Rehabilitation Engineering & Applied Research

Seated Anatomy and its Impact on Pressure Ulcer Risk

Sharon Eve Sonenblum, PhD

Disclosures

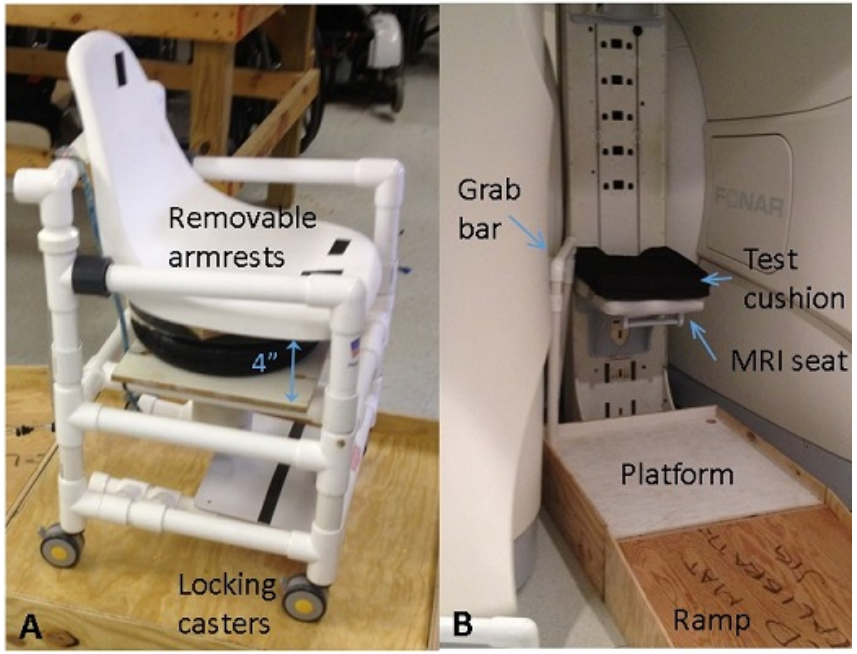
- Ride Designs is paying for my travel expenses to be here.

Learning Objectives

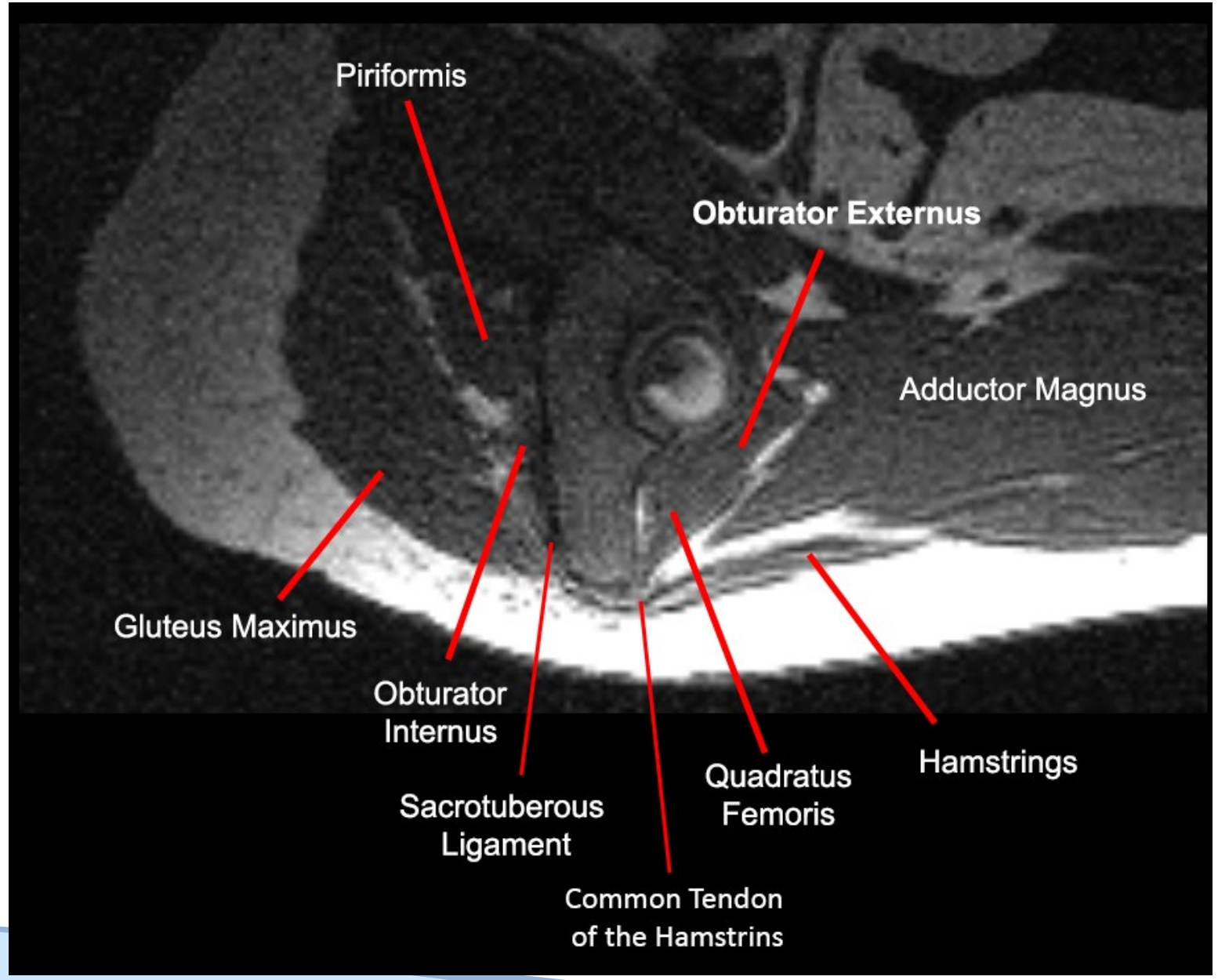
- Report the percent of individuals with gluteus maximus coverage underneath their ischium.
- Identify two aspects of anatomy or skeletal morphology that are associated with pressure ulcer risk.
- Describe one clinical measurement that might have value in predicting biomechanical risk.

