The Biomechanical Influence of Static Friction and Shearing on Heel Tissue Damage

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The Role of Friction and Associated Shear in Heel Ulcers: Reducing Friction Protects Tissues

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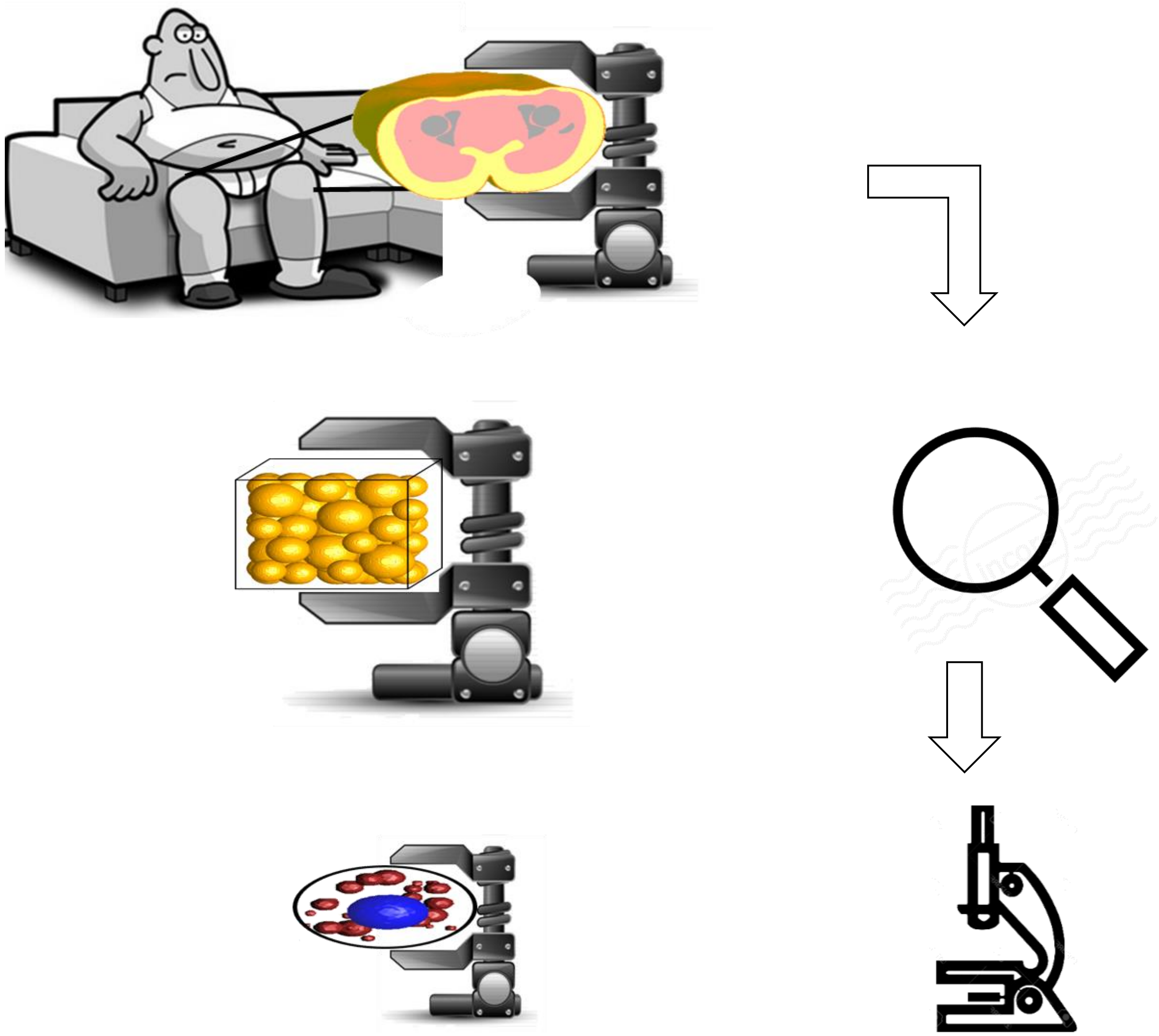
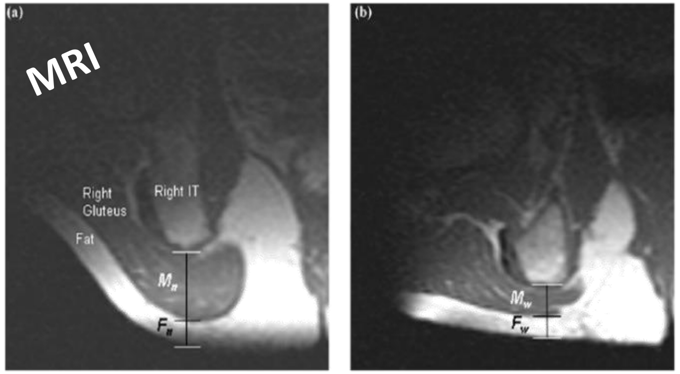
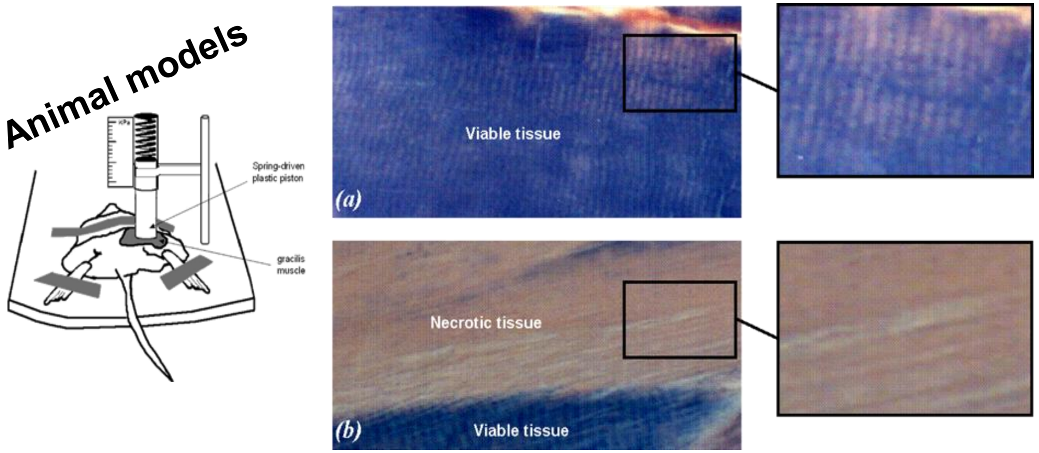
When bodyweight applies, tissues and cells are distorted

