HAND ARM VIBRATION

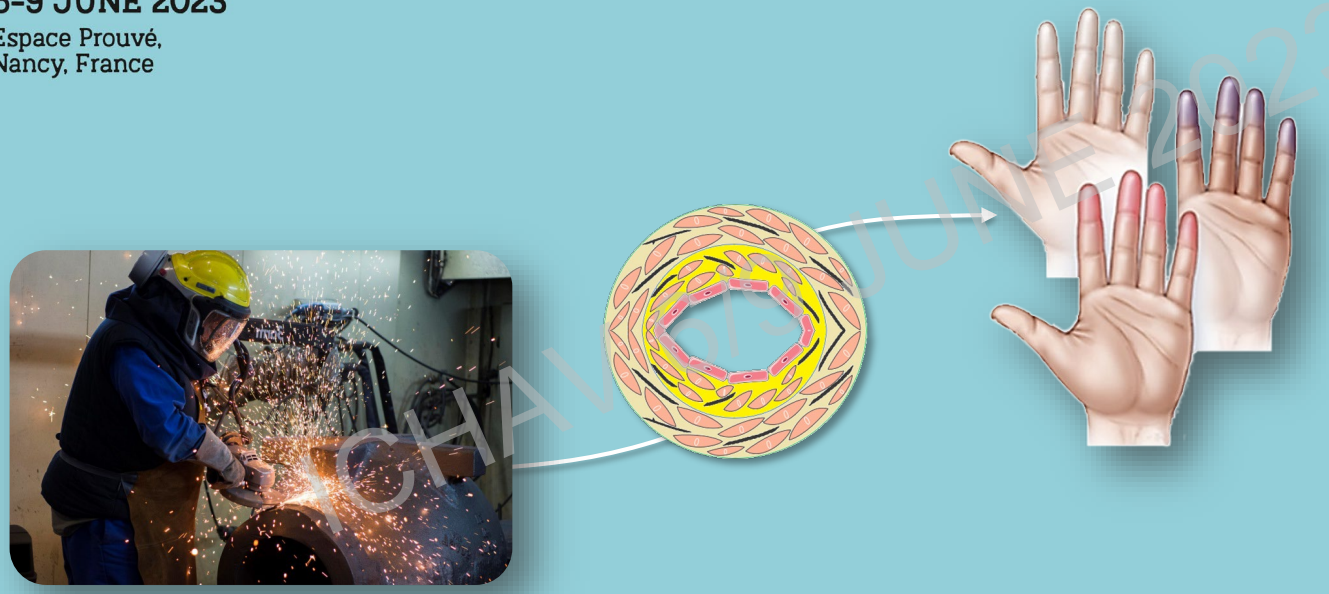
Arterial stenosis stemming from vibration-altered Wall Shear Stress:

A way to prevent vibration-induced vascular risk?

International conference

6-9 JUNE 2023

Espace Prouvé,
Nancy, France



Christophe NOEL

Maha REDA

Nicla SETTEMBRE

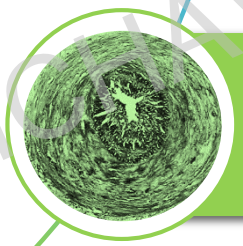
Emmanuelle JACQUET

Talk outline

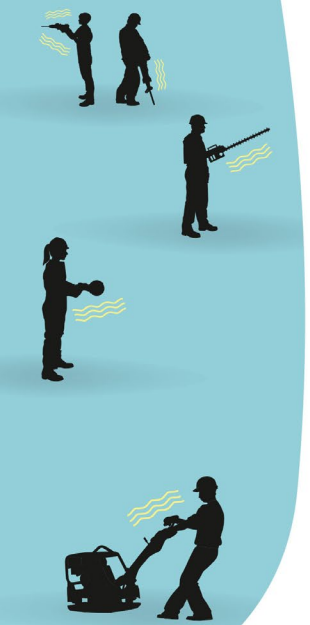
General framework / Goal

Strategy: multiscale approach

Acute effects



Chronic effects



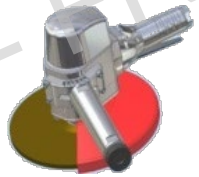
Hand-Arm Vibration general issues and goal

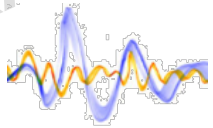
Hand-Arm Vibration in France

Workers exposed: **2.2 M**
8% > 20 h/week

200 occupational diseases/year
8.5M€/year

> ¾ using rotating hand-held machines





f > 50 Hz

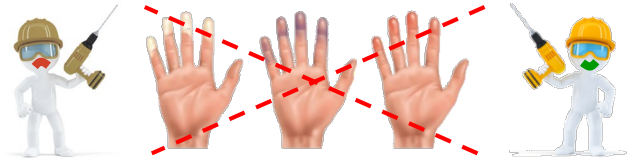
Regular exposure, high level => vascular, sensory-neuronal, musculoskeletal disorders

A need to protect the workers: ISO 5349 standard +

Pathophysiological effects of vibration > 50 Hz **underestimated**

Improving the vibration exposure assessment

Better protect workers against Vibration White Finger

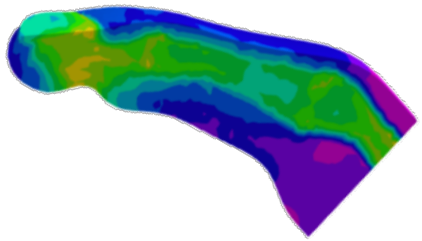


A two-scale approach

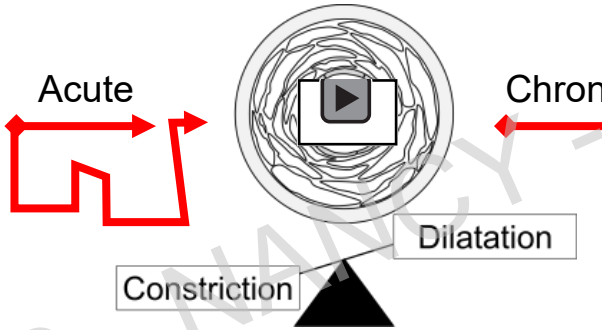
From working conditions to pathological effects