THE SEATED BUTTOCKS

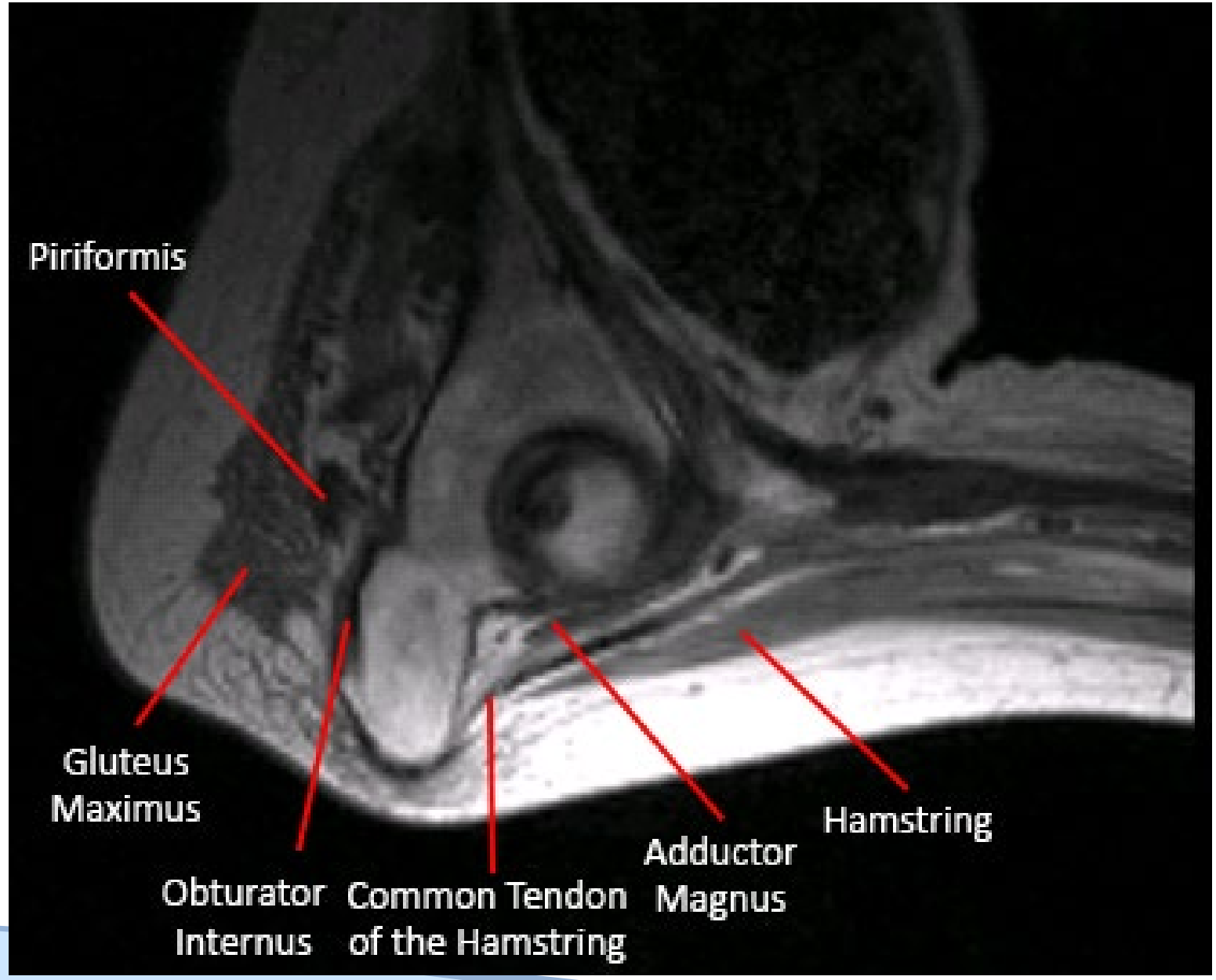
MRI Studies of the Buttocks: FONAR “Stand-up” MRI