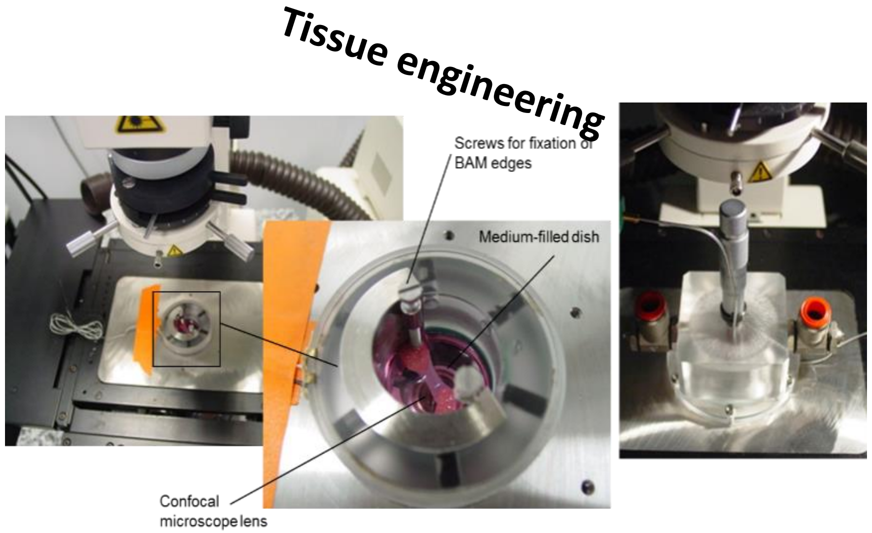


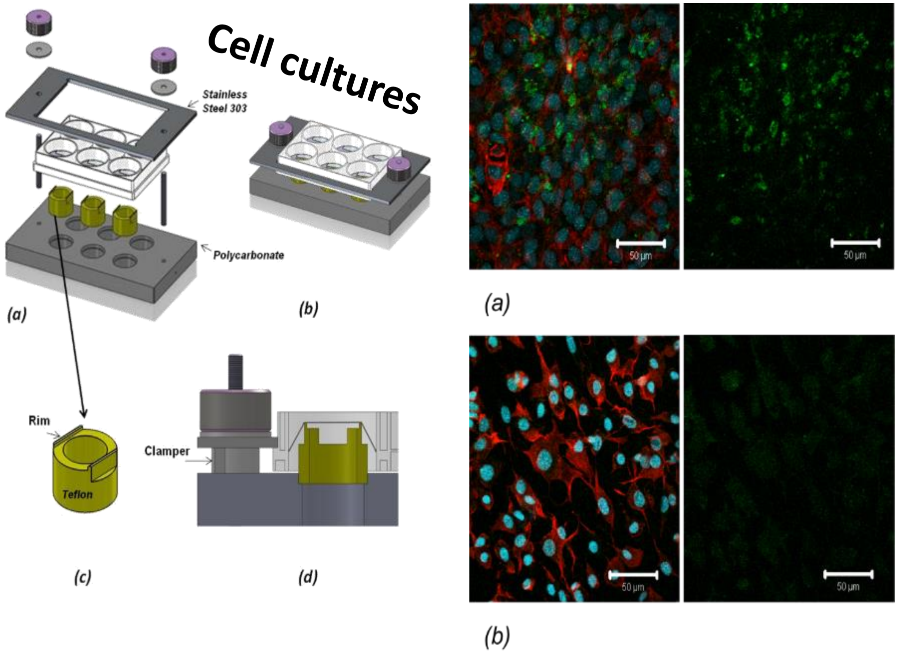
Shoham et al. *Biomech Model Mechanobiol* 2016

All model systems indicate:
Sustained tissue deformations damage cell structure and function

