
- ▶ Faculty of Law
- ▶ Faculty of Mechanical Engineering
- ▶ Faculty of Health Care Studies
- ▶ Institute of Applied Language Studies
- ▶ New Technologies - Research Centre
- ▶ 11.000+ students
- ▶ ~2.000 employees
- ▶ 300+ study programs
- ▶ 55.000 alumni
- ▶ Materials research
- ▶ Sustainable power production
- ▶ Transportation systems
- ▶ Industrial technologies
- ▶ Control systems
- ▶ Informatics and Cybernetics
- ▶ Bioengineering
- ▶ Social sciences



- ▶ University research institute since 2000
 - ▶ State of the art computing and lab equipment
 - ▶ Cutting edge R&D from idea to prototype
 - ▶ International and industrial cooperation
- ▶ Multinational team of 130 employees from 13 countries



(Europe, Asia, Africa)

- ▶ 20% of foreign researchers
 - ▶ HR Award since 2018
 - ▶ GEP 2021
1. Ecological energy sources
 2. Smart transportation means
 3. Human well being and health



- Location
 - Science and Technology Park Pilsen
- Our international team 
counts 14 people
 - 1 Administrator 
 - 1 Assoc. Prof. 
 - 7 Researchers 
 - 5 PhD students 



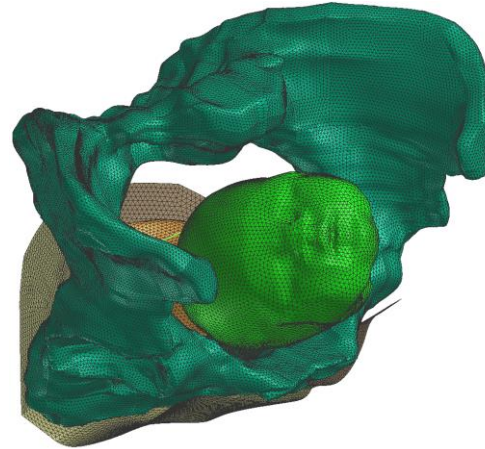
Projects

- ▶ **TA01031628** Scalable human models for increasing traffic safety
- ▶ **TA04030689** Development of Vehicle Active Bonnet System Regarding Variability of Population
- ▶ **TE01020038** Competence centre for rail vehicles
- ▶ **MYMOSA** Motorcycle and Motorcyclist Safety
- ▶ **MOTORIST** Motorcycle Rider Integrated Safety
- ▶ **COST TU1407** Scientific and technical innovations for safer Powered Two Wheelers
- ▶ **LTC17001** Exploitation of virtual human model for reducing injury risk of PTW riders
- ▶ **BY-CZ no. 38** Virtual human models for the prevention, therapy and rehabilitation of shoulder pathologies
- ▶ **BY-CZ no. 182** Obstetrics 2.0 - Virtual models for the prevention of injuries during childbirth
- ▶ **ITI AMTMI** Application of Modern Technologies in Medicine and Industry
- ▶ **TRANS-SAFE** HORIZON-CL5-2021-D6-01-11: Radical Improvement of road safety in low- and medium-income countries in Africa