Able-Bodied Buttocks



SCI (Atrophied) Buttocks



The ischium runs at an oblique angle

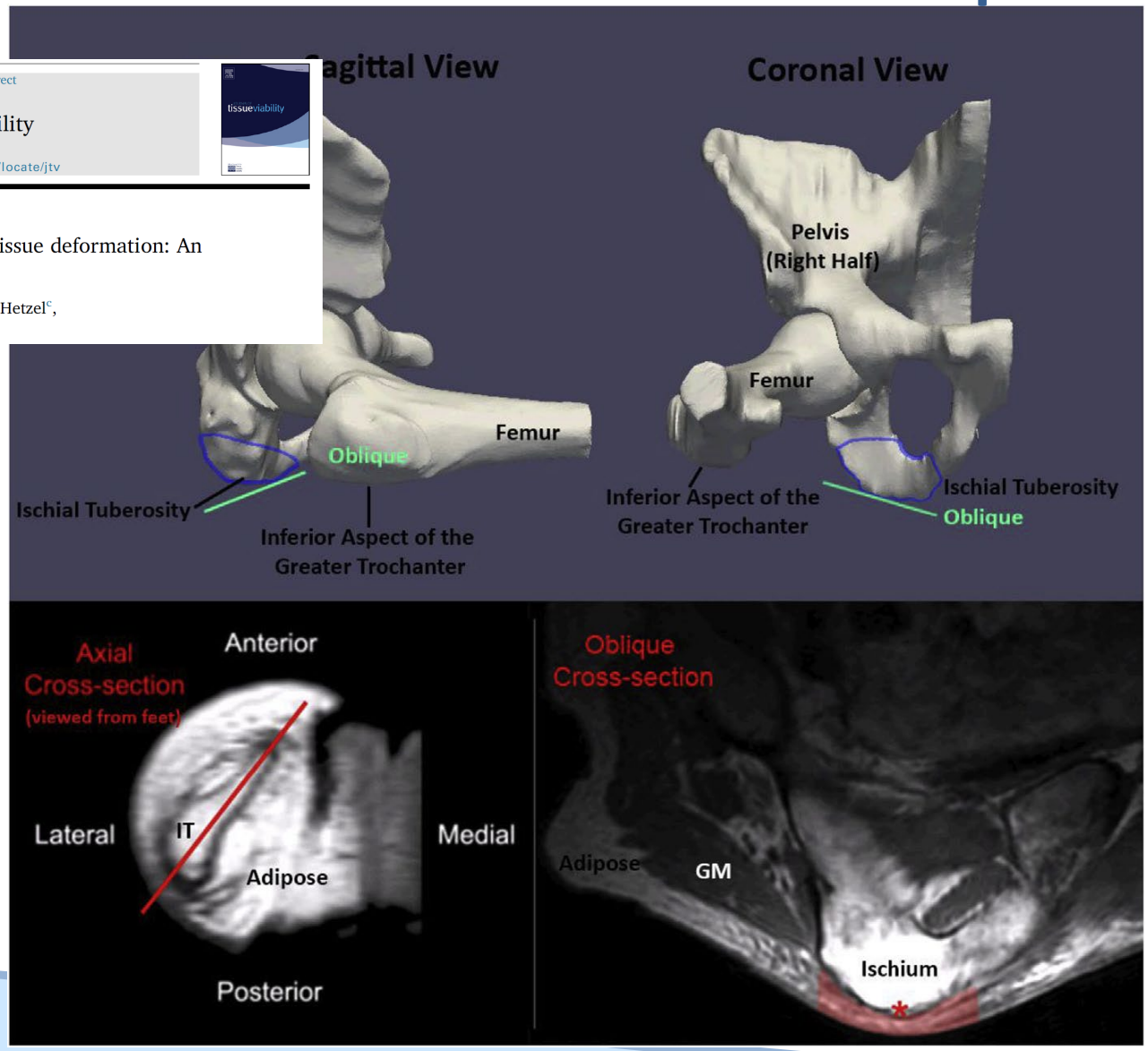
Contents lists available at ScienceDirect