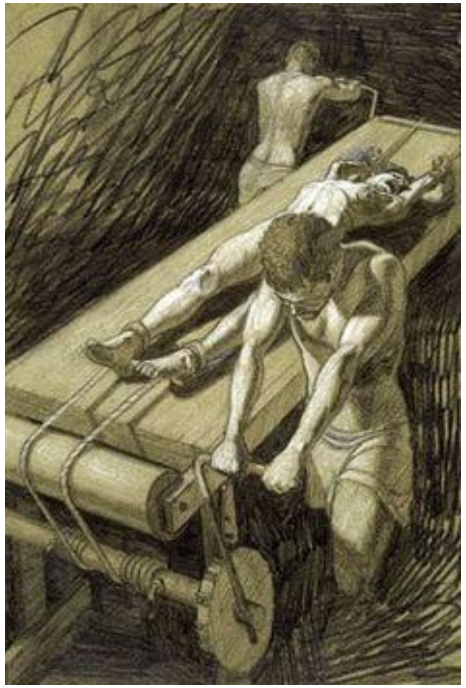


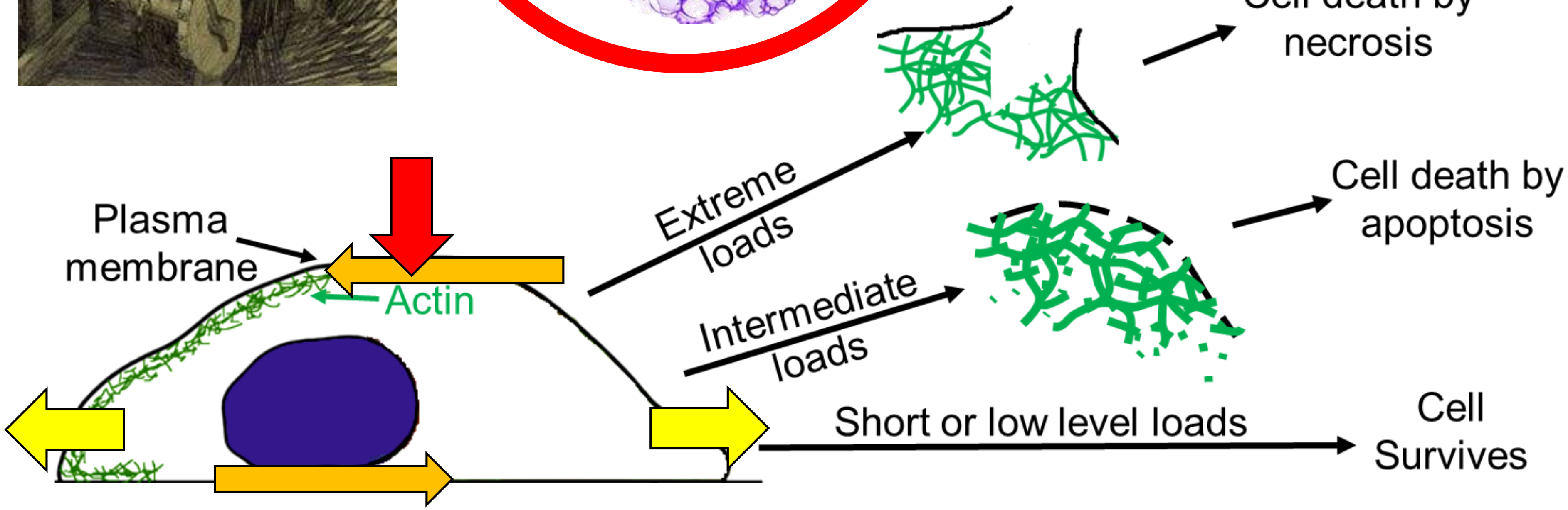






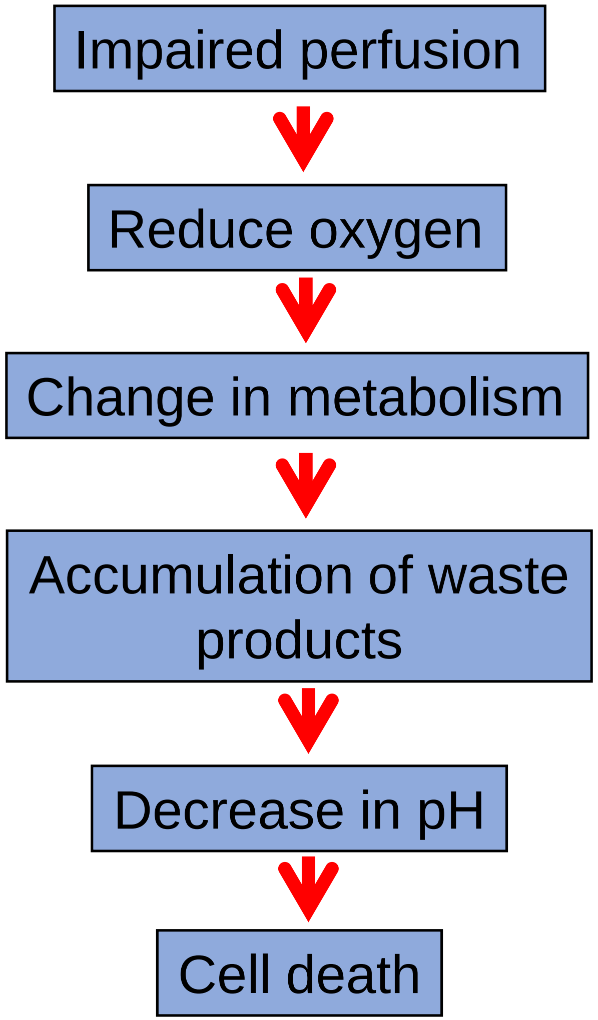
Sustained cell distortion causes the skeleton of the cell (cytoskeleton) to break-down