References

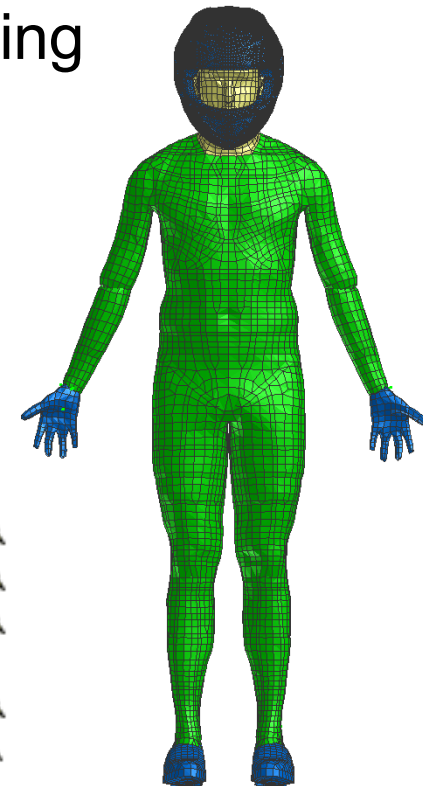
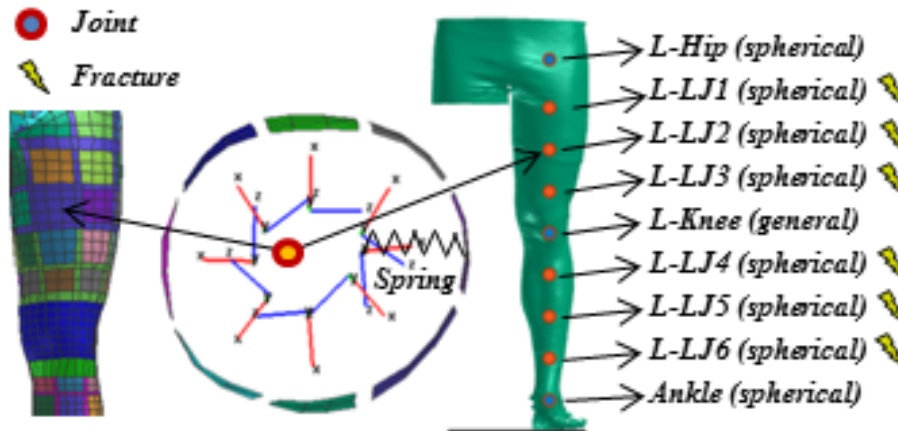
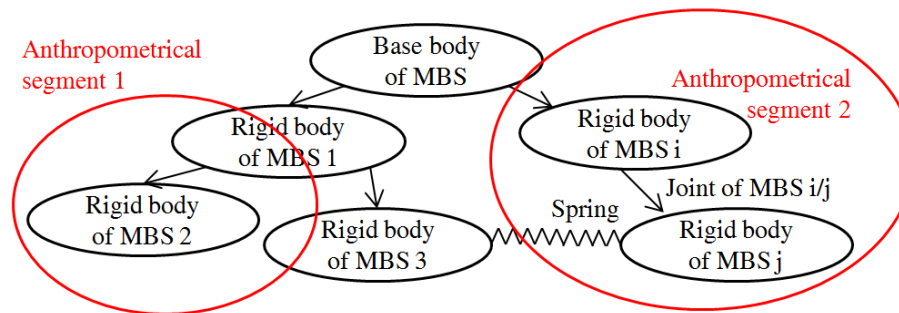
- ▶ **Aalborg University** (DK)
- ▶ **AMSAFE** (US)
- ▶ **Charles University** (CZ)
- ▶ **Criminalistic Institute in Prague** (CZ)
- ▶ **ESI Group** (AU, CZ, FR, KR)
- ▶ **TH Ingolstadt** (DE)
- ▶ **OTH Regensburg** (DE)
- ▶ **The University of Western Australia** (AU)
- ▶ **The Institute for the Care of Mother and Child** (CZ)
- ▶ **Tianjin University of Science and Technology** (CN)
- ▶ **TRW** (DE)
- ▶ **Vision Consulting Technology** (CZ)
- ▶ **Warsaw University of Technology** (PL)

1. Mobility safety and impact injury assessment
2. Childbirth-induced injury risk assessment
3. Prostheses optimization and rehabilitation



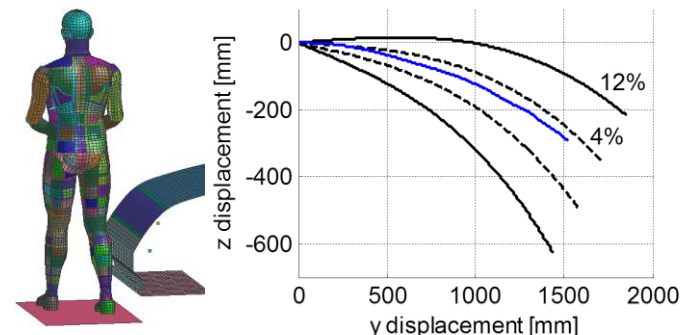
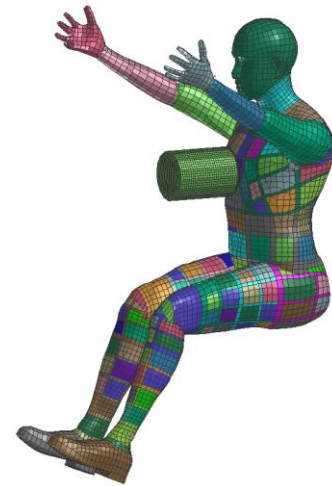
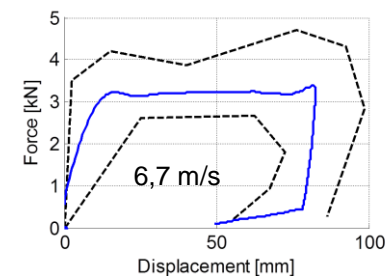
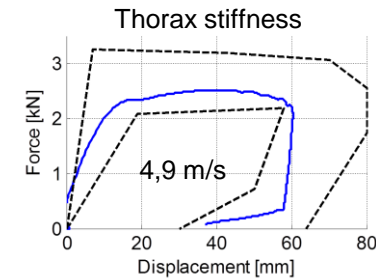
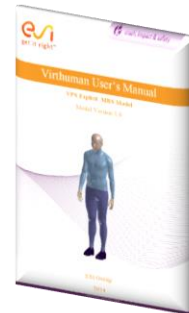
- Scaling and mesh-morphing methods for personalizing human models to develop subject-specific human digital twins
- Model order reduction, artificial intelligence and machine learning techniques

- Hybrid approach coupling MBS and FEM
 - MBS + compressible segments
 - Easy manipulation
 - Extensive validation
 - Parametric model
 - Scaling and morphing