Journal of Tissue Viability

journal homepage: www.elsevier.com/locate/jtv

Measuring the impact of cushion design on buttocks tissue deformation: An MRI approach

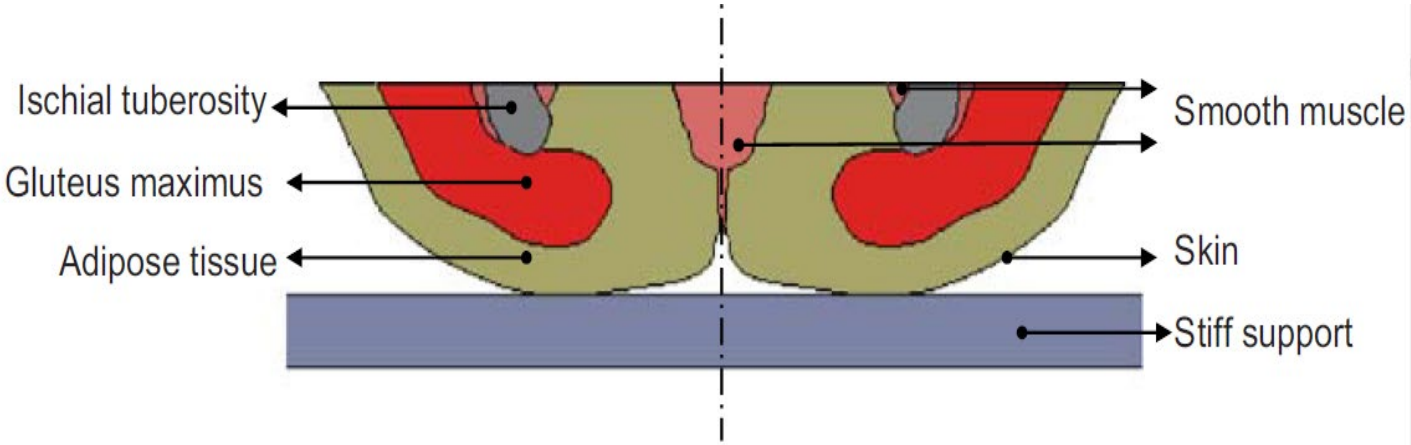
Sharon E. Sonenblum[a,*], Jason Ma, Stephen H. Sprigle[b], Thomas R. Hetzel[c], John McKay Cathcart[d]



Question: What are you sitting on?

