EVALUATION OF HUMAN SPACEFLIGHT-RELATED TISSUE WEIGHT RELIEF USING WHOLE BODY FINITE ELEMENT MODEL SIMULATIONS

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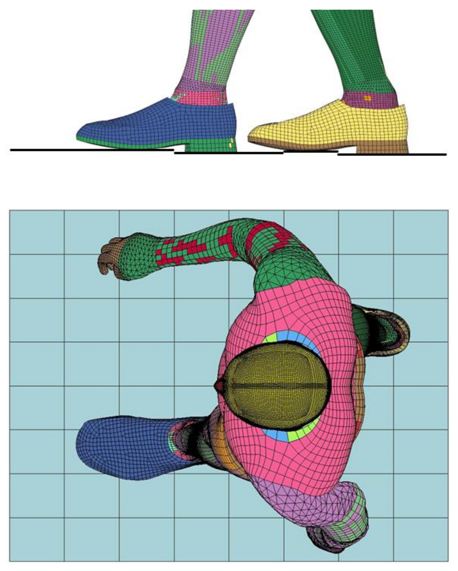
INTRODUCTION

- Tissue weight relief is a proposed mechanism contributing to physiological changes observed in human spaceflight. It is hypothesized to impact the cardiovascular system fluid redistribution by altering tissue-related transmural pressure on the large venous blood vessels.
- Understanding the potential effects of tissue weight relief is important because of the role it may play in Space Associated Neuro-Ocular Syndrome (SANS).
- Limited ability to test experimentally makes biomechanical models useful tools in evaluating analog suitability, understanding the mechanisms of SANS and informing the development of effective countermeasures. [1]
- Commercial off the shelf (COTS) LS-DYNA crash simulation models with the appropriate modifications to simulate the gravitational effects on tissue weight can be used to study tissue weight relief. [2]

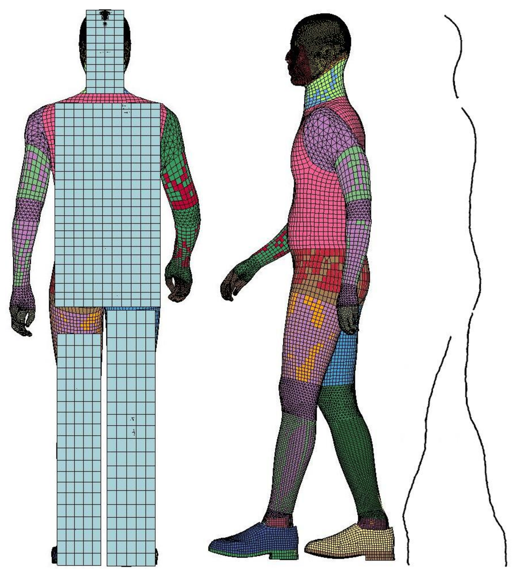
MODEL SETUP

A rigid surface was added beneath the body in the COTS Elemance and THUMS LS-DYNA models of a full anatomical average man to simulate a floor to prevent the body from moving continuously when a gravity load was applied.

The distance between the surface and model was held at a spacing between 1-2 mm.