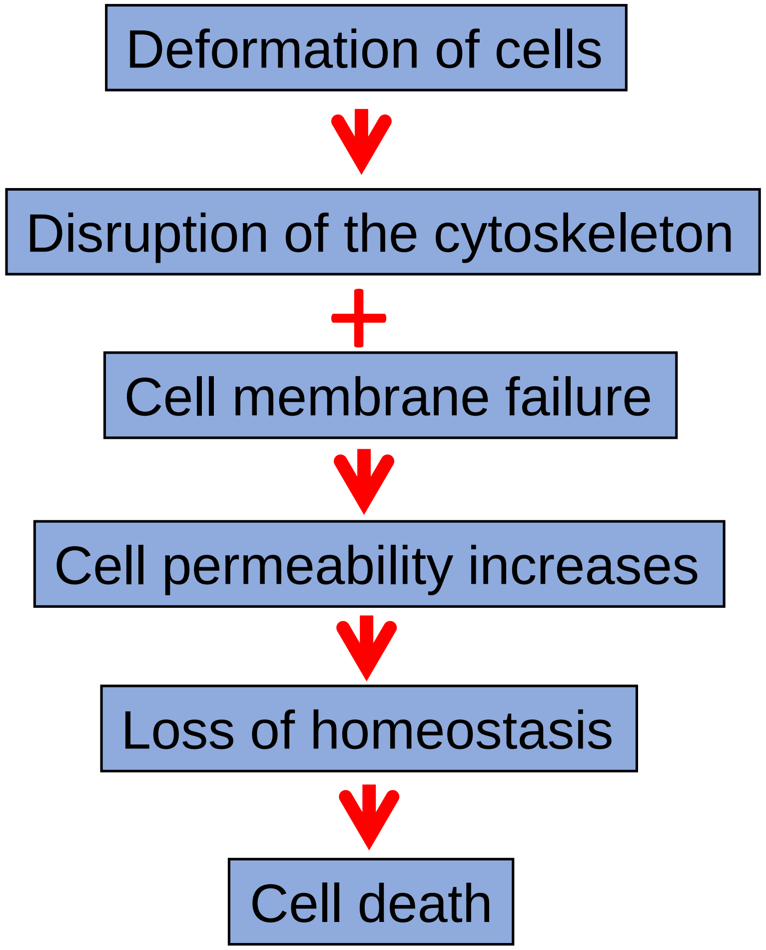


Weihs and Gefen *Medical Engineering & Physics* 2016

Ischemia



Deformation



Ischemia

Impaired perfusion

Reduce oxygen

Chang… …sm

Accumulation of wast… products

Decrease in p…

Cell death

Up to 6 – 8 hours

Deformation

Deformation of cells

…isruption of the cytoskeleton

Cell … …ure

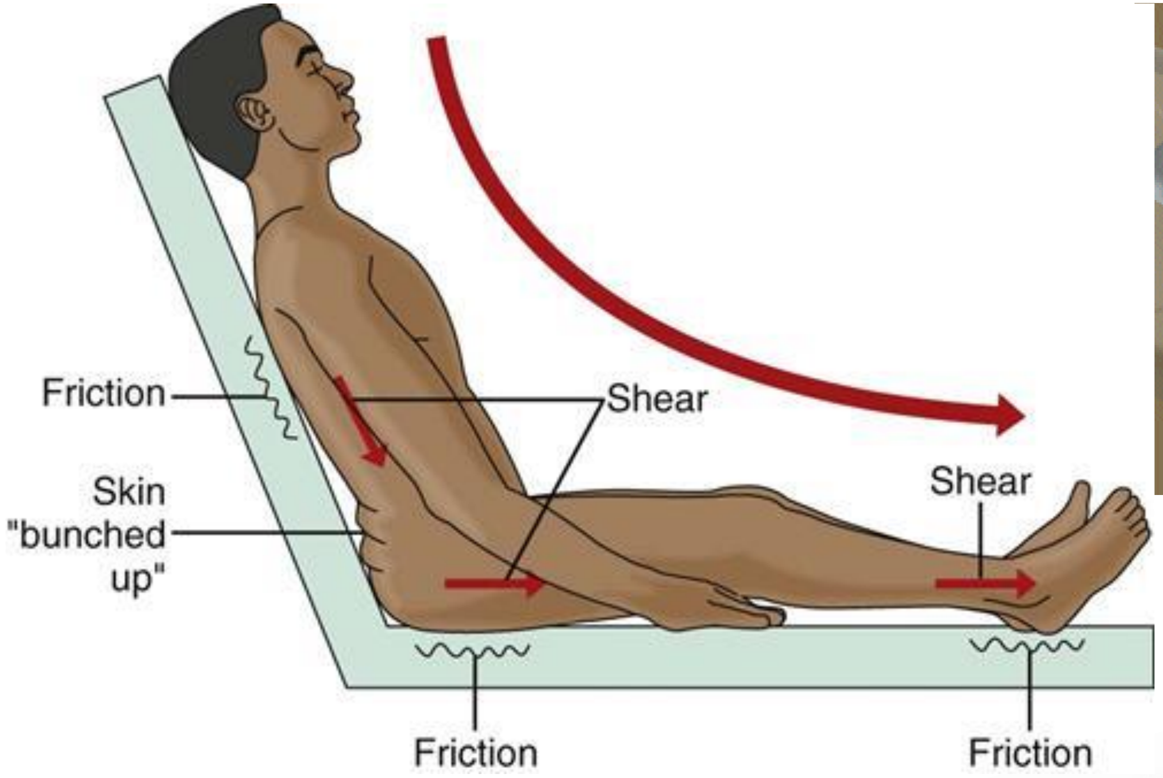
…ermeability increases

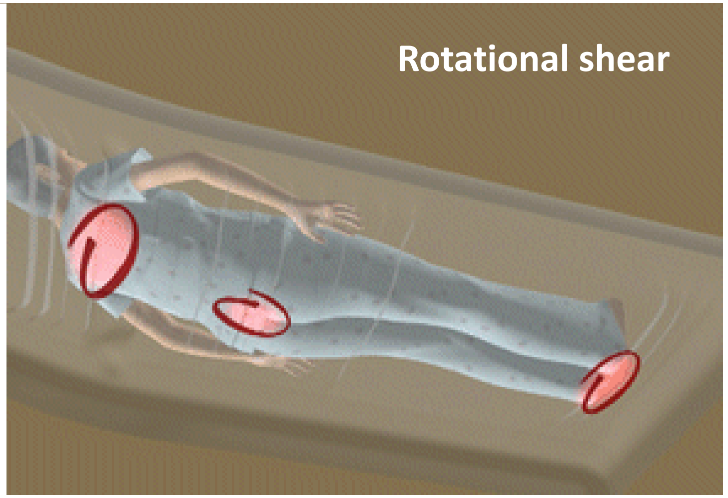
…of homeostasis

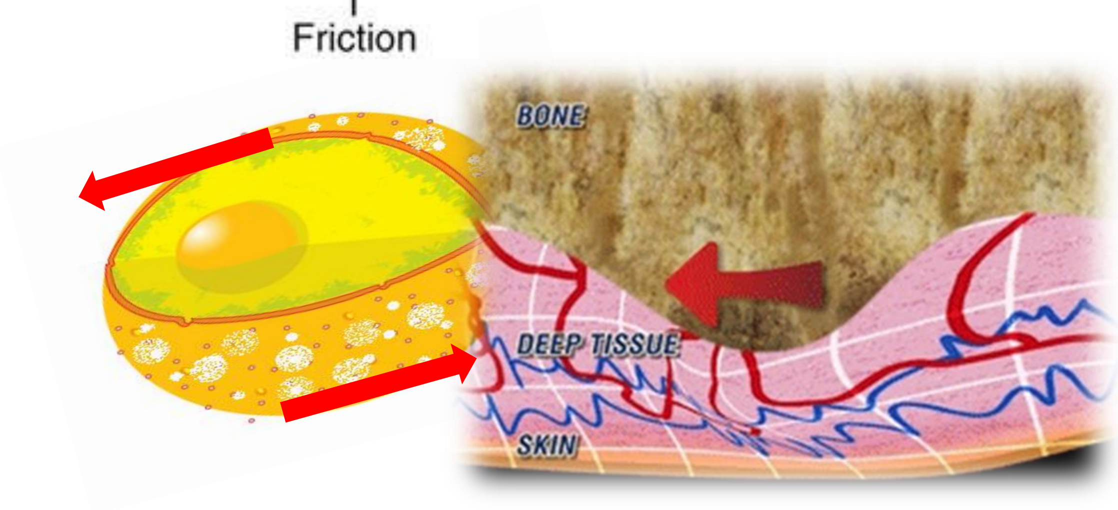
Cell death

Minutes to hours

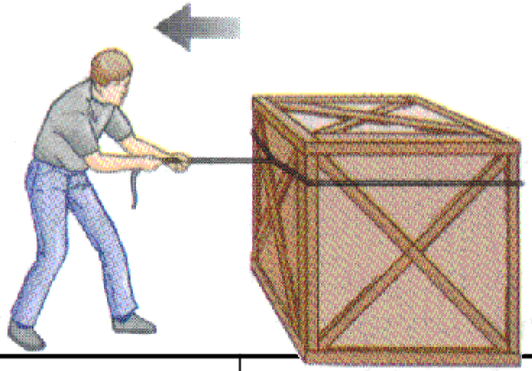
What do the tissues of the heels experience when lying in bed?