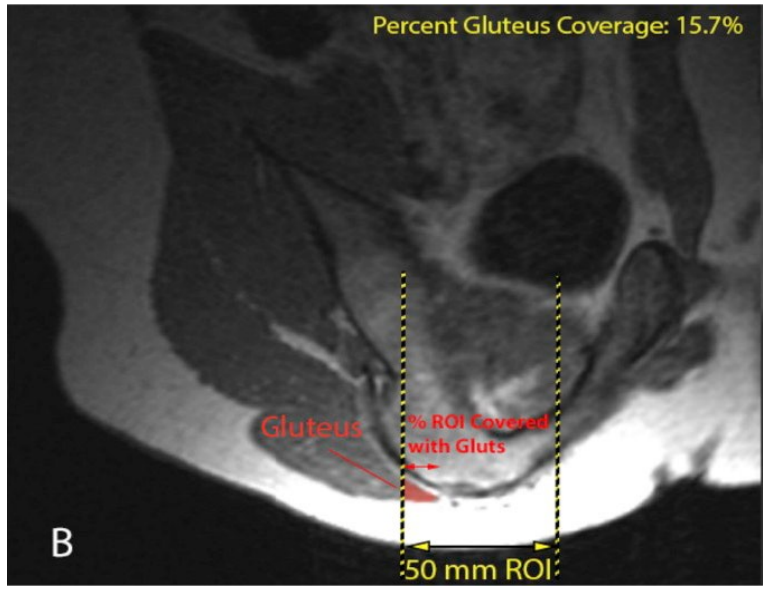
A. Muscle
B. Fat
C. Connective Tissue and Skin
D. An uncomfortable conference chair

Typical Assumption: People are Sitting on Muscle



Sopher, R., et al. *J Biomech, 2010. 43(2): p. 280-6.*

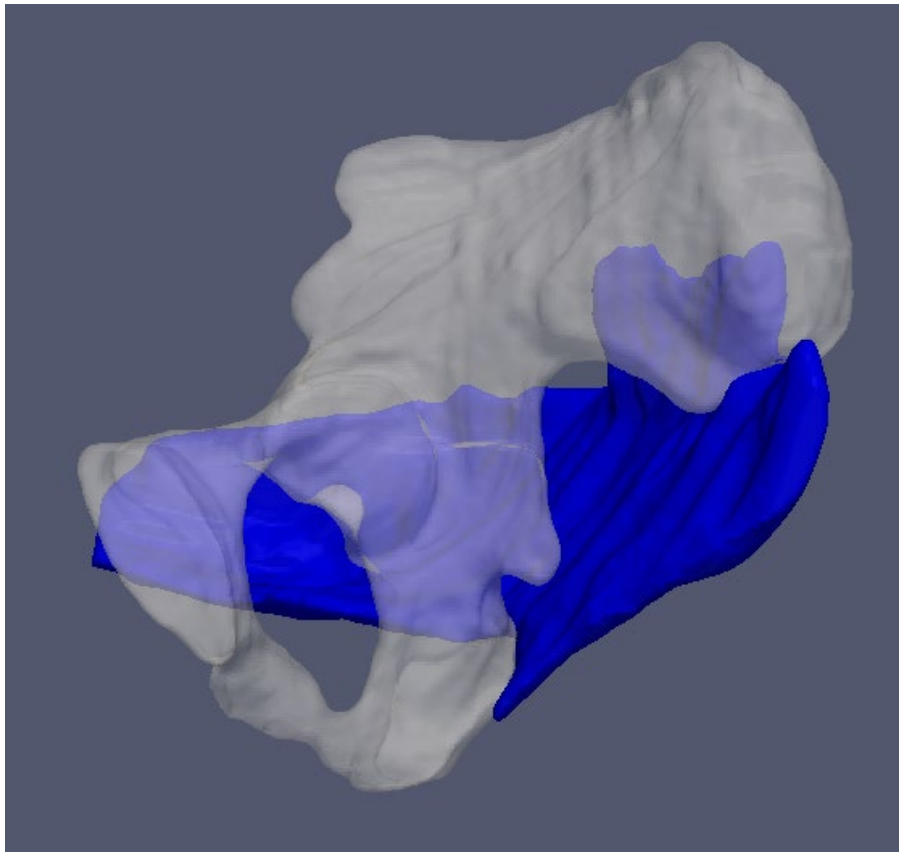
Gluteus Maximus coverage of ischial tuberosities