Working conditions → Acute → **Mechanical effects** → Acute → **Physiological effects** → Chronic → **Pathological effects**

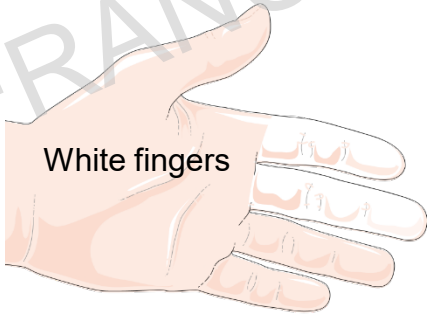
Acceleration/Force



Stress/dissipated power



Vasoregulation unbalance

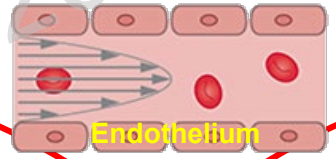


Vasospasm

A two-step process

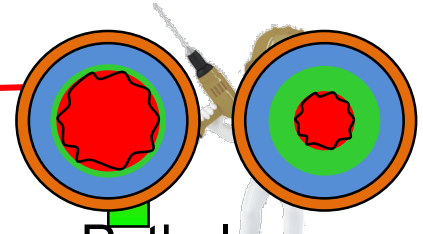
Biomechanics
Vibration

Model A



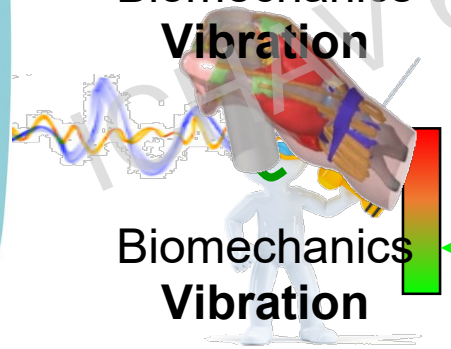
Physiology
Vibration-altered WSS

Model B



Pathology
Arterial stenosis

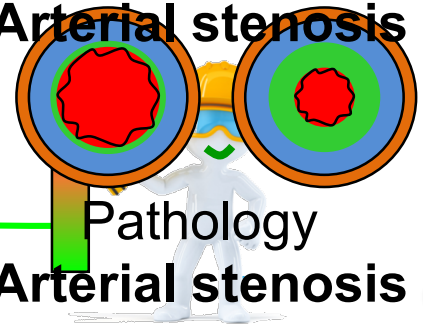
Model A



Biomechanics
Vibration

Physiology
Vibration-altered WSS

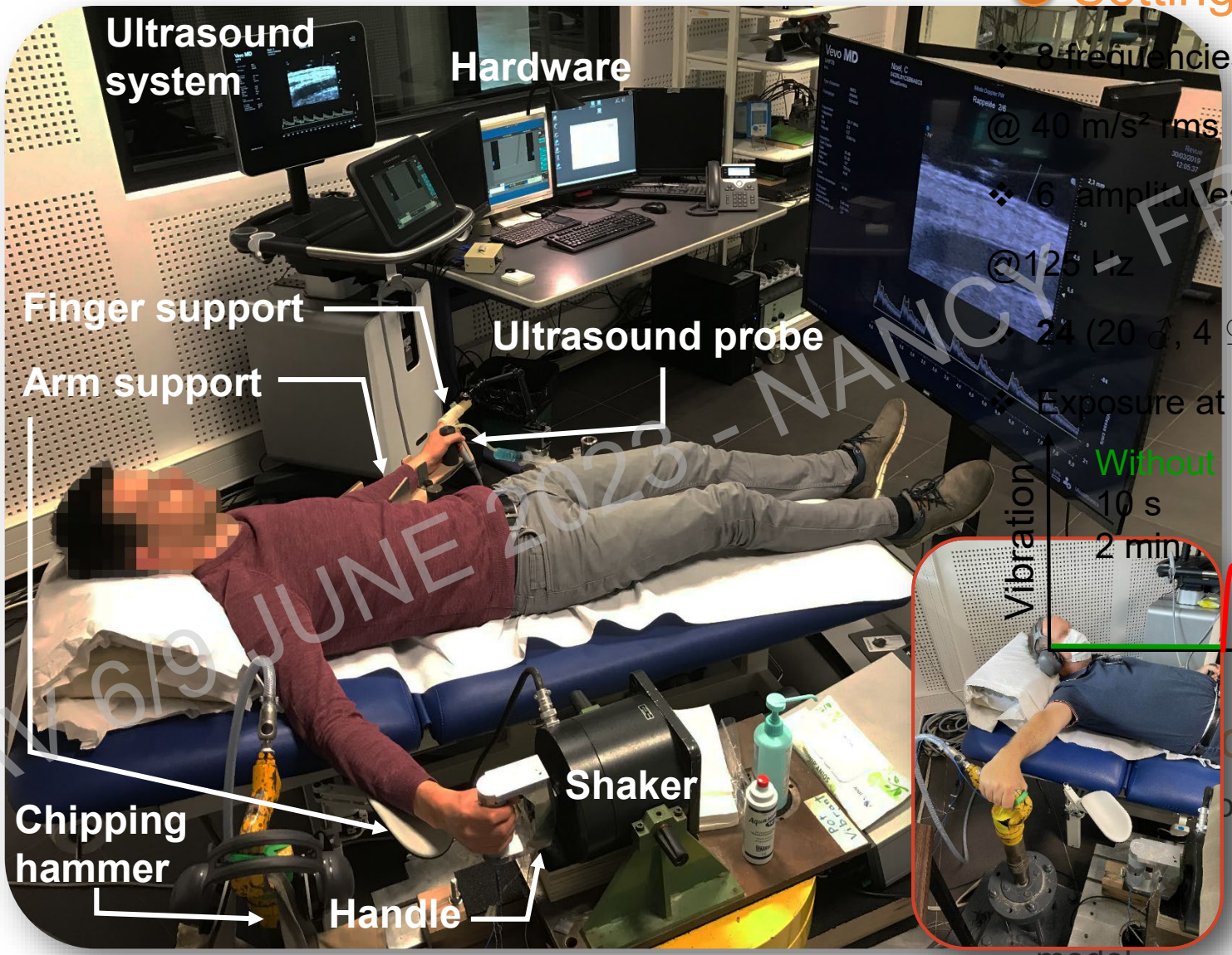
Model B



Pathology
Arterial stenosis

Noël et al., **Vibration**, 5(2), 2022

Wall Shear Stress assessment



Settings

- 8 frequencies: **31 - 400 Hz**
- @ 40 m/s² rms, unweighted
- 6 amplitudes: **1 - 40 m/s²**
- @125 Hz
- **24** (20 ♂, 4 ♀) healthy subjects
- Exposure at **23°C** (±0.5°C):