Virthuman

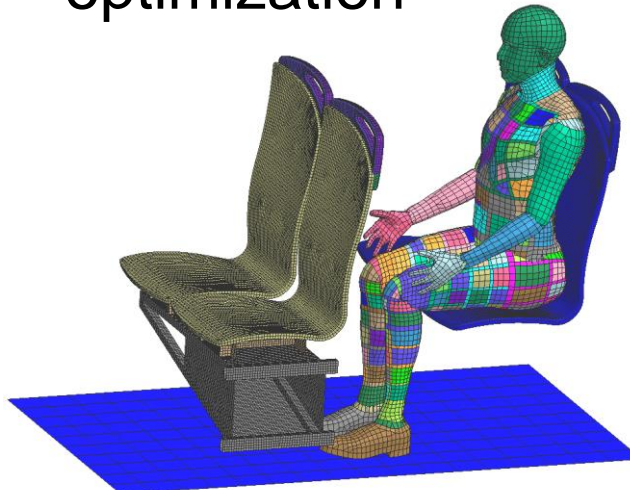
- ▶ Reference model of an average male (P_{50} , 178 cm, 75 kg)
 - ▶ European database CAESAR (close to Hybrid III and Eurosid II)
 - ▶ Fully validated (SAE *Technical Papers*)
 - ▶ 2014-01-0534, DOI:[10.4271/2014-01-0534](https://doi.org/10.4271/2014-01-0534)
 - ▶ 2016-01-1511, DOI:[10.4271/2016-01-1511](https://doi.org/10.4271/2016-01-1511)
 - ▶ 2017-01-1451, DOI:[10.4271/2017-01-1451](https://doi.org/10.4271/2017-01-1451)
- ▶ Scaling (age, gender, height, mass)



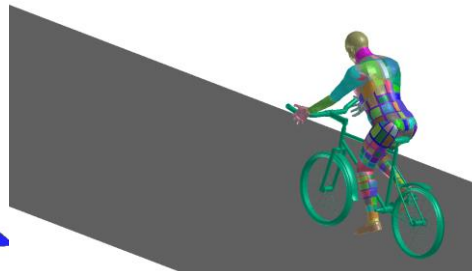
- ▶ Personalization (parametrization)

GOOD
ACCEPTABLE
MARGINAL
POOR
- ▶ EuroNCAP-based injury risk

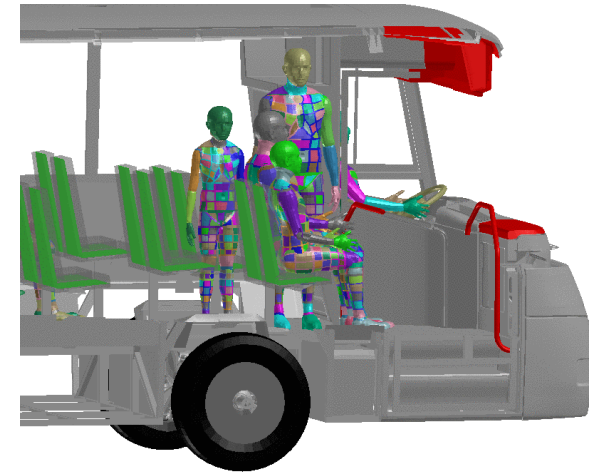
- Fast calculation and evaluation
- Personal protective equipment and safety systems optimization



Courtesy of MECAS ESI



recon-VH_014b-03b.pcx



1 / 0.00000

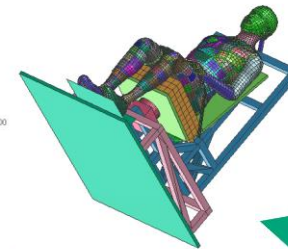
Courtesy of VCA

Prototyping
assessment

60_deg_setup.pcx

Cooperation
with WUT
(Poland)

181 / 900.000977



1 / 0.00000

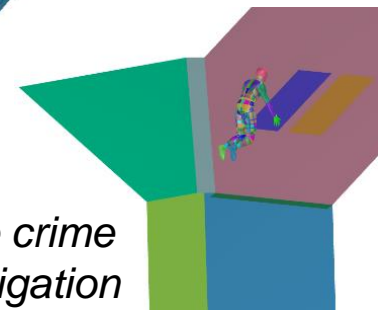


1 / 0.00000



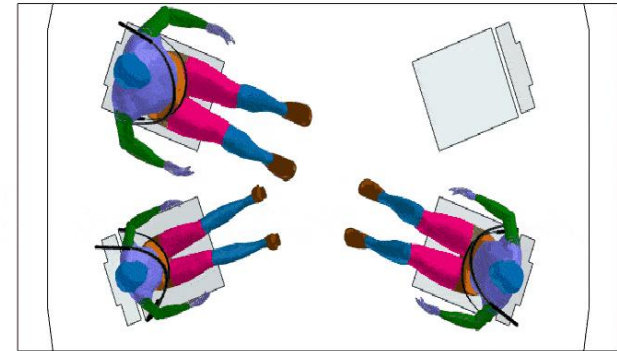
1 / 0.00000

Police crime
investigation





Occupants' safety in
highly automated vehicles (HAVs)



