UNIVERSITÀ DEGLI STUDI DI PADOVA

INTERNATIONAL CAE CONFERENCE
2020, 30th November - 4th December
Vicenza, Italy

Centre for Mechanics of Biological Materials

# LOWER LEG BIOMECHANICS AND SKI BOOT: COMPUTATIONAL APPROACH

**Chiara Giulia Fontanella *[1,2], Ilaria Toniolo[1,2], Lorenzo Bortolan[3], Emanuele Luigi Carniel[1,2]**

[1] Centre for Mechanics of Biological Materials, University of Padova, Padova, Italy
[2] Department of Industrial Engineering, University of Padova, Padova, Italy
[3] Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Verona, Italy

## Aims

Computer methods provide reliable support for the investigation of the mechanical functionality of biological structures. Computational models can be further exploited to analyze interaction phenomena between biological tissues and devices, providing data that allow for their reliability assessment and optimal design. With specific regard to ski boots, the methods of computational biomechanics allow analyzing the stress and the strain fields that occur within lower leg and foot tissues, depending on ski boot conformation, buckling level and skiing actions [1-2]. Such mechanical stimuli determine relevant phenomena, with particular regard to vasoconstriction effects.

## Materials and methods

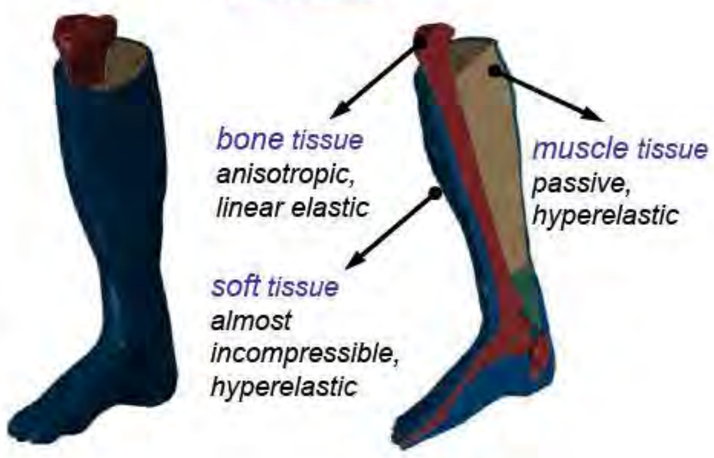
### Leg biomechanics

- ❑ experimental tests for the evaluation of the mechanical behavior of lower leg tissues
- ❑ characterization of leg tissues mechanics by means of hyperelastic constitutive formulations and identification of constitutive parameters
- ❑ development of the virtual solid model of lower leg structures from CT scan and anatomical data
- ❑ finite element model of lower leg

CT SCAN

MECHANICAL TESTS

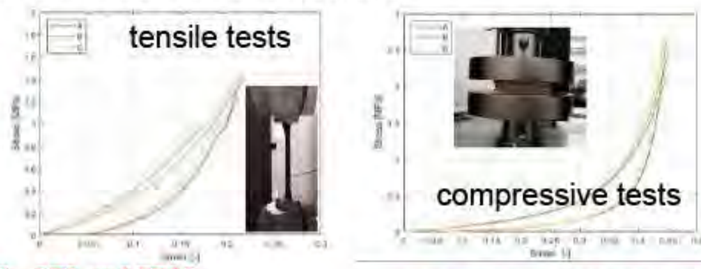
FEM MODEL




### Ski boot mechanics

- ❑ tensile and compression tests on ski boot components and inner boot materials
- ❑ definition of the virtual solid model of the ski boot from CAD model
- ❑ geometric configuration of inner boot from 3D laser scanner acquisitions
- ❑ finite element model discretization

TENSILE AND COMPRESION TESTS




INNER BOOT – STL and FEM MODELS

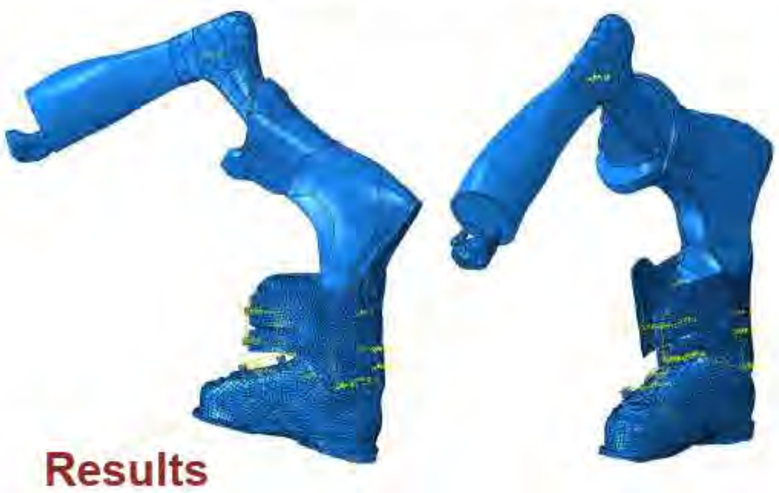
SKI BOOT - CAD MODELS

### Experimental analysis

- ❑ evaluation of interaction phenomena between ski boot and biological tissues because of ski boot buckling

