Finite Element Modeling and Analysis of Shear Stresses on the Buttocks while lying on a Spine Board

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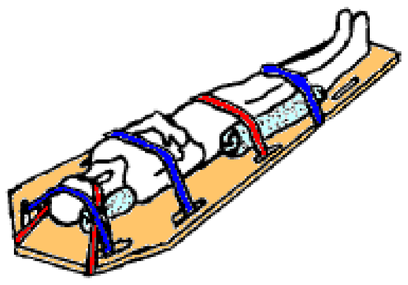
Introduction

- Spine board is used to immobilize patients with spinal injury.



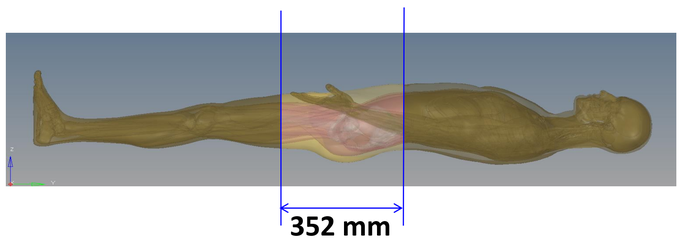
- Immobilization of spine is of utmost importance
- Removal of patients from spine board becomes a low priority for the hospital staff.
- Prolonged stay results in pressure ulcers(PU).
- A PU is a localized injury to the skin and underlying tissue, usually over a bony prominence, as a result of pressure or pressure in combination with shear [1].
- Hence it is necessary to understand and minimize the tissue loading experienced by a patient while immobilized on a spine board.
- Previous studies focused on assessing the normal pressure acting on the skin and the Von-Mises stresses acting in the tissues.

Objective

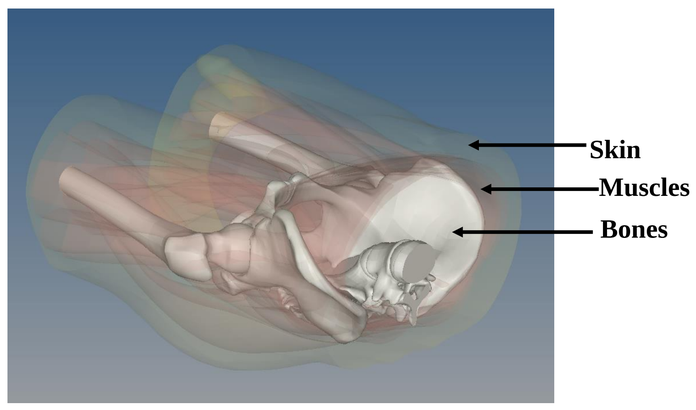
The objective of this study is to estimate the shear stresses experienced on the buttocks when a patient is immobilized on a spine board with cushions of various stiffness.

Computer Aided design data

- Zygote solid 3D male human body CAD model
- The model includes bones, muscles, fat and skin



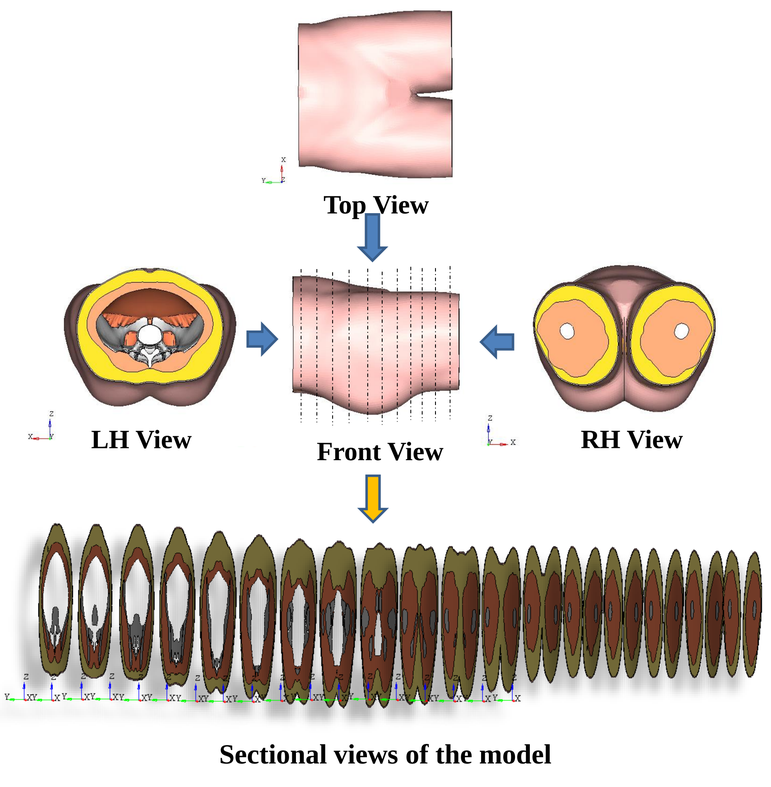
Side view of male human body CAD data showing skin, muscles and skeleton