Fast Injury prediction

Interior type
☒ Standard
 ☐ Conversation
 ☐ Living room I
 ☐ Living room II
 ☐ Living room III
 ☐ Arbitrary

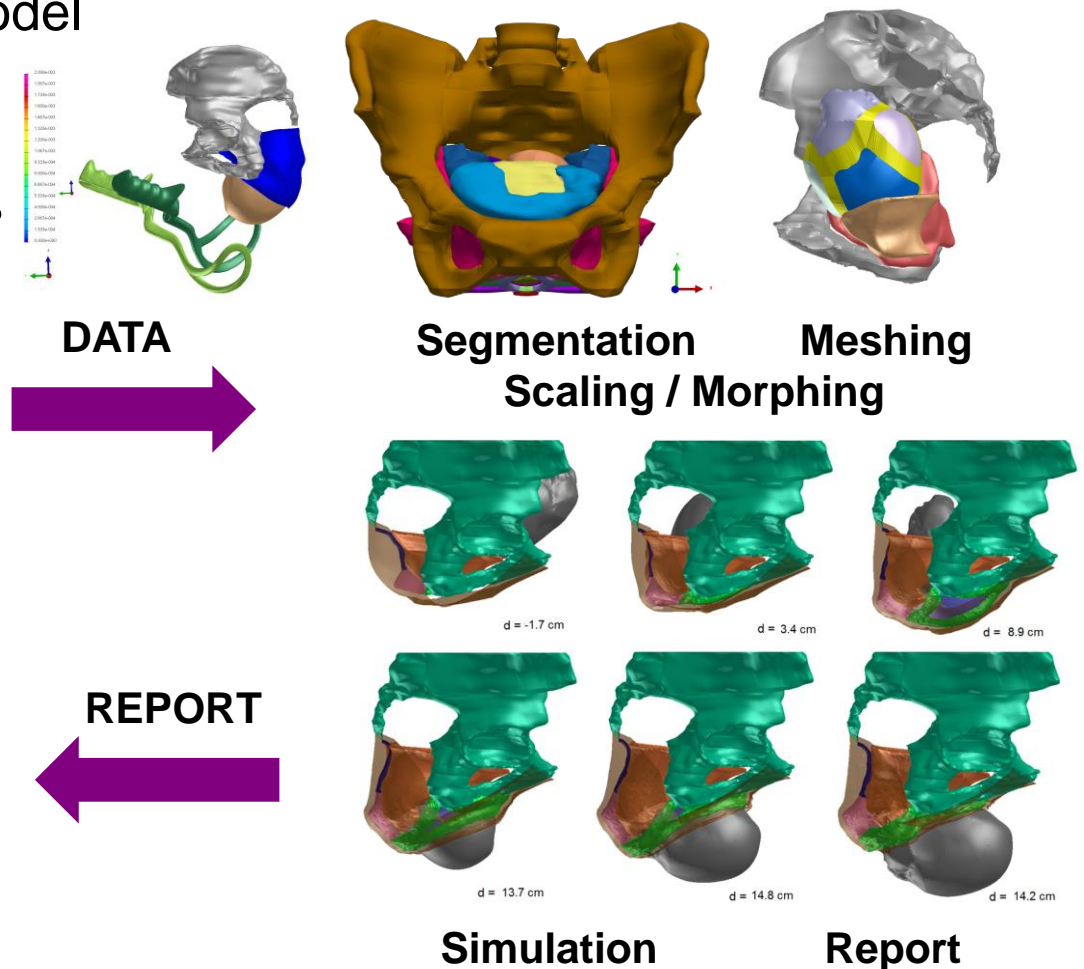
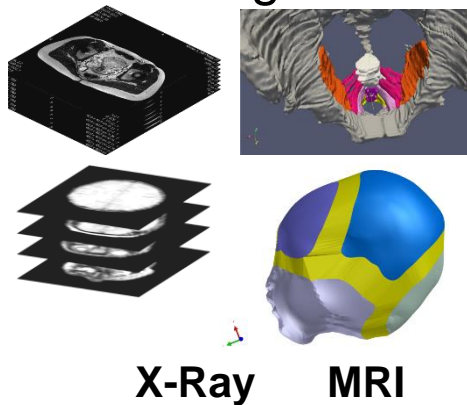
speed (km/h)

Orientation

	Occupant no.1	Occupant no.2	Occupant no.3	Occupant no.4
Occupied	<input type="button" value="YES"/> <input type="button" value="NO"/>	<input type="button" value="YES"/> <input type="button" value="NO"/>	<input type="button" value="YES"/> <input type="button" value="NO"/>	<input type="button" value="YES"/> <input type="button" value="NO"/>
Gender	<input type="button" value="Male"/> <input type="button" value="Female"/>	<input type="button" value="Male"/> <input type="button" value="Female"/>	<input type="button" value="Male"/> <input type="button" value="Female"/>	<input type="button" value="Male"/> <input type="button" value="Female"/>
Age	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Height (cm)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Weight (kg)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