Without	With	Back
10 s	10 s	10 s
2 min	2 min	2 min

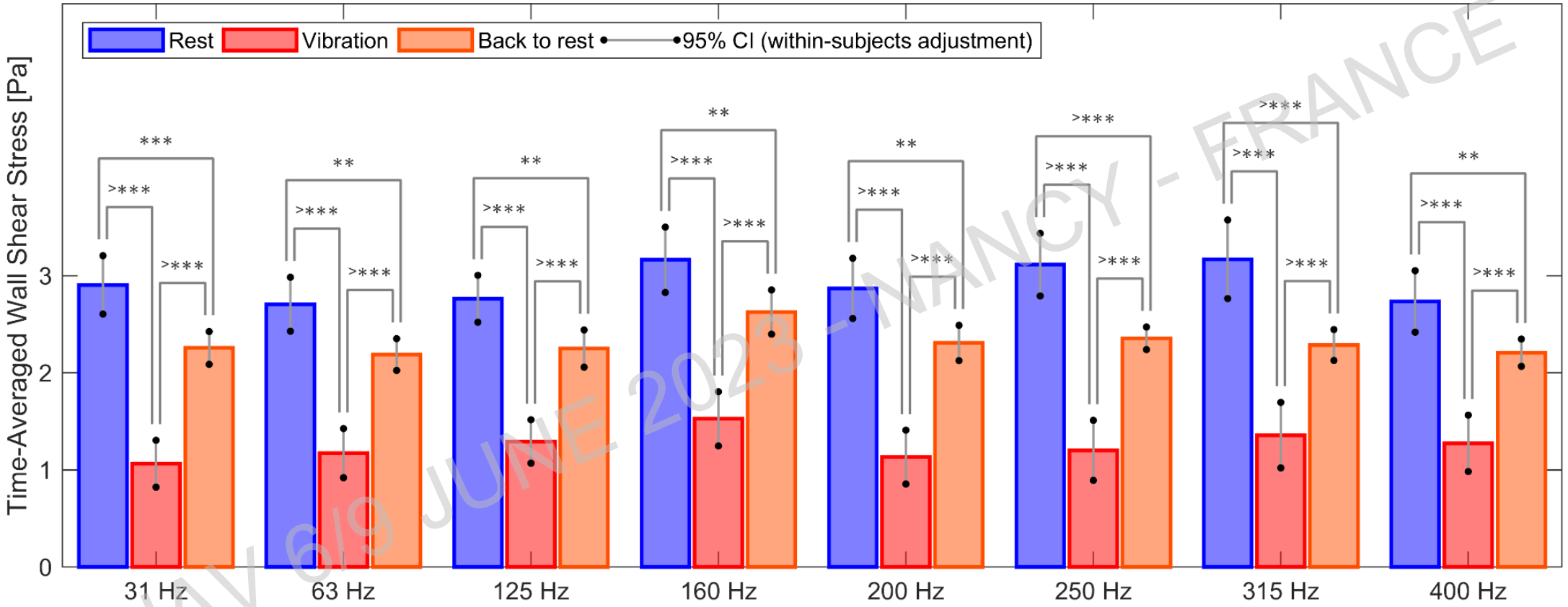
d

on image processing

pulsatile fluid flow model

Noël and Settembre, **Journal of Biomechanics**, Volume 131, 2022

Wall Shear Stress: effect of frequency

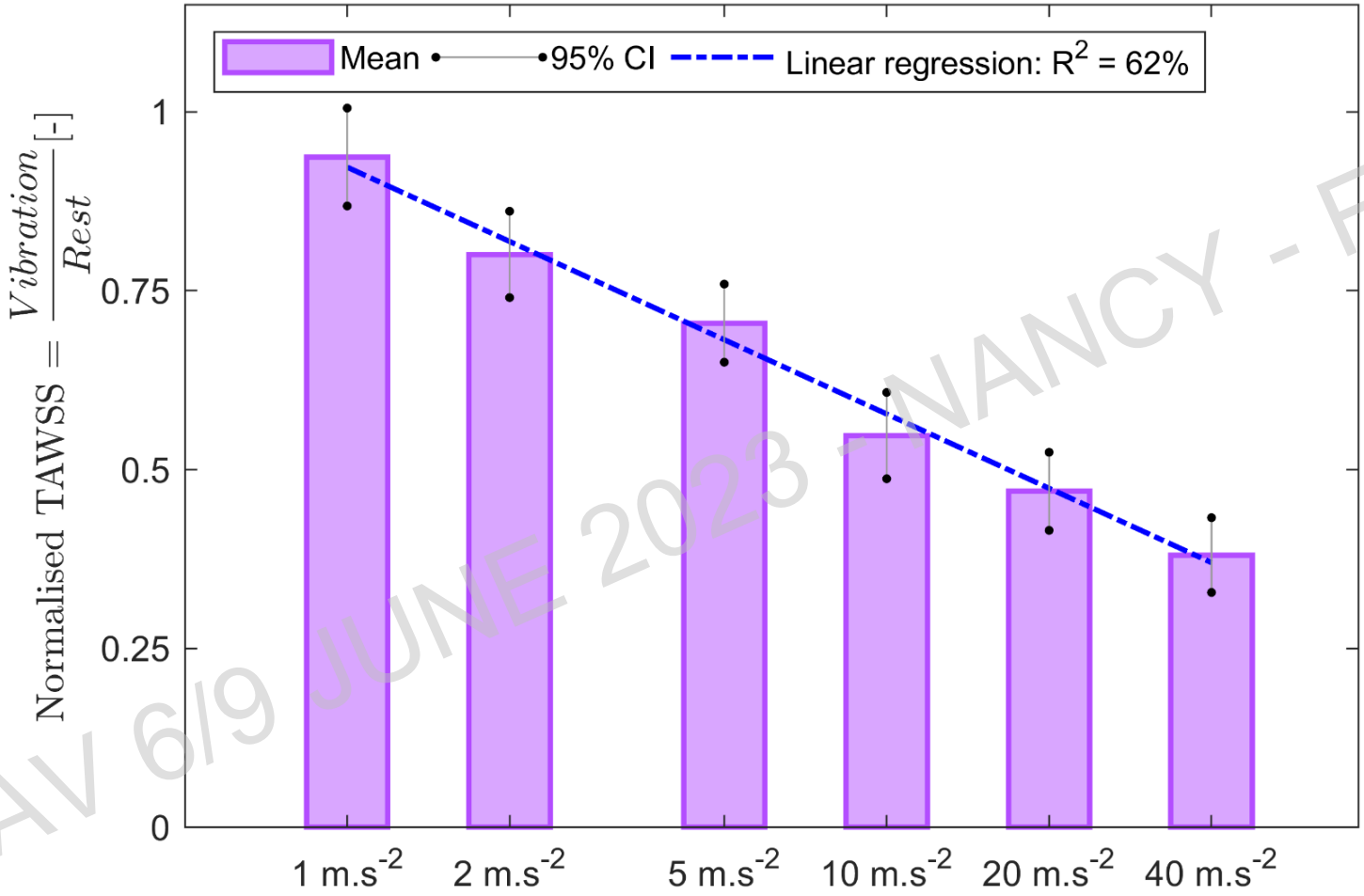


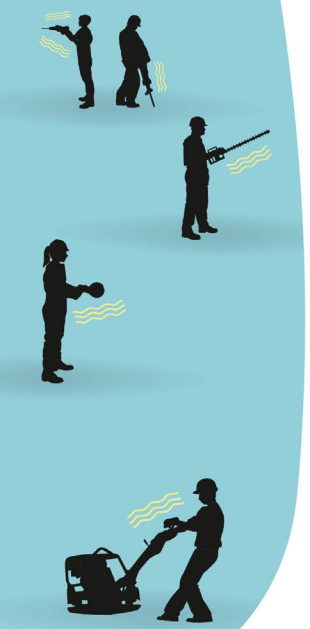
n.s. No Significance
* p < 0.05
** p < 0.01
*** p < 0.001
>*** p < 0.0001

- For each frequency =>WSS drops
- WSS drop is frequency **independent**

Rest	Vibration
2.9 Pa	**1.2 Pa**

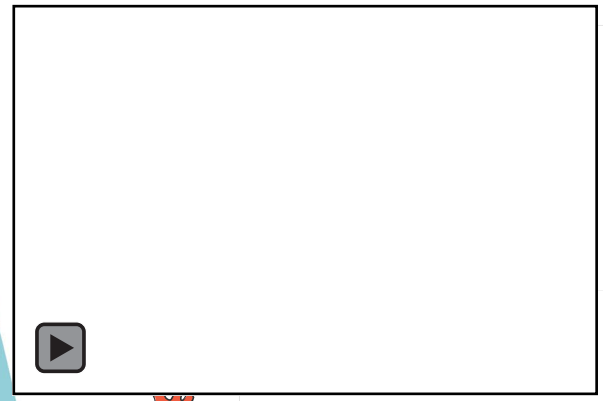
Wall Shear Stress: effect of vibration level

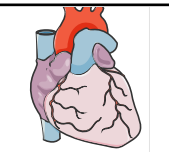


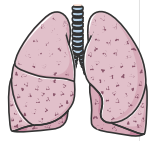


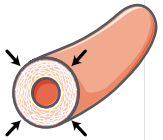
- WSS drop **depends on** vibration acceleration
- Normalized_WSS= $-\beta_1 \log_2(AccelerationRMS) + \beta_2(Age) - \beta_3(HandMass) + \beta_0, \beta_i > 0$

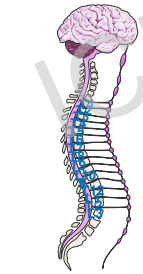
Haemodynamic oscillations in fingers arteries