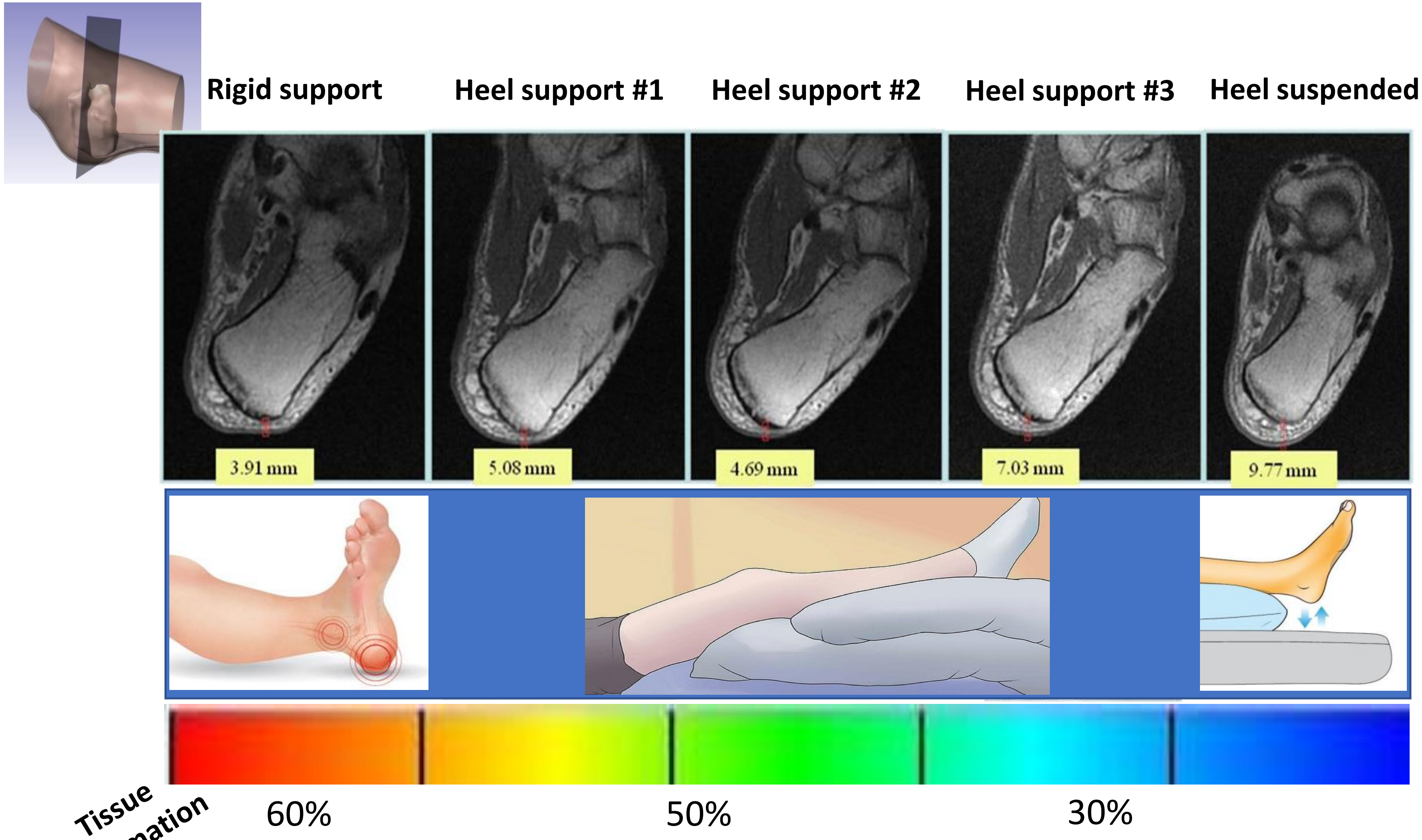


Frictional forces at contacting surfaces are proportional to the coefficient of friction



Material	Coefficient of Static Friction μ_S	Coefficient of Kinetic Friction μ_S
Rubber on Glass	2.0+	2.0
Rubber on Concrete	1.0	0.8
Steel on Steel	0.74	0.57
Wood on Wood	0.25 – 0.5	0.2
Metal on Metal	0.15	0.06
Ice on Ice	0.1	0.03
Synovial Joints in Humans	0.01	0.003

Tissue deformations at the supported (posterior) heel are substantial and depend upon the type of the interface which is used



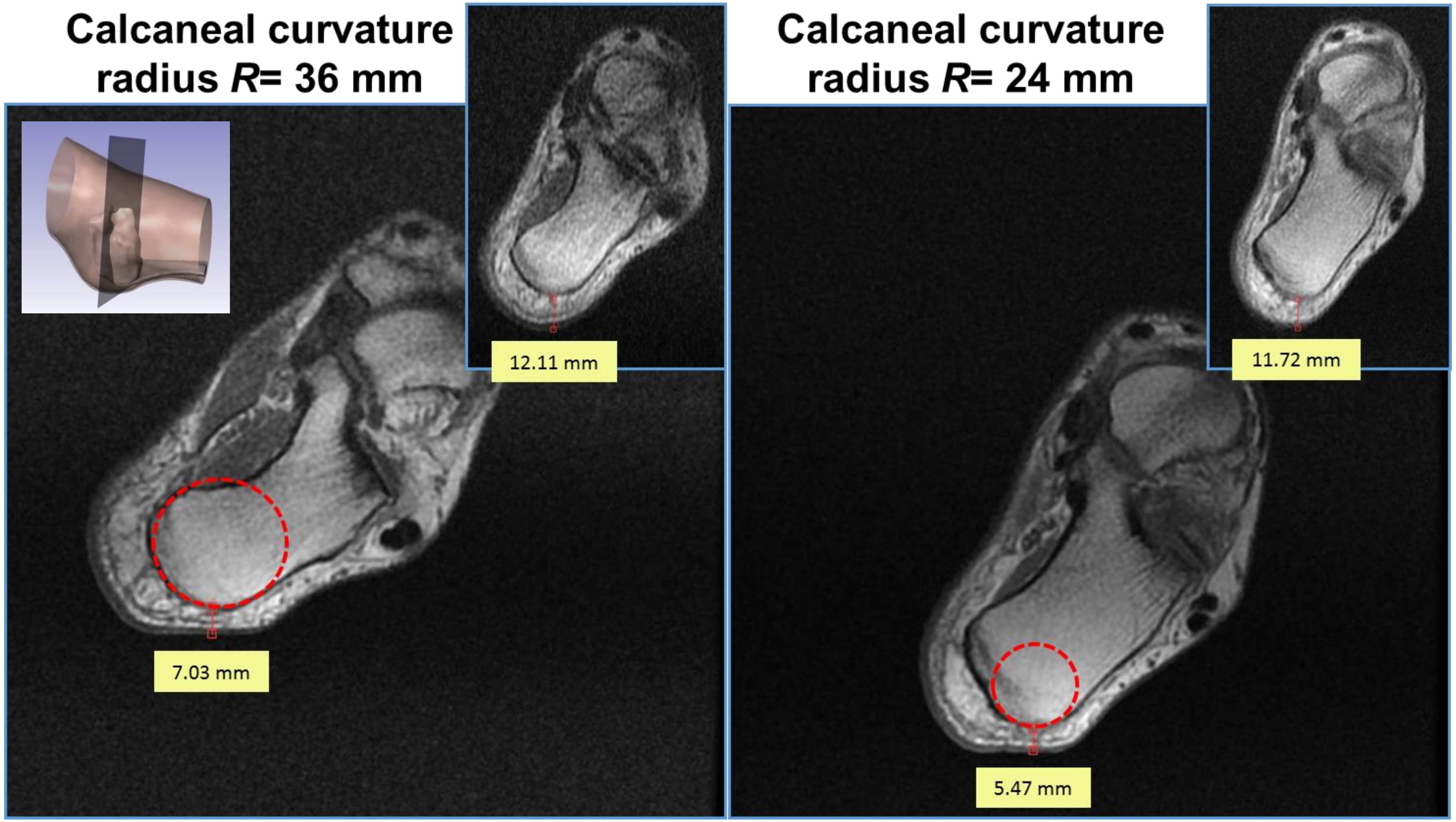
Protecting the heel tissues needs to balance between alleviating tissue deformations in a sustainable manner while also allowing free movement of the rest of the body

Tenenbaum et al. *Journal of Rehabilitation Research and Development* 2013

Tissue deformations at the supported (posterior) heel also depend on the individual anatomy: Some anatomies bear more risk than others