- Prediction of the successful course of labour in relation of bony pelvis anatomy and fetal head size and position

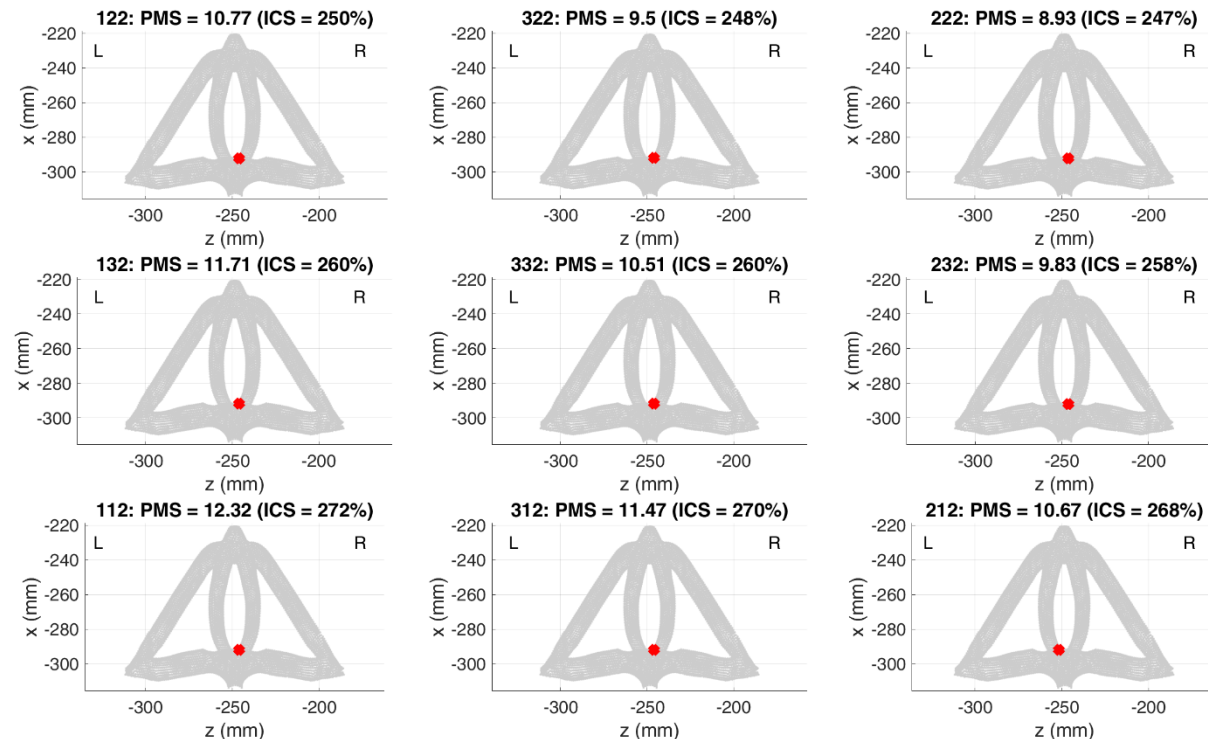
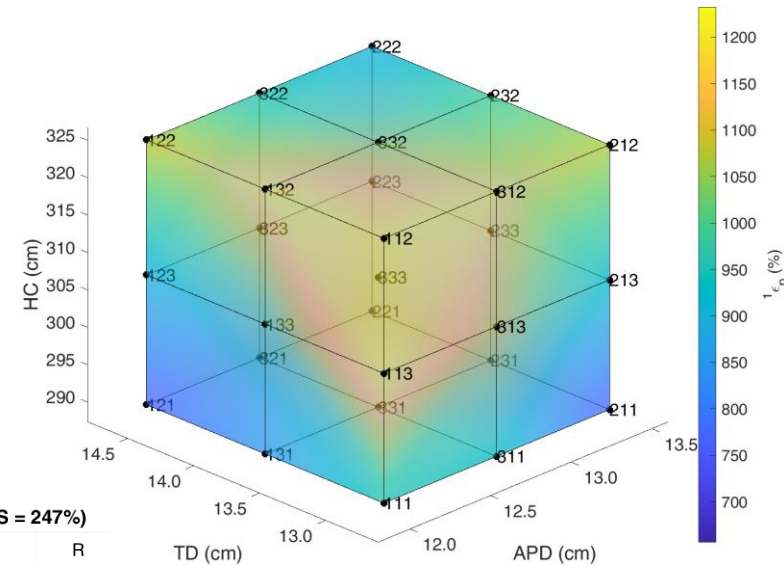
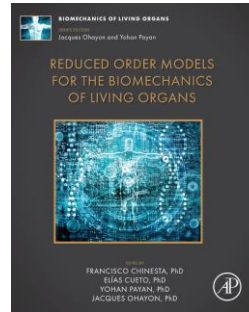
- MRI-based template model
- Female pelvic floor
- Assessing interventions