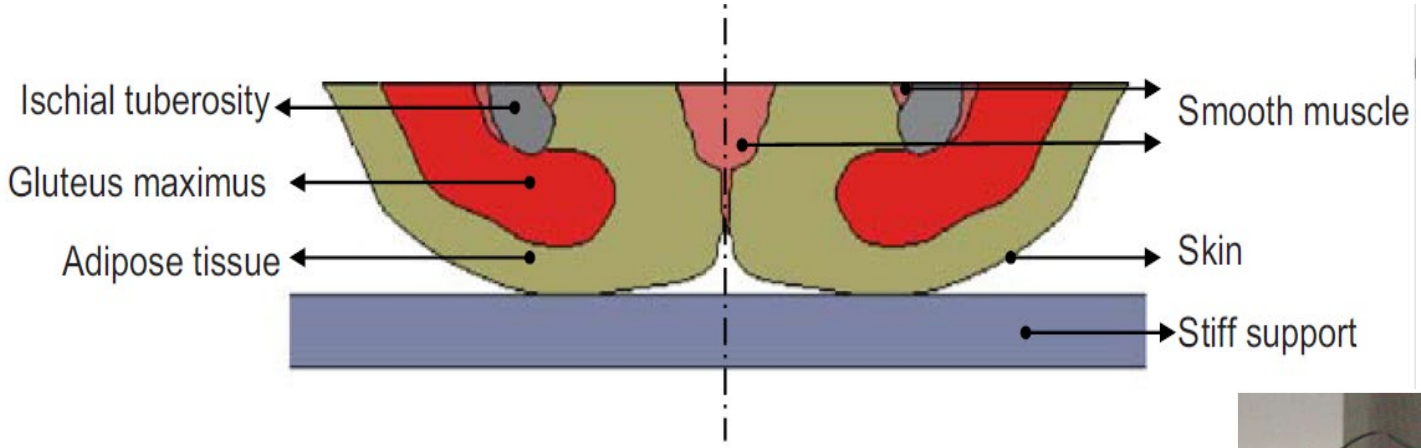
% Gluteus Coverage	Able-bodied	Wheelchair Users	% of Total
0%	3	30	61 %
1-25%	7	10	31 %
25-50%	1	1	4 %
50-75%	0	0	0 %
75-100%	1	1	4 %

n=54

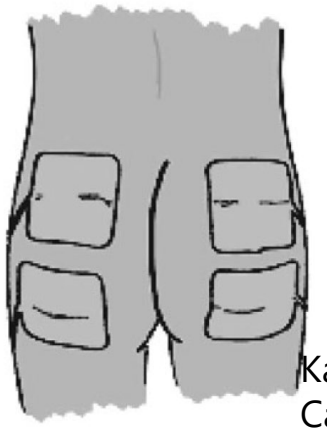
Example of the Gluteus Maximus While Seated
T12 SCI Male, Medial View



Why does it matter if we sit on our gluts anyway?



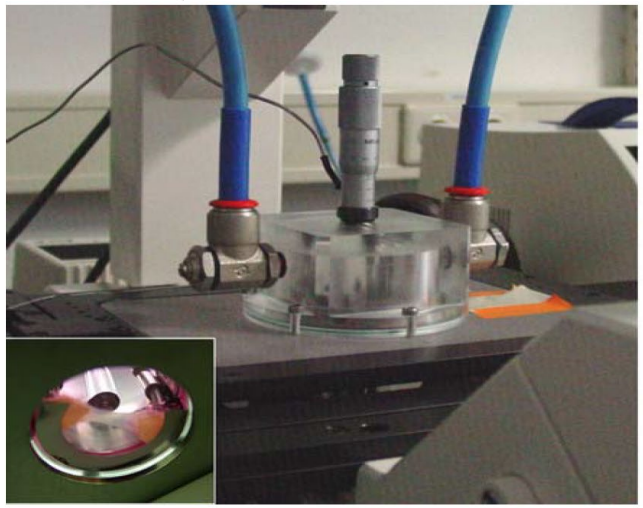
Sopher, R., et al. *J Biomech, 2010. 43(2): p. 280-6.*

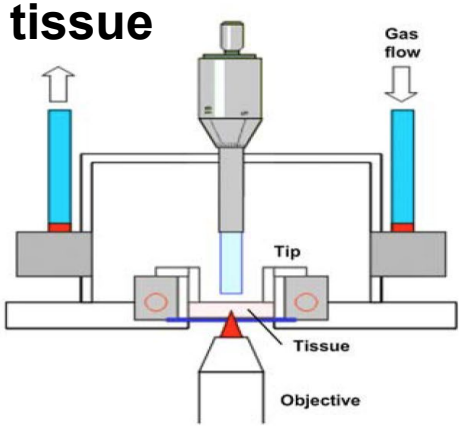


Kane, A., et. al. Advances in Wound Care, 2017. vol 6, no 4, pp. 115-124.