Calcaneal curvature radius *R*= 36 mm

Calcaneal curvature radius *R*= 24 mm

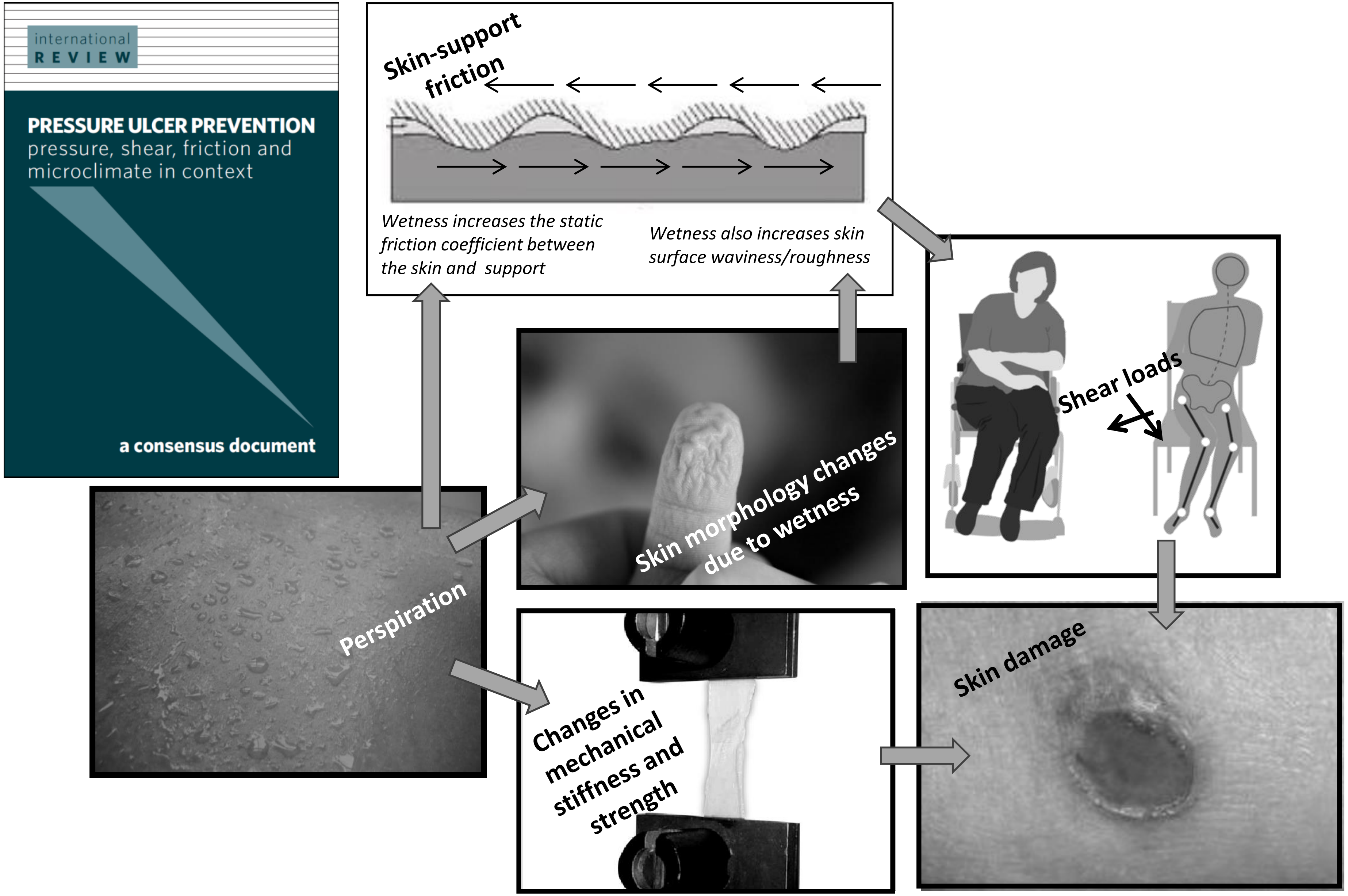


42% strain

53% strain

Tenenbaum et al. *Journal of Rehabilitation Research and Development* 2013

Potential contributors to high frictional forces at the skin-support contact and their influence on skin integrity



Gefen *Journal of Wound Care* 2014

Repositioning a patient whose skin is wet, especially if dragging the patient in bed, may result in superficial and deep tissue damage

simulated dragging of the body part over the mattress

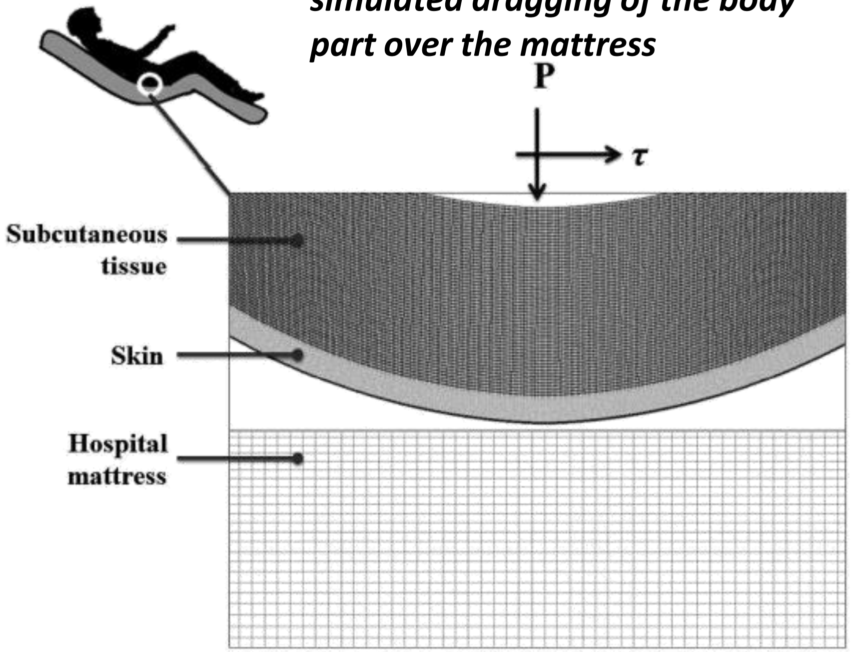


FIGURE 1 | The model of the skin in interaction of the hospital mattress.