► Design of experiment

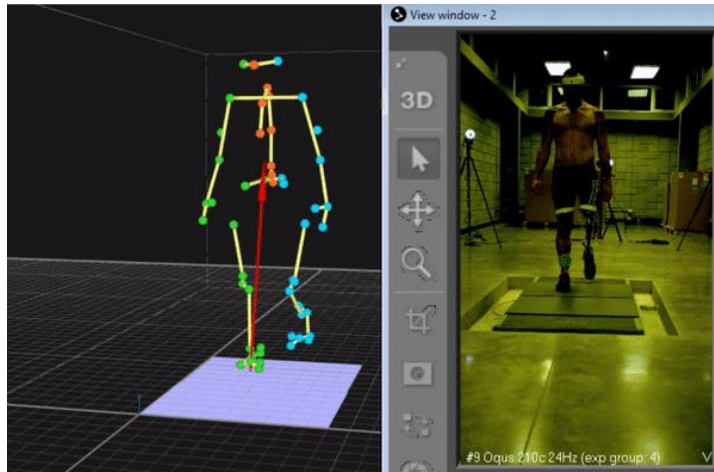
- Statistical model
- Response surface

to predict maximum pelvic muscle strain depending on APD, TD and HC

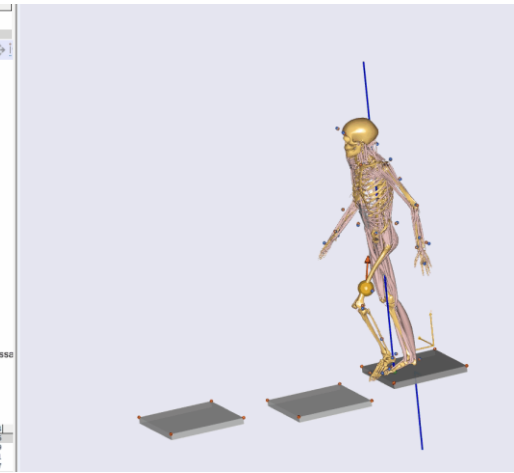
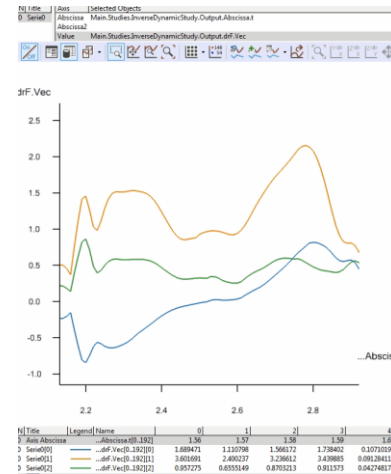


Design	$1p\epsilon$ (%)	Error (%)
331	781	-0.46
332	1.051	-1.51
113	1.230	11.11
213	924	0.85
123	894	-2.95
223	762	-1.62
313	1.085	7.38
133	992	-1.47
323	827	-2.48
233	845	-0.08
311	929	7.51
131	846	-1.53
321	714	0.56
231	723	1.77
312	1.147	-0.22
132	1.171	1.35
322	950	-3.72
232	983	0.33

1. Gait Analysis



2. Kinematics



4. Prosthesis Adjustment

Most critical part



focus on
tissue-socket
interaction

3. Finite Element Analysis



- ▶ Child-birth induced injuries
- ▶ 3-month internship (Gledden Fellowship support)

1. Automating the process of creating a mother-specific computational biomechanics model of the pelvic floor

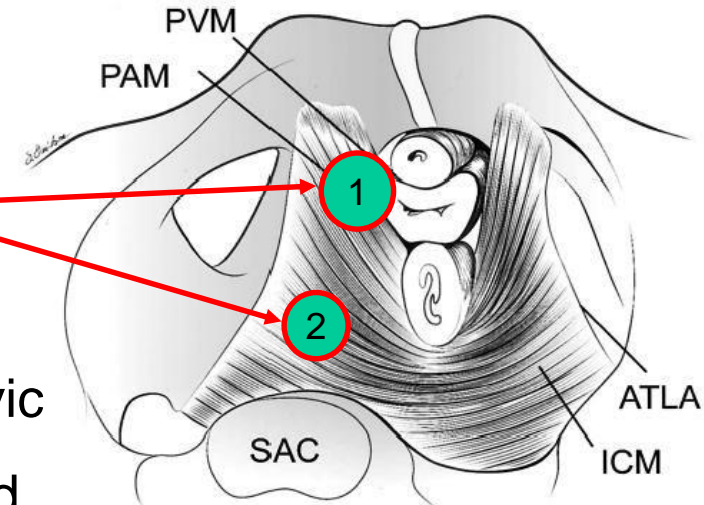
- Pelvis and pelvic floor muscles

2. Verification of the proposed biomechanical approach for safer childbirth through

- Conducting computer simulations of the vaginal delivery using an automatically generated mother-specific pelvic floor model
 - To assess the maximum perineal muscles strain due to childbirth
 - To compare pelvic muscles' strain to real injury appearance
- Commercial software (VPS), open-source software (FE, mesh-less)