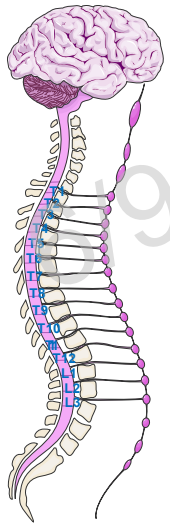


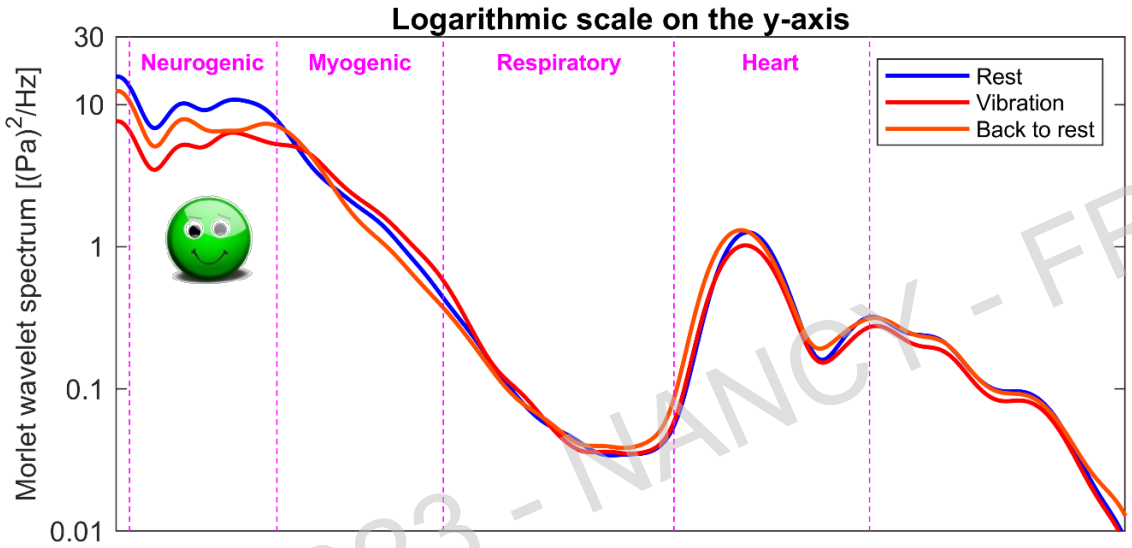


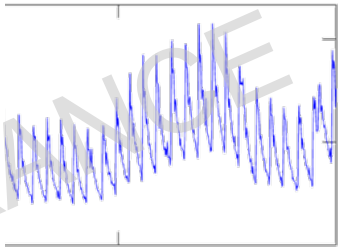


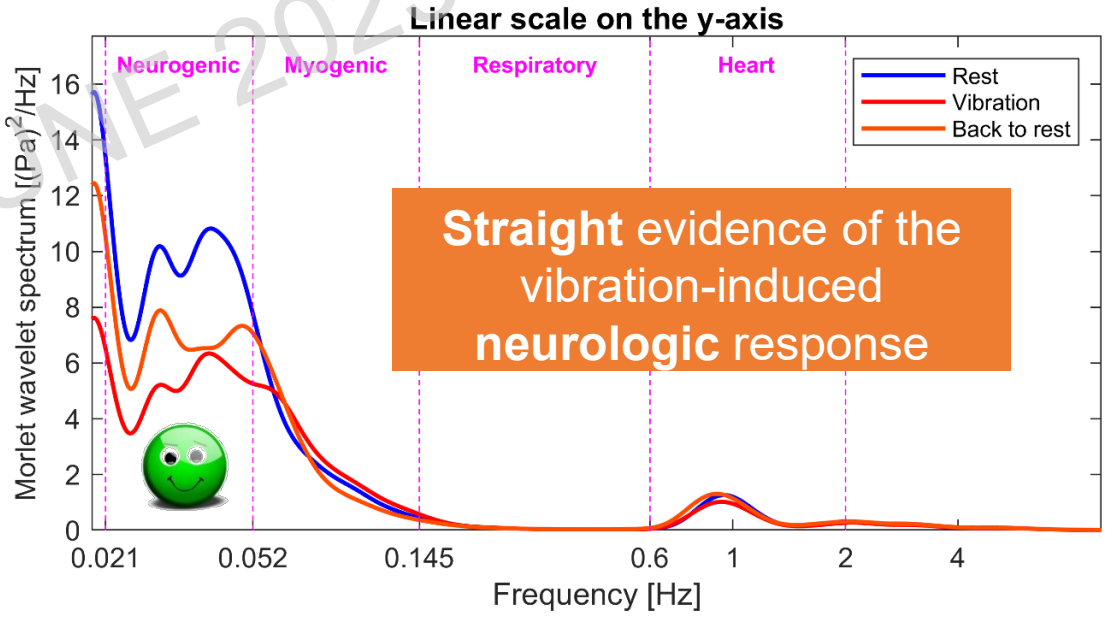








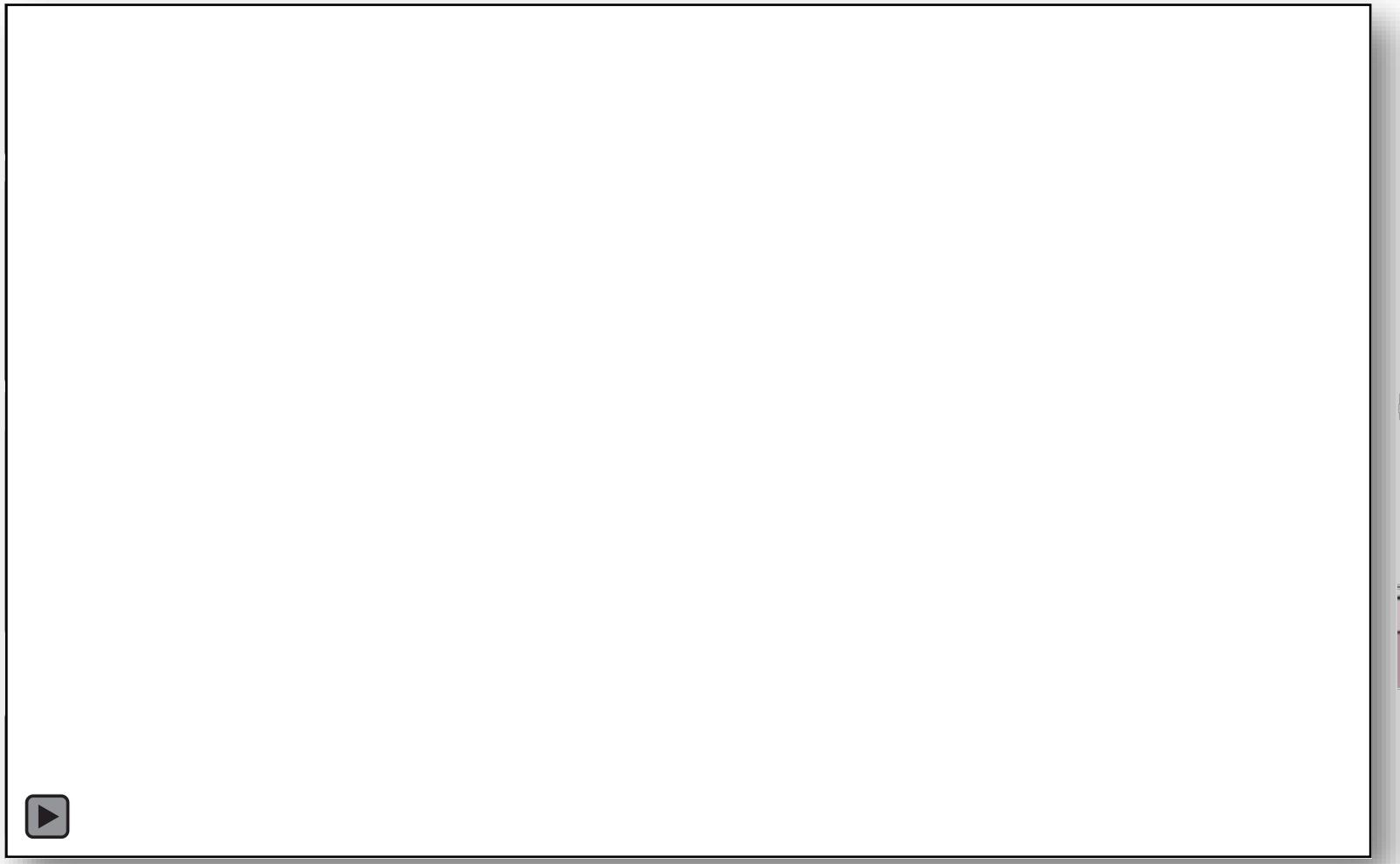




Straight evidence of the vibration-induced **neurologic** response

Noël and Settembre, **Computer in Biology and Medicine**, under review