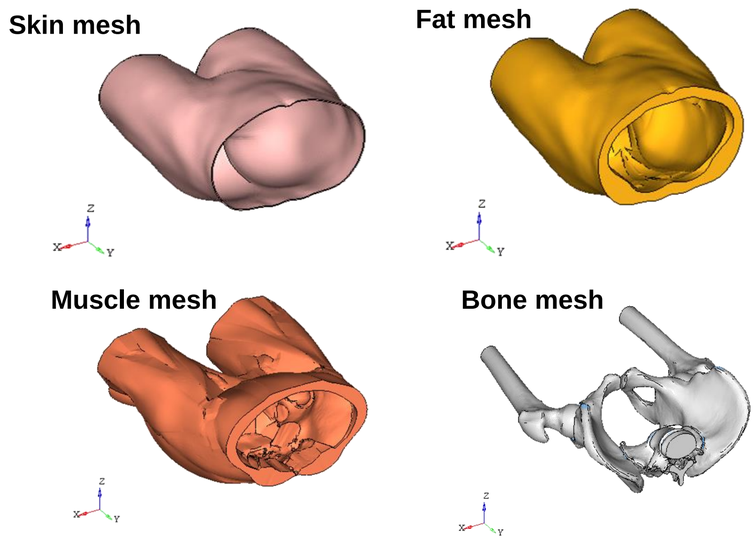
Isometric view of the Sacrum region CAD data

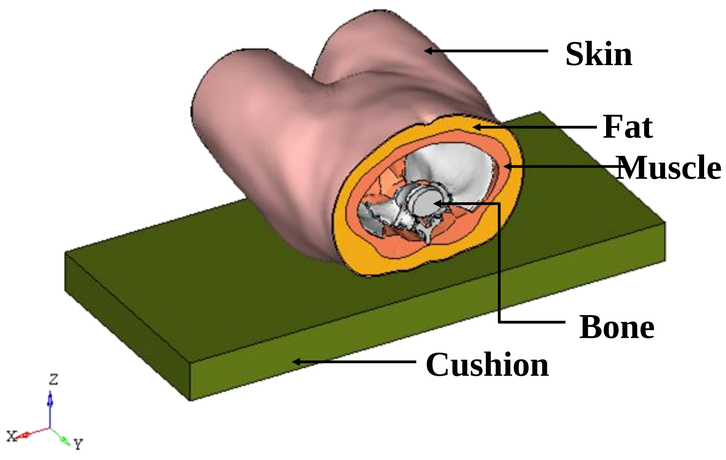
Finite Element Modeling

- HyperMesh software was used.
- Tetra mesh was used to mesh the bones, the muscles, the fat and the skin
- The mesh size used was 3mm – 6mm.
- The cushion was meshed with hexa mesh of size 6mm.



Sectional views of the model





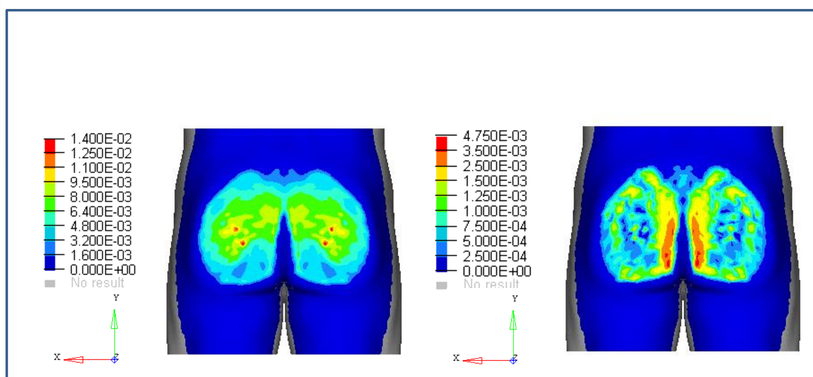
Isometric view of Meshed assembly

Material Properties

- Bones : linear elastic isotropic (E= 7GPa, v=0.3)
- Cushion : linear elastic isotropic (E= 10 KPa to 100 KPa, v=0.3)
- Skin, fat and muscles: Neo-hookean material [2]
- Neo-hookean material is a hyper elastic material

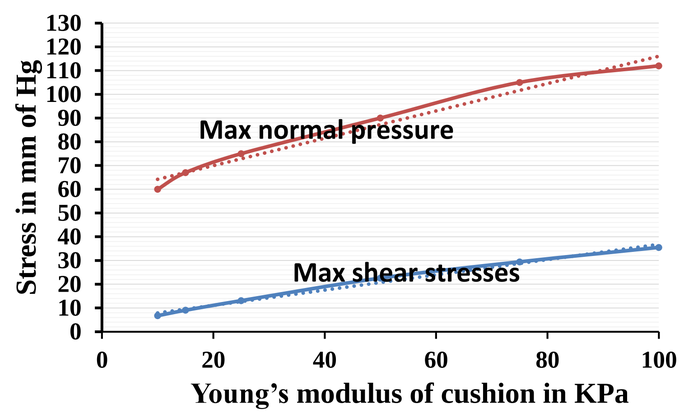
	Shear modulus (μ_0) MPa	Bulk modulus (K_0) MPa
Skin	0.2138	21.313
Fat	0.000286	0.0285
Muscle	0.0071	0.7076

Results



Normal pressure Shear stresses

Contact pressure and shear stresses on the skin surface near the buttocks for a cushion with E = 100 Kpa.



Max Shear stress (in mm Hg) = 0.56* (Max Normal pressure in mm of Hg) - 28

Discussion and Conclusions

- Frictional shear stresses at the buttocks cannot be ignored when immobilized on a spine board.
- Significant changes occur in the shear stresses induced in the tissues when the cushion properties are changed.
- A relationship is proposed to estimate the maximum shear stresses at the buttocks in terms of the maximum normal pressure for different Young's modulus of cushion
- These results can be used as a guide to select the cushion material that minimize normal and shear interface stresses and thus prevent the formation of pressure ulcers

References

[1] European Pressure Ulcer Advisory Panel and National Pressure Ulcer Advisory Panel, 2009, http://www.npuap.org

[2] *Ayelet Levy, Kara Kopplin, and Amit Gefen*, J. of Mechanical behavior of Biomedical Materials, 2013.