► Childbirth-induced injuries

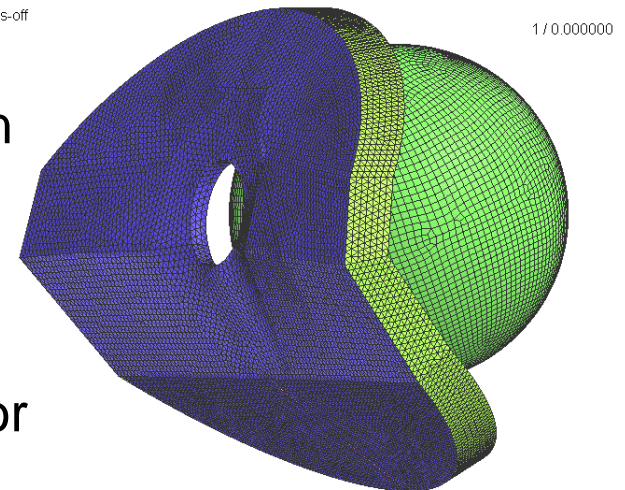
- Over 23% in general women's population
- Muscle damage from overstretching
- Bony pelvis dimensions and fetal head size incompatibility known as cephalopelvic disproportion (CPD) risk not usually tested



Ashton-Miller and Delancey (2004)

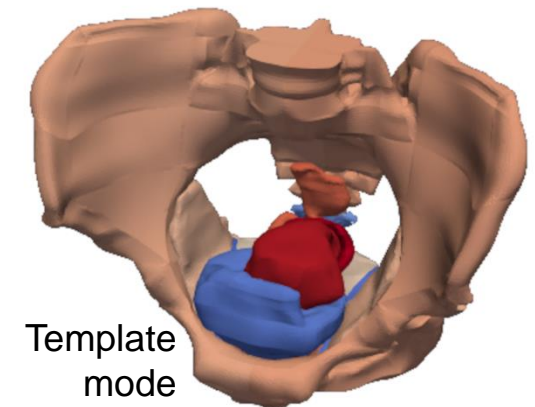
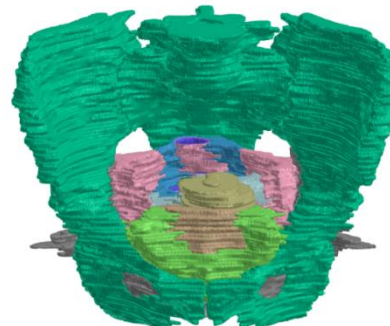
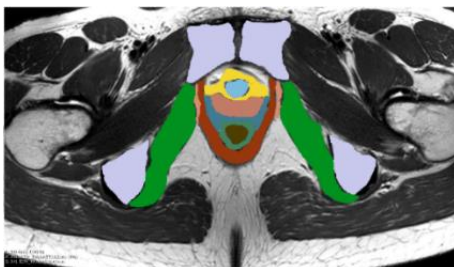
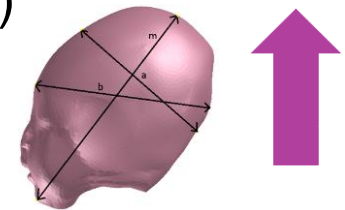
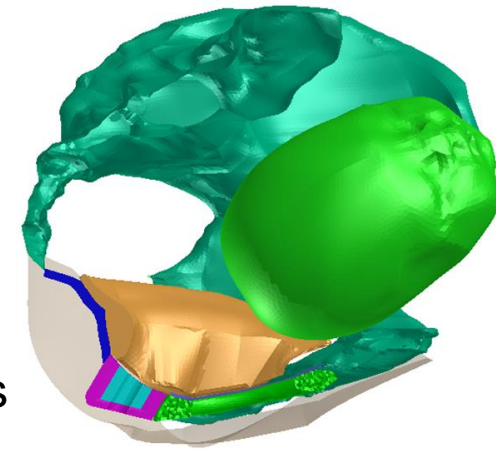
► Vaginal birth difficulties leading to pelvic floor disorders (PFD)

- Pilsen Faculty of Medicine of the Charles University and University Hospital in Pilsen
- The Institute for Mother and Child Care in Prague
- Mechanical strain as stretch injury predictor