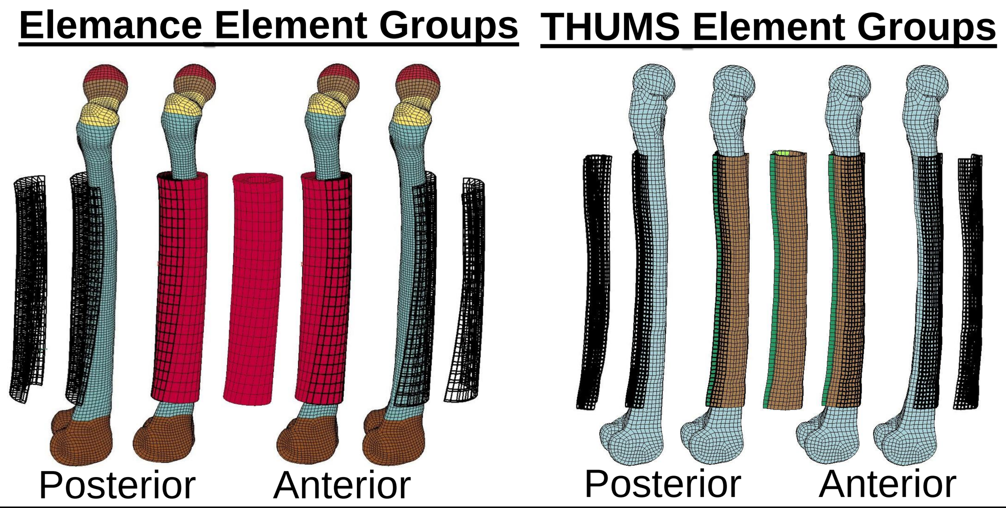


Horizontal Multi-Level Surface



Vertical Contoured Surface

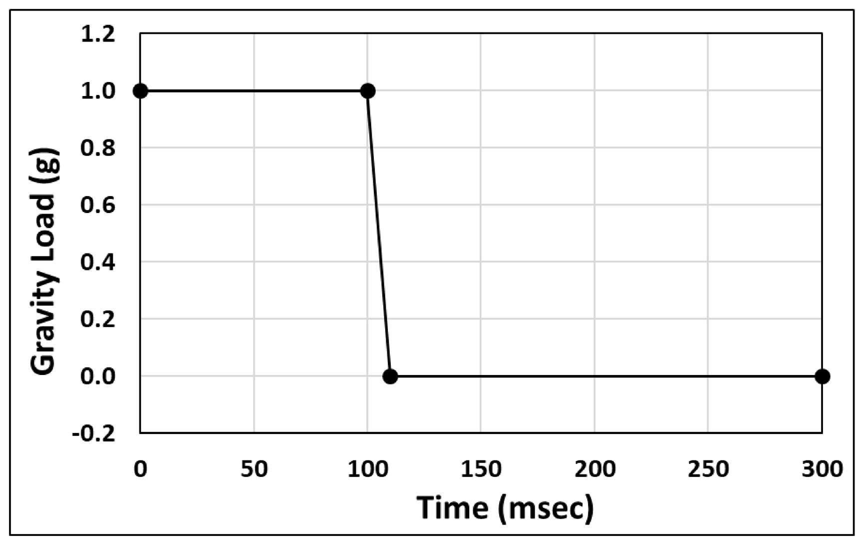
Pressure results were extracted from two groups of solid elements surrounding the right femur. The pressure of all the elements at each time step was averaged to obtain a value for each group.



SIMULATION SCENARIOS

1. Supine Position: 300 msec total
   - 1g load for 100 msec
   - 10 msec ramp to 0g
   - 0g load for 190 msec
2. Supine Position: 200 msec total
   - 1g constant gravity load
3. Standing Position: 200 msec total
   - 1g constant gravity load