Figure 1. Electrode placement on buttocks.

Bioartificial muscle tissue





Gawlitta, D., et. al. Ann. Biomed. Eng. 35(2):273–284, 2007.

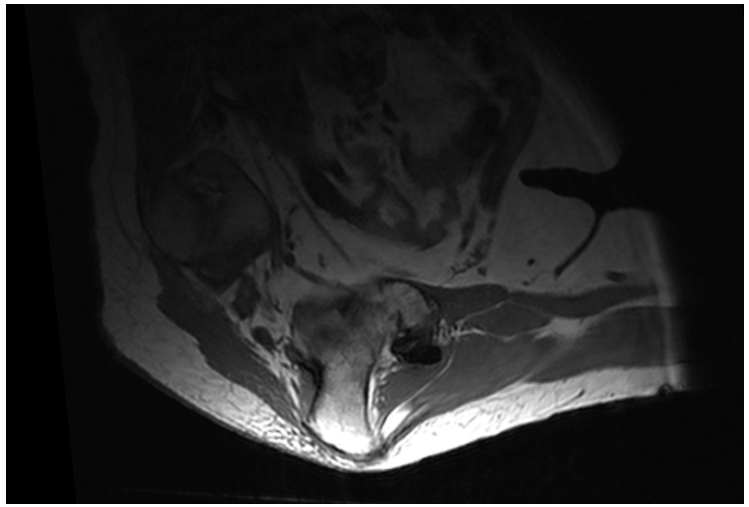
Gluteus Maximus Characteristics

Table 3 Gluteus maximus muscle characteristics.

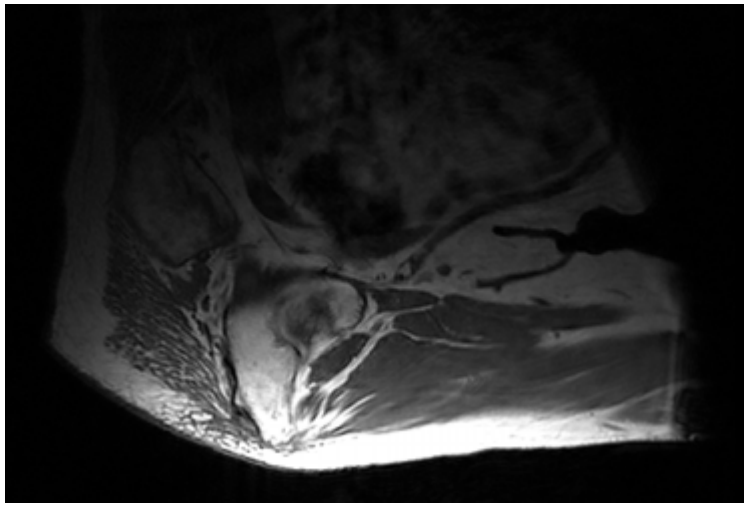
Gluteus maximus	SCI [range]	AB [range]	*p* value
Volume (cm^3)	379 ± 159 [154 to 582]	667 ± 114 [504 to 892]	<0.05
CSA (cm^2)	22 ± 8 [7 to 30]	40 ± 5 [30 to 43]	<0.05
Fat (%)	29 ± 23 [3 to 84]	8 ± 9 [2 to 35]	<0.05
Low density muscle (%)	19 ± 6 [5 to 25]	18 ± 5 [11 to 28]	NSD
Lean muscle (%)	30 ± 19 [3 to 63]	59 ± 18 [29 to 81]	<0.05
LDM/total muscle (%)	45 ± 15 [23 to 74]	26 ± 11 [13 to 40]	<0.05

Wu & Bogie, 2013. J Tissue Viability. 2013 Aug;22(3):74-82.