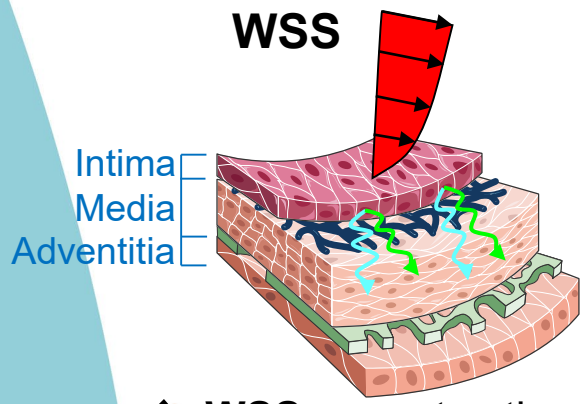
Mechanobiological modelling of arterial stenosis



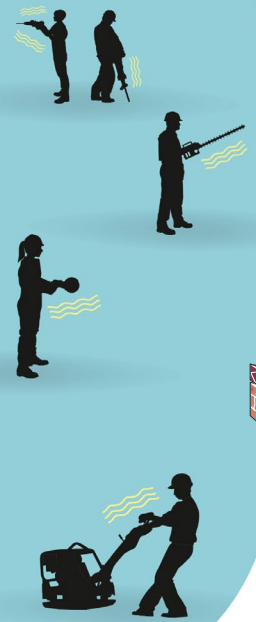
"This is gobbledygook. I asked for mumbo-jumbo."

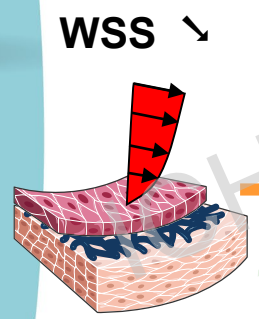
Modelling the intimal hyperplasia mechanisms

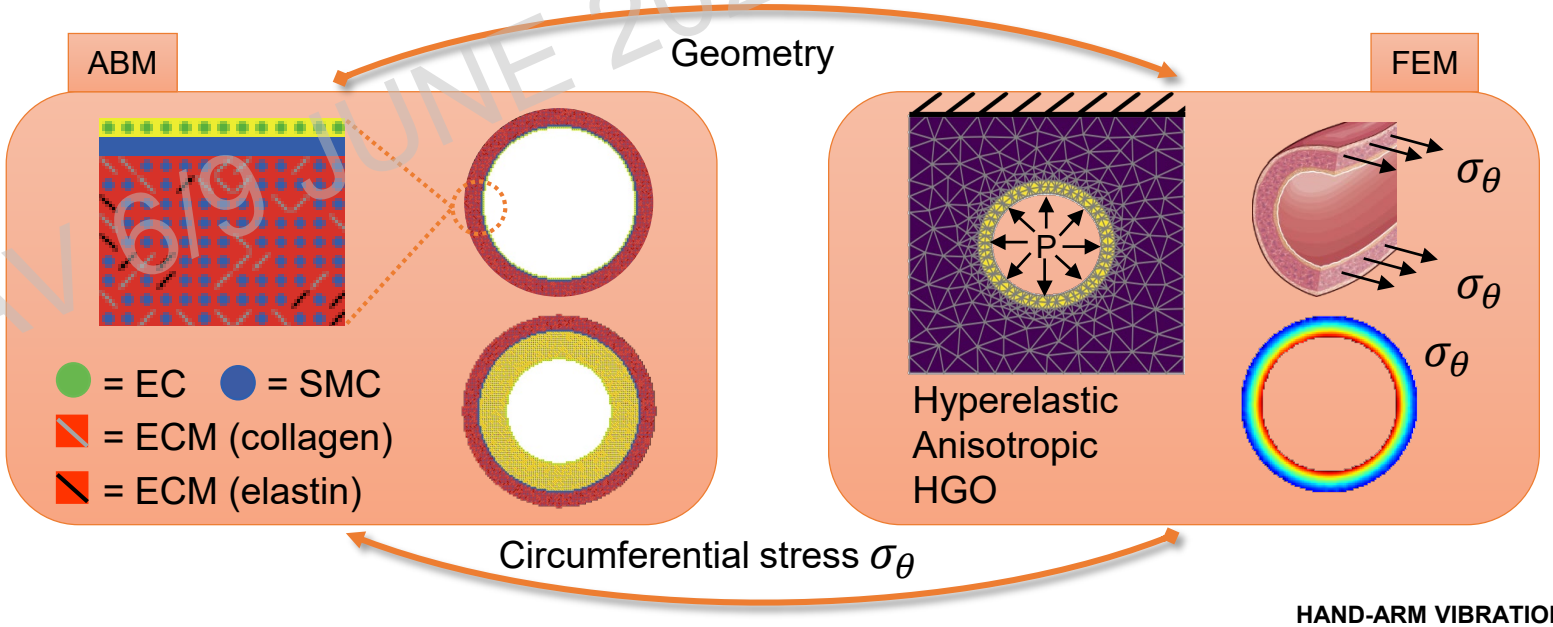
- **Intimal hyperplasia:** abnormal proliferation/migration of smooth muscles cells