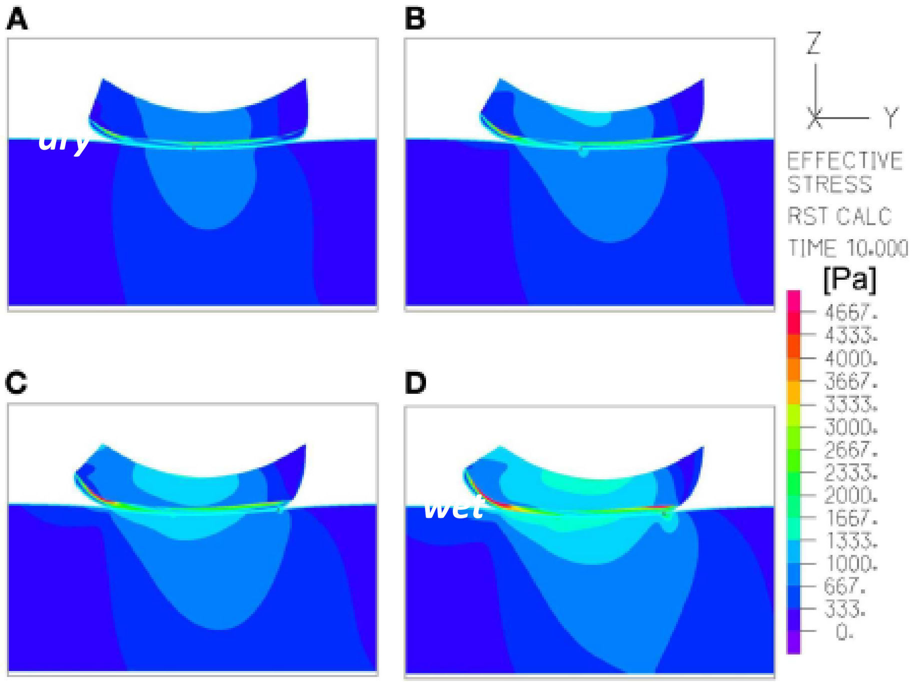
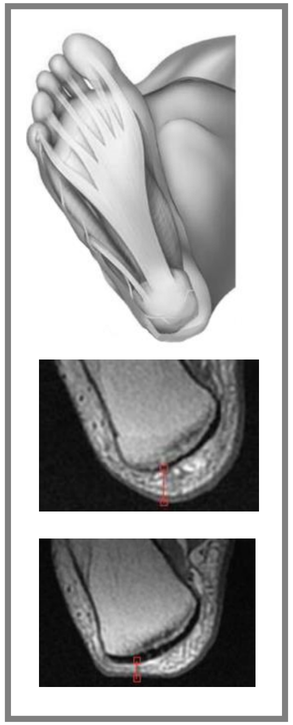
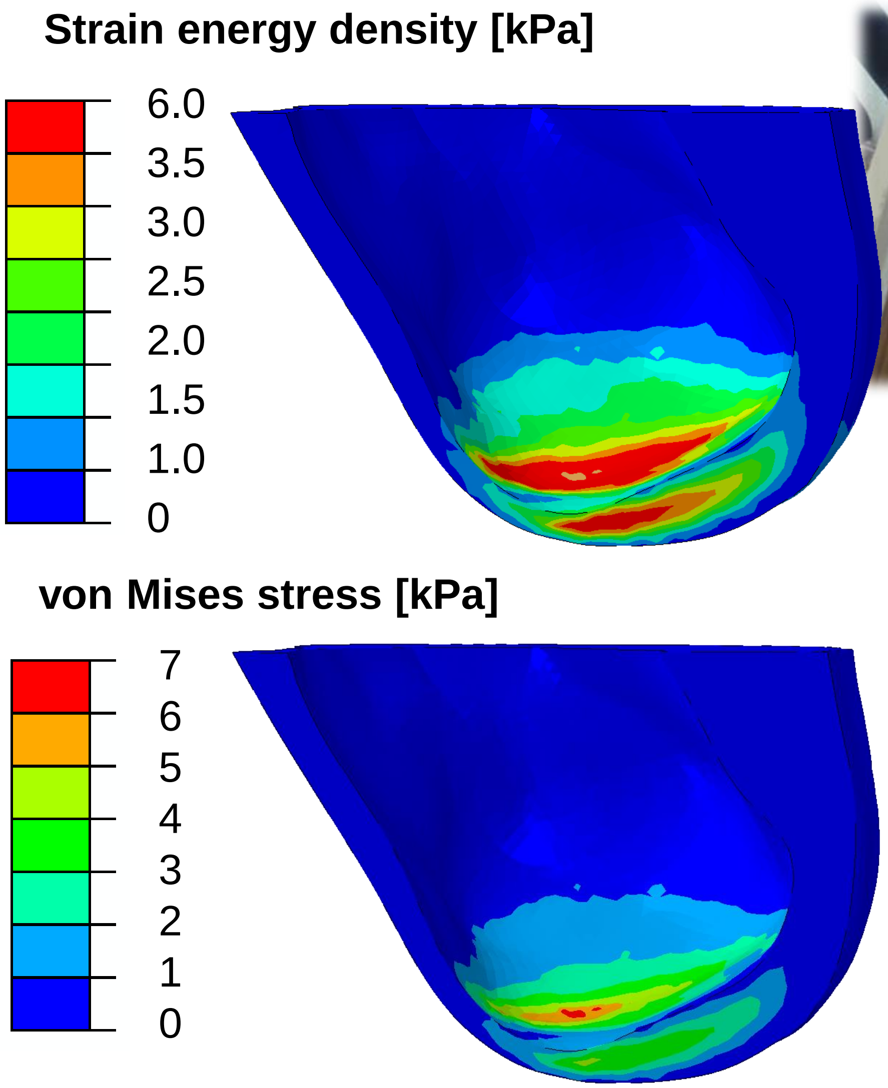


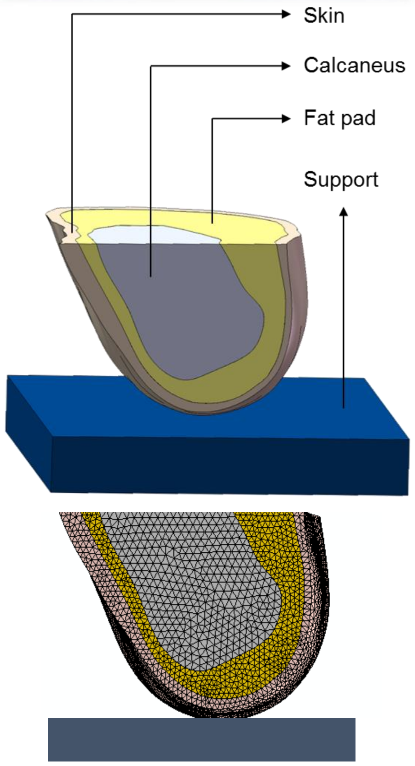
FIGURE 5 | An example of the distribution of effective stresses in the region of interest, at the end-point of the repositioning process in the simulations ($t = 10$ s), which depicts how the moisture-related skin-support coefficient of friction (COF) influences internal skin and subcutaneous stresses. The skin and subcutaneous stress data were always collected from the latest time-step of the simulations, that is, at the end-point of the displacement regime, since tissue loads were maximal at that time point. In this example, the skin stiffness was 100 kPa and the COF varied as followed: **(A)** 0.2; **(B)** 0.4; **(C)** 0.6; **(D)** 0.8. The value range in the color bar was set to be from zero to a maximum of 4.5 kPa.