Variable Gravity 10 msec Ramp Profile

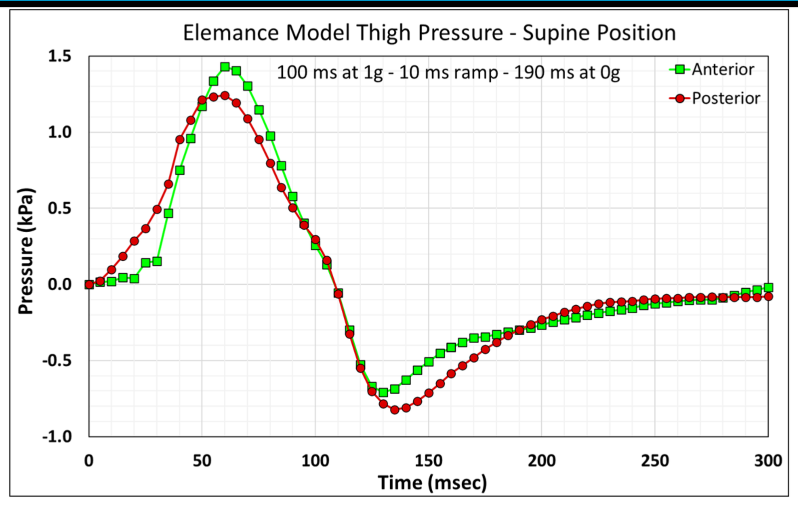


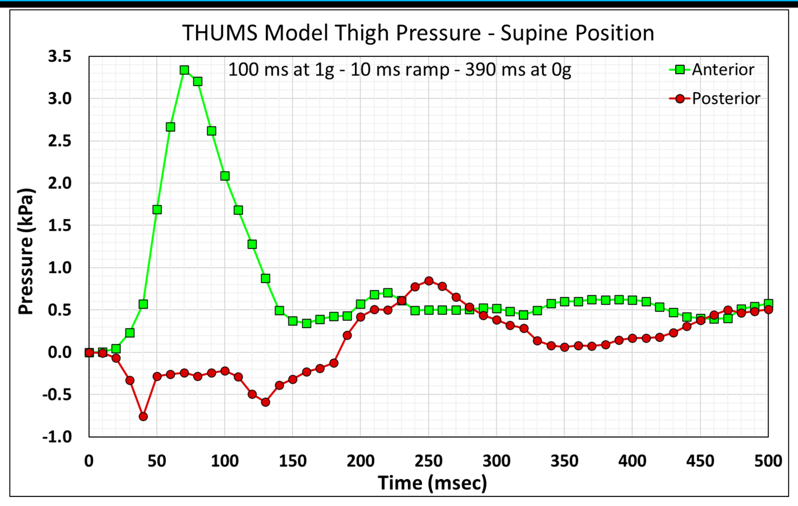
Additional Simulation Scenarios

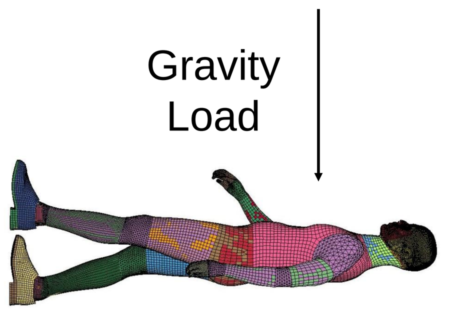
Gravity Load	Subject Orientation	Table Angle	Ramp Time	Total Time
g		degree	msec	msec
1	standing	90	10	20
1	supine	0	10	40
1	supine	6	0	40
1	supine	12	0	40
0	standing	90	0	20
0	supine	0	0	20

RESULTS

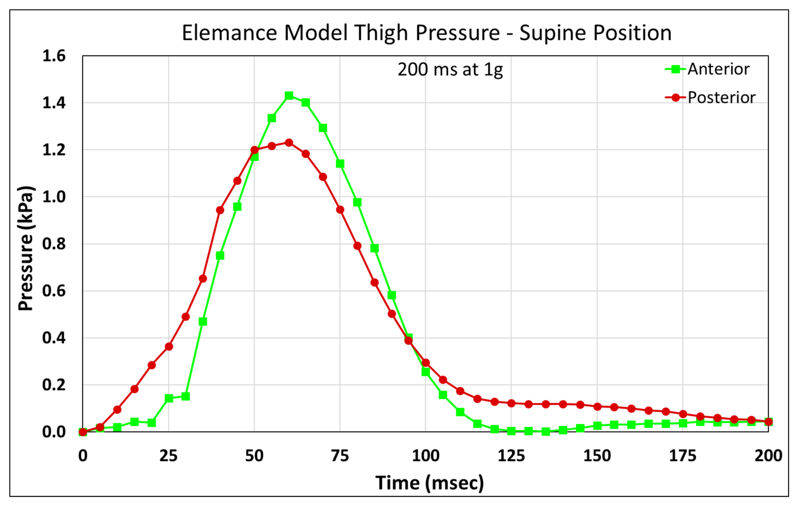
Transmural Pressure Delta, 1G→0G, kPa (Pa)
Elemance (50th Male Simplified Pedestrian)
~1.45 (1450)/10.9 mmHg
THUMS (50th Male Simplified Pedestrian)
~2.76 (2760)/20.7 mmHg