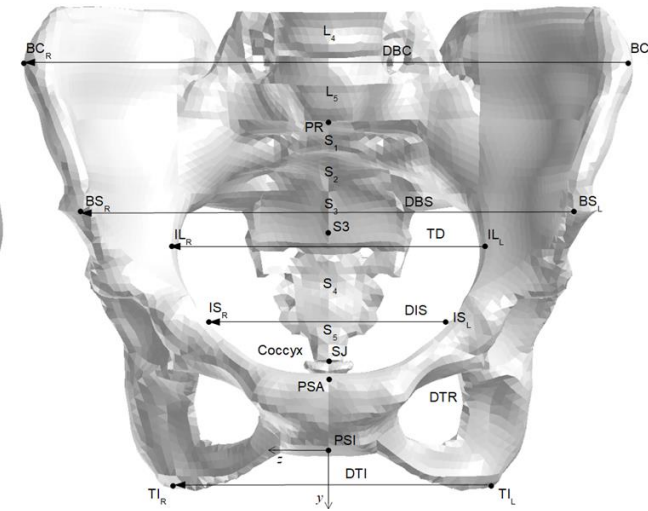
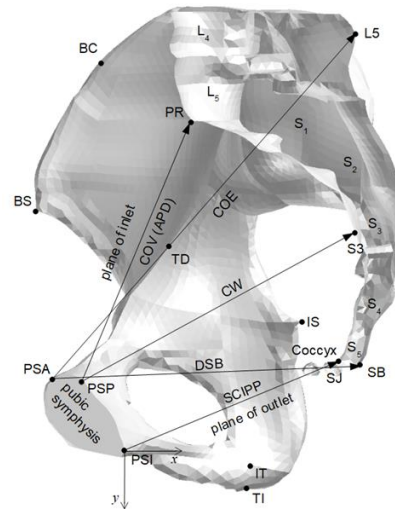


► Computational biomechanics

- Reference (template) biomechanical FE model
- Pelvic floor (muscles and tissues)
 - Hexagonally shaped structure connecting bony pelvis at the sacrum, ischial spines and pubic bones
- Personalization by image registration (MRI-based data)
 - MRI not common practice for pregnant women due to radiation dose and related risks
 - Only when ultrasound unable to detect causing issues in a problematic pregnancy or in long-term injuries assessment

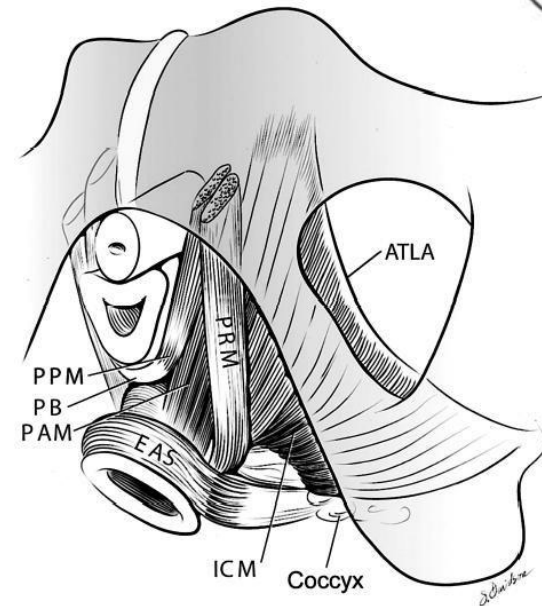
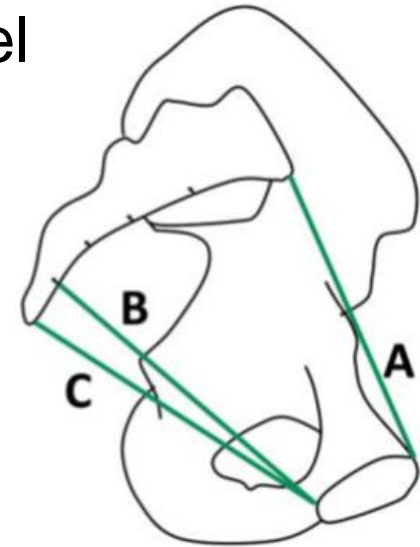
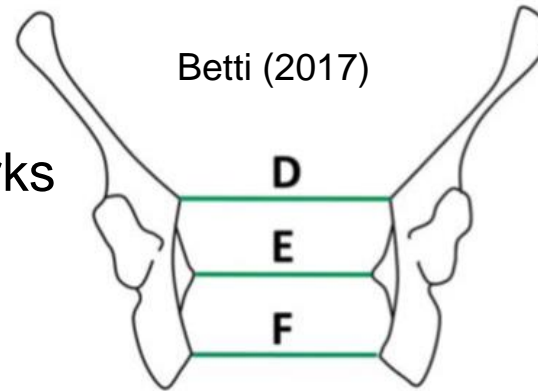


- ▶ Previous work at UWB (only bony pelvis) and UWA (Amira Ilyas) under MPE Engineering Research Project (mesh-morphing full pelvic floor model using RBF adding soft tissue landmarks)
 - ▶ Insufficient accuracy to morph the full pelvic floor model using either 23 (bony pelvis landmarks only) or 33 landmarks
 - ▶ Additional study to be done (soft tissue MRI-based internal landmarks)
 - ▶ Correlation between external and internal dimensions (*paper in review*)
 - ▶ **Critical (short) injury risk** versus POP analysis (long-term)
 - ▶ Detailed full pelvic floor model versus simplified child-birth model



- ▶ Simplified parametric predictive child-birth model
- ▶ Second stage of labor
 - ▶ Baseline bony pelvis landmarks defining the child-birth canal
 - ▶ Pelvic floor muscles warping

1. Baseline landmarks-based warping to target geometry
2. Verifying bony pelvis and internal structures to MRI
3. Implementation under 3D Slicer



Ashton-Miller and Delancey (2004)

► Questions?