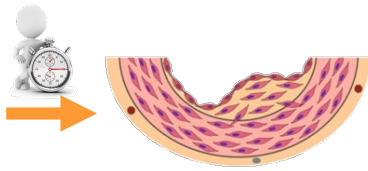


- **Coupling ABM-FEM:** Agent-Based Model - Finite Element Method





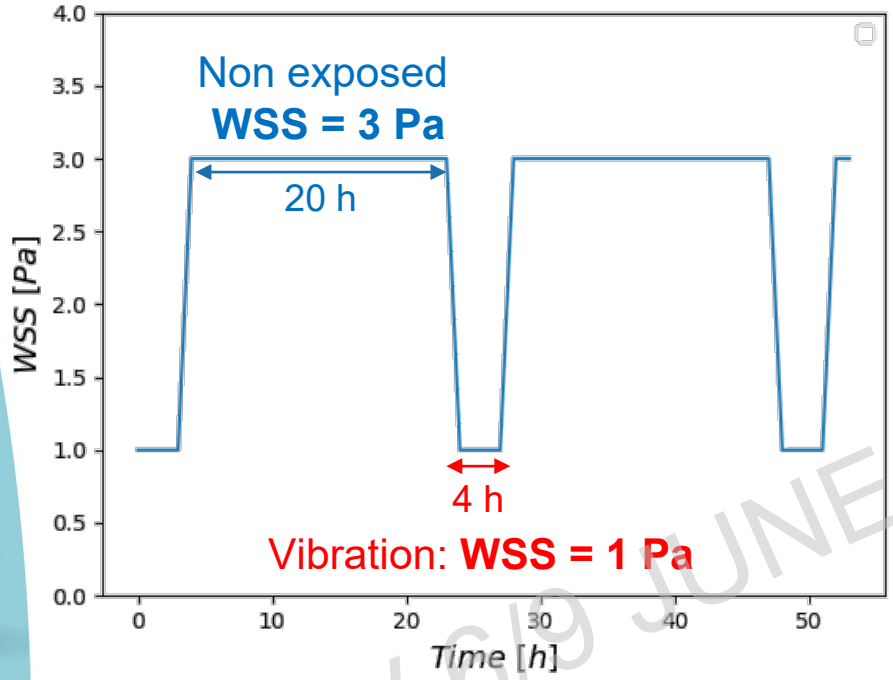




Reda et al., **Biomechanics and Modeling in Mechanobiology,** 21, 1457–1481, 2022