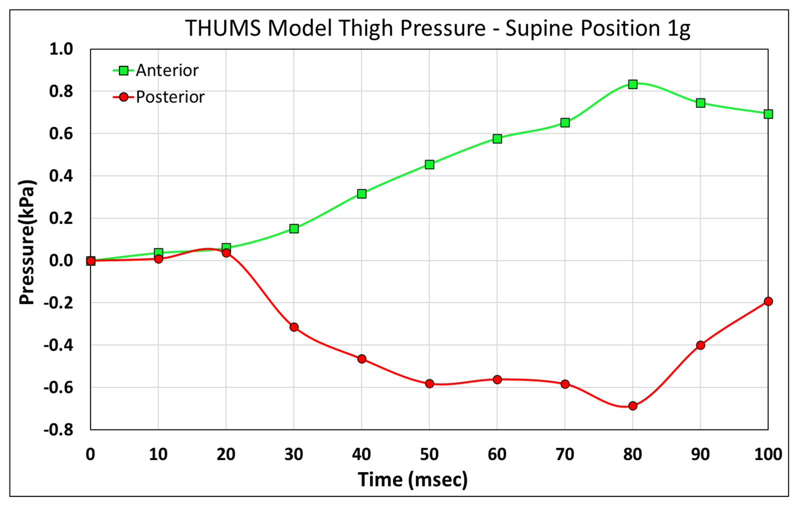


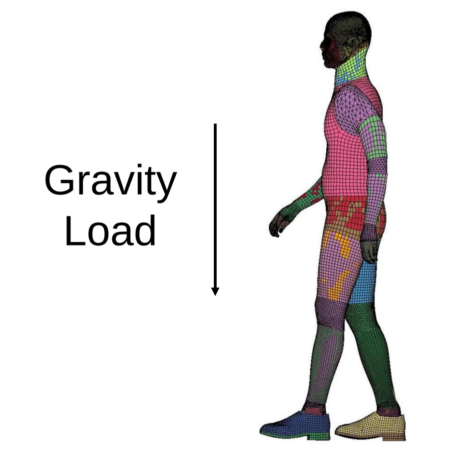




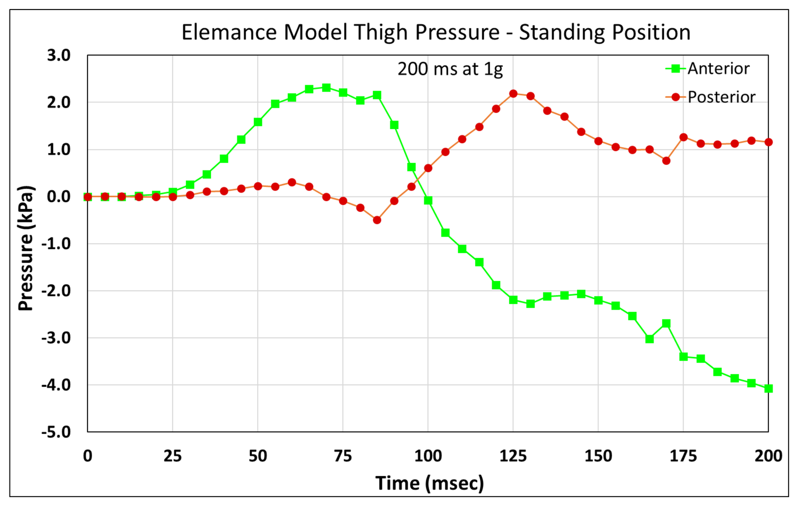
Supine Position

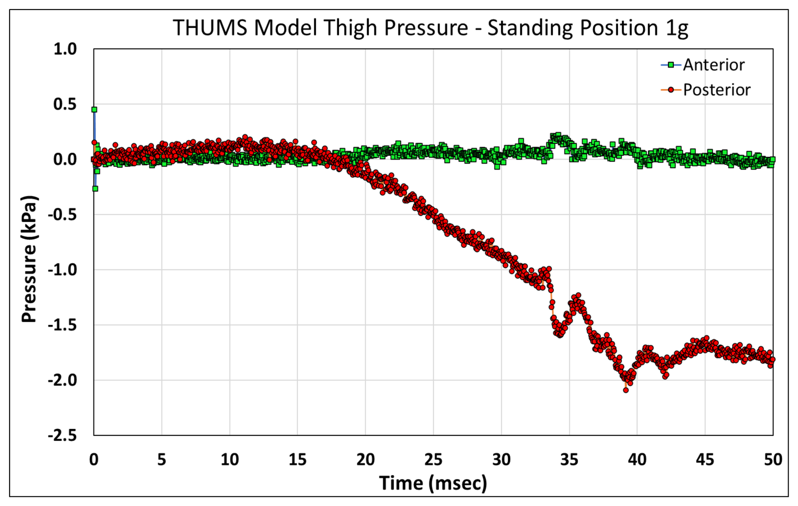






Standing Position





CONCLUSIONS

Elemance and THUMS 3D Higher order simulations incorporating representations of different tissue material properties and connectivity predict that tissue weight relief will produce a maximum of 10 mmHg and 21 mmHg changes in venous transmural pressure. These FE model predictions are 25 - 50% lower than Lu's (2017) 0D-1D lumped parameter model input parameter calculations [3]. This implies that simple representations of tissue relief may overestimate on transmural pressure changes.

FUTURE DIRECTIONS

- Conduct additional simulations cases that did not reach steady state.
- Extract pressure measurements from additional anatomical locations of interest.
- Record lower venous pressure during free fall.
- Investigate the differences in results for the different computational models (FE vs. LP).

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[3] Lu, R. (2017) "Essential Parameters for Modeling Space-Induced Visual Changes"

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