Shaked and Gefen *Frontiers in Bioengineering and Biotechnology* 2013

Frictional forces generated at the contact of the heels with the support are transferred to internal tissues which distorts cells in these tissues

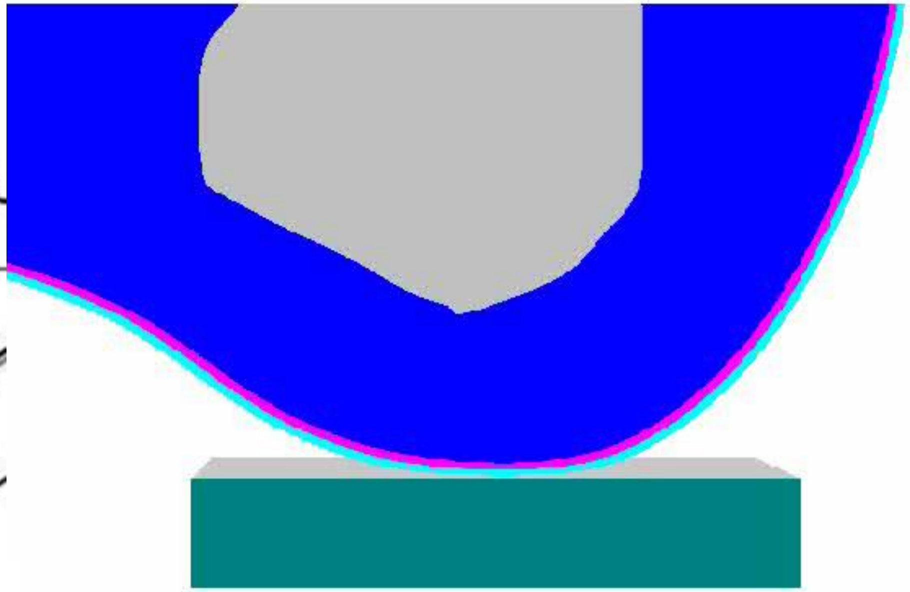






Sopher et al. *Journal of the Mechanical Behavior of Biomedical Materials* 2011

Shear deformations at the tissues of the supported heel



Levy et al. *Journal of Tissue Viability* 2015

Topography, organization and texture of the interface fabric determines the coefficient of friction and hence, the frictional forces applied to tissues

POLYCOTTON SHEET

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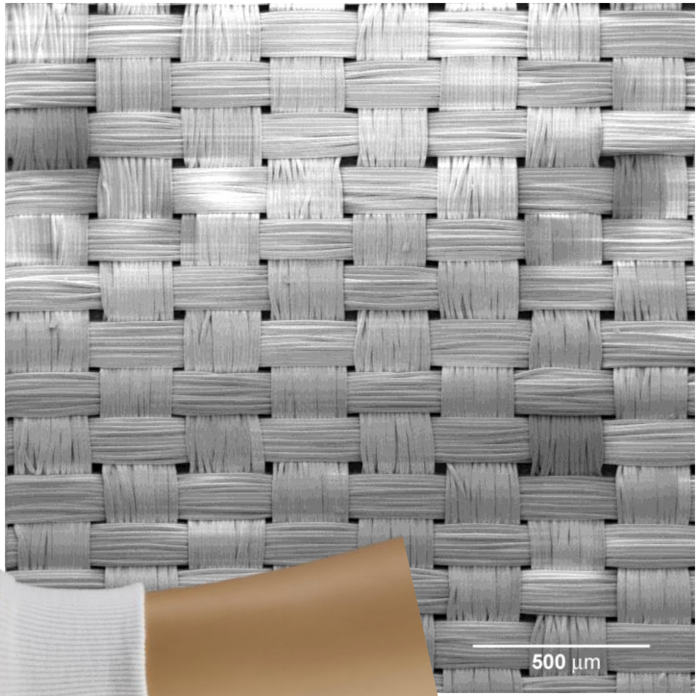

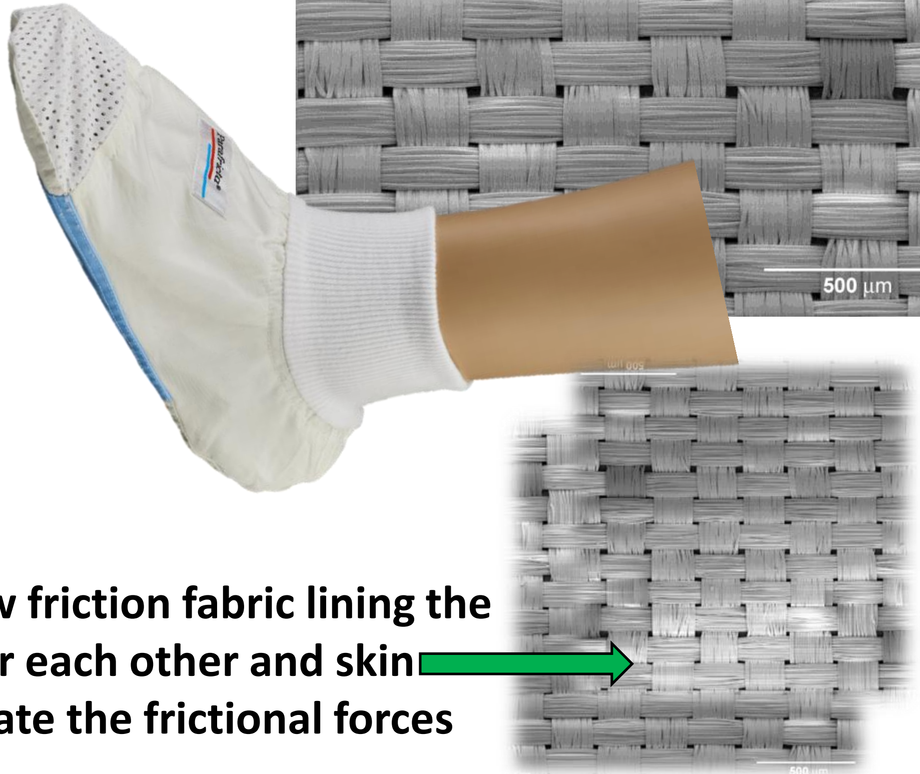

Two layers of low friction fabric lining the bootee slide over each other and skin in order to mitigate the frictional forces

Conclusions

- Sustained bodyweight deformations cause cell and tissue damage
- Deformation damage occurs rapidly – so prevention should be timely
- Frictional forces cause tissue shearing at the skin and in deep tissues
- The posterior heels are vulnerable to friction-related shear damage
- Low-friction fabric garments are effective in reducing the frictional forces
- Prevention by (among other measures) managing friction is the way forward