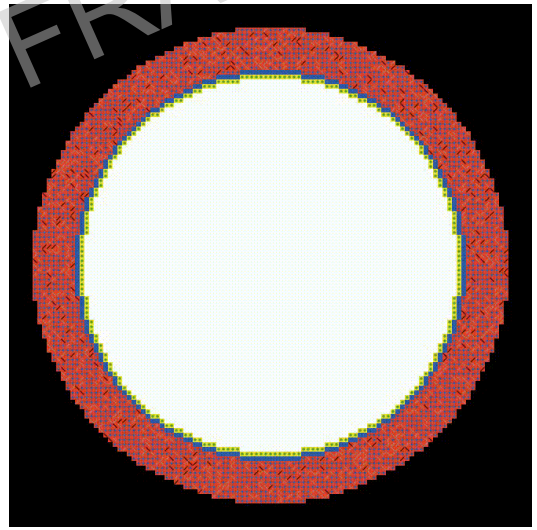
Modelling arterial stenosis: exposure

- Vibration exposure: 4 hours per day - 40 m/s² rms non weighted for 10 years



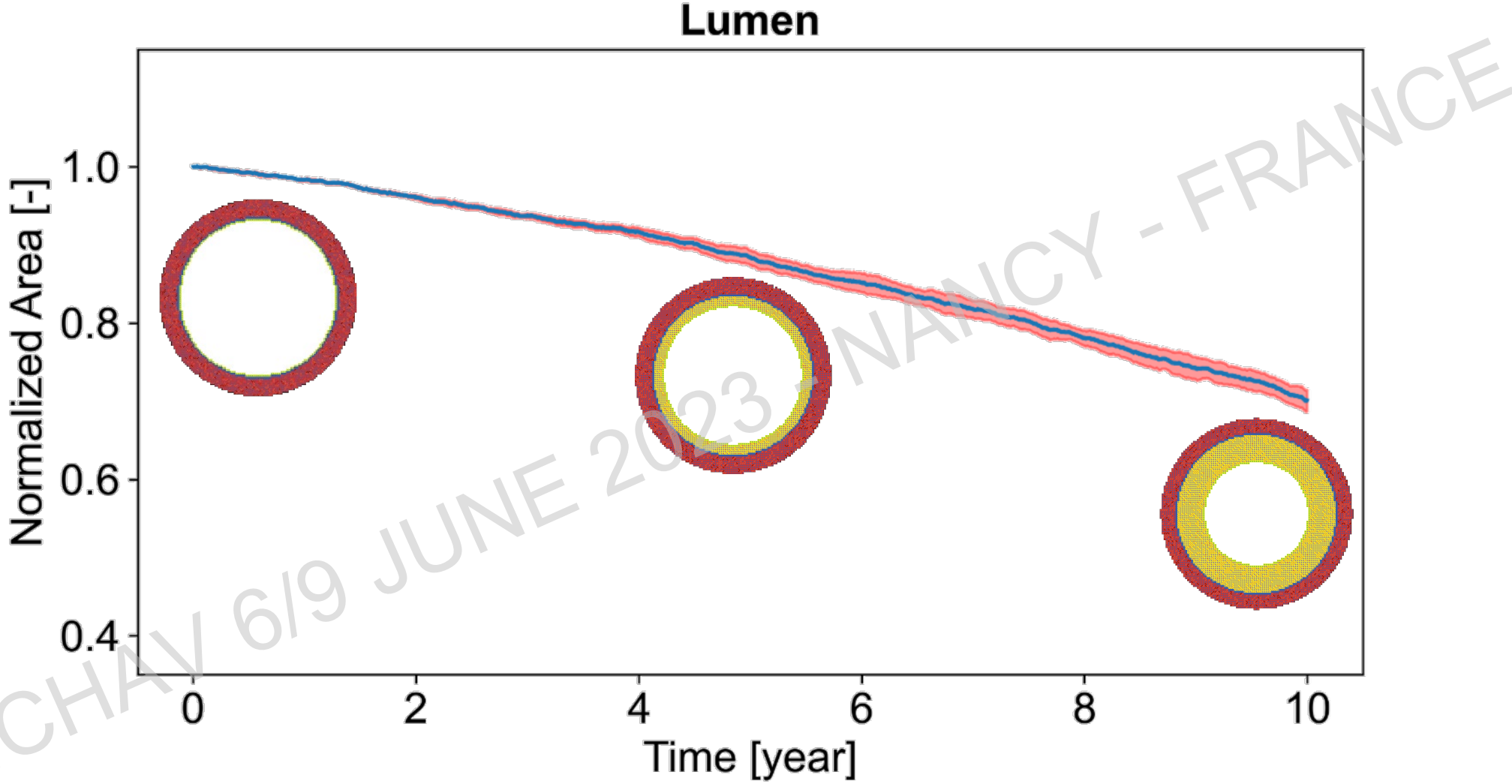
WSS = 1 Pa

ABM ⇄ FEM



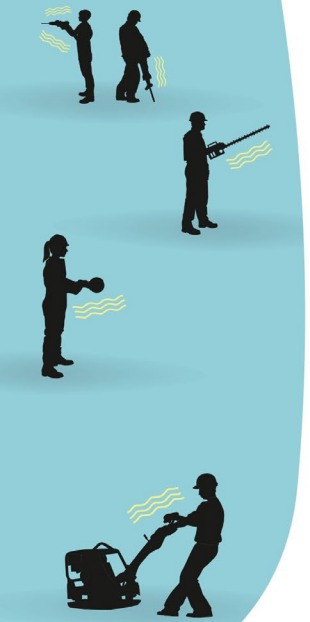
10 years

Modelling arterial stenosis: results



30% of stenosis after 10 years of exposure to vibration 4 h per day

Conclusion