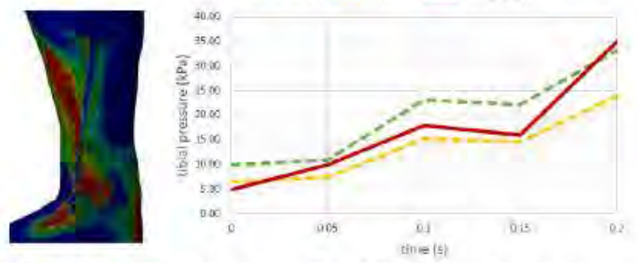
### Computational analysis

- ❑ specific computational algorithms are exploited to simulate ski boot buckling



INITIAL STEP — SECOND STEP — FINAL STEP

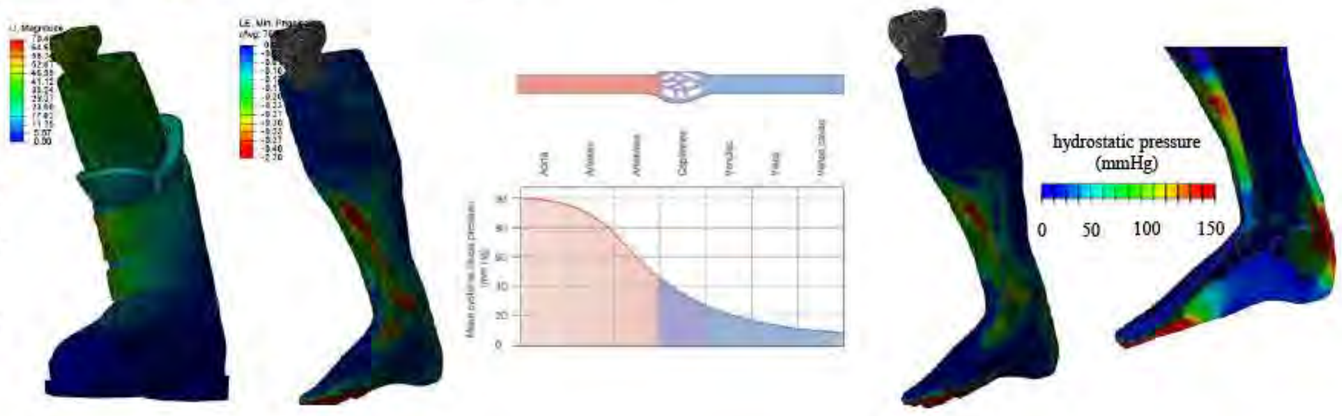
FEM MODEL VALIDATION




- ❑ comparison of tibial pressure between experimental data and computational results

## Results

- ❑ the developed model allows evaluating stress and strain fields within biological tissues because of ski boot buckling
- ❑ the intensity of such mechanical stimuli may induce vasoconstriction phenomena, jeopardizing the ergonomics of the device
- ❑ hydrostatic pressure (mmHg) within leg tissues compared to the mean systematic blood pressure




## Discussion and conclusion

The principal challenges of computational modeling consist in the identification and validation of the models, and the solving time due to model complexity. In-silico analysis leads to an interpretation of the global and local response of lower leg tissues considering ski boot performance and buckling. Computational methods provide reliable tools and quantitative data that permit a rational approach during the design and the optimization process of sport devices by considering the actual ski boot ergonomics.

## Funding

Progetto POR FESR 2014-2020: "SMAC: SMArt and Creative technologies for the sportsystem".

## References

[1] A.N. Natali, S. Todros, C. Venturato, C.G. Fontanella (2014). Evaluation of the mechanical behaviour of Telemark ski boots: part I – materials characterization in use conditions, P I MECH ENG P-J SPO. 228:195-203. [2] A.N. Natali, C.G. Fontanella, E.L. Carniel, C. Venturato, P.G. Pavan, S. Todros (2014). Evaluation of the mechanical behaviour of Telemark ski boots: part II - structural analysis,P I MECH ENG P-J SPO, 228:204-212.

***Corresponding author:** **Chiara Giulia Fontanella, University of Padova, Via Venezia 1 I-35131 Padova (Italy) – chiaragiulia.fontanella@unipd.it**