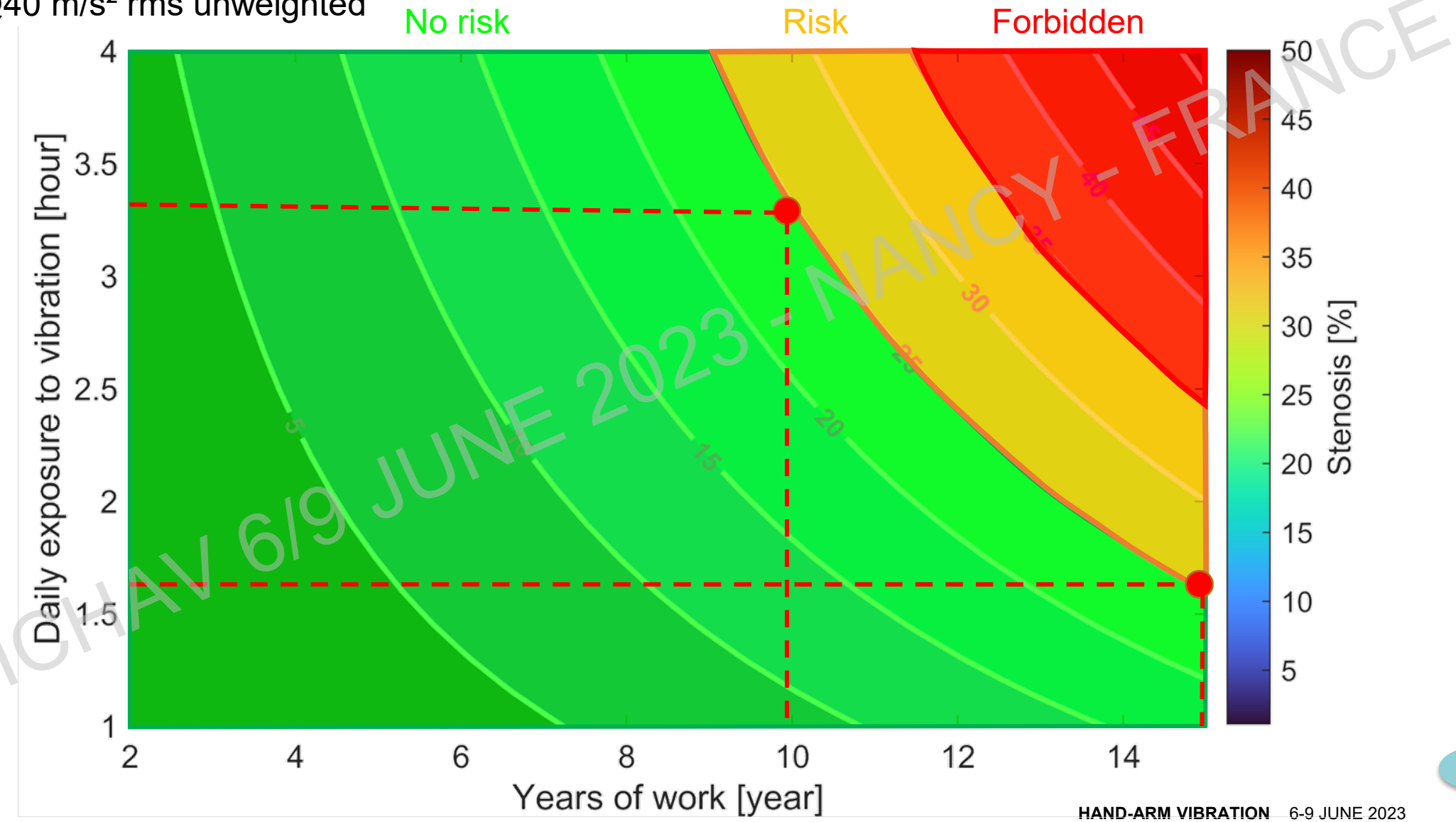


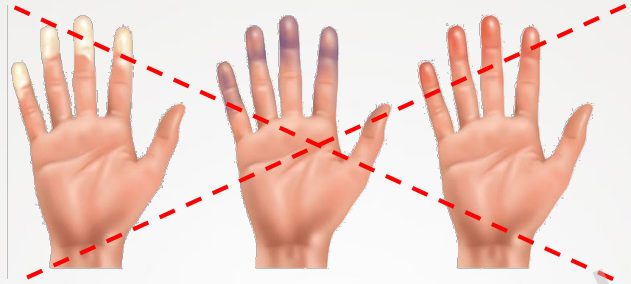
All models are wrong,
but some are useful.

George E. P. Box

Perspective: predictability chart for arterial stenosis i.e. pathology

Degree of stenosis (%) computed according to the years of the working life and the daily exposure time to a vibration@40 m/s² rms unweighted





Our job: making yours safer

Thanks for your attention

www.inrs.fr YouTube in