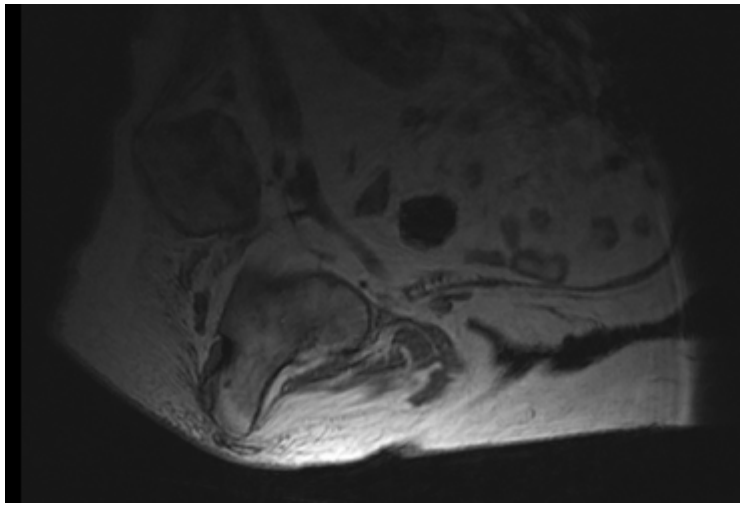
Fatty Infiltration in Men with SCI



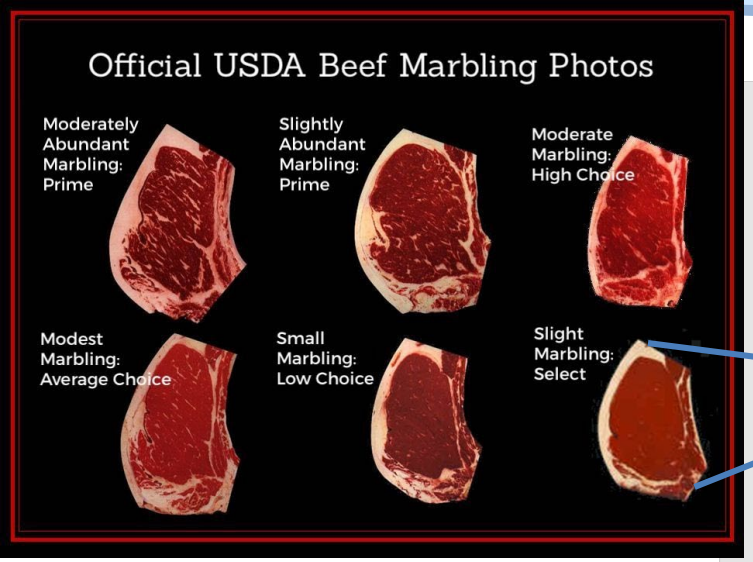
27yo, 6 years post injury
BMI = 24.1
Mild spasms
No history of PrU

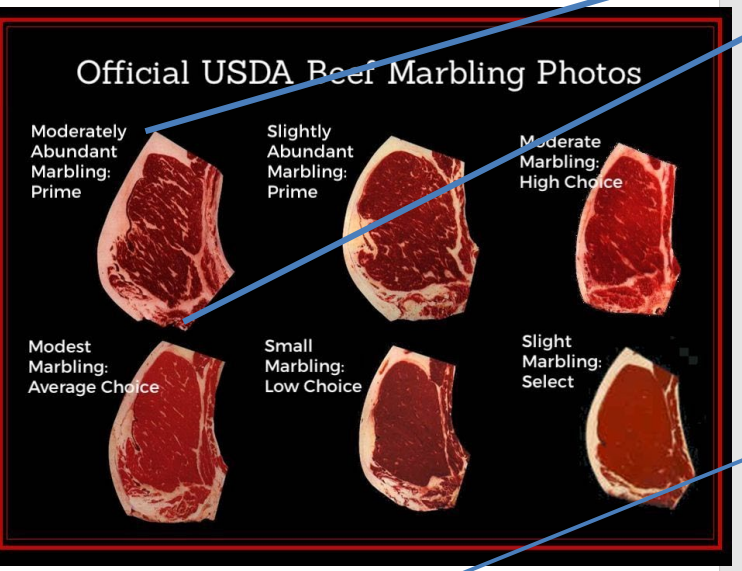


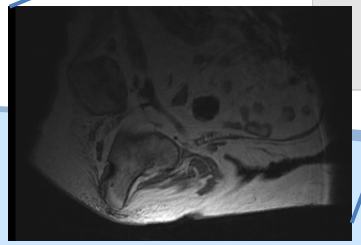
49yo, 29 years post injury
BMI = 27.3
Infrequent spasms (<1/hr)
History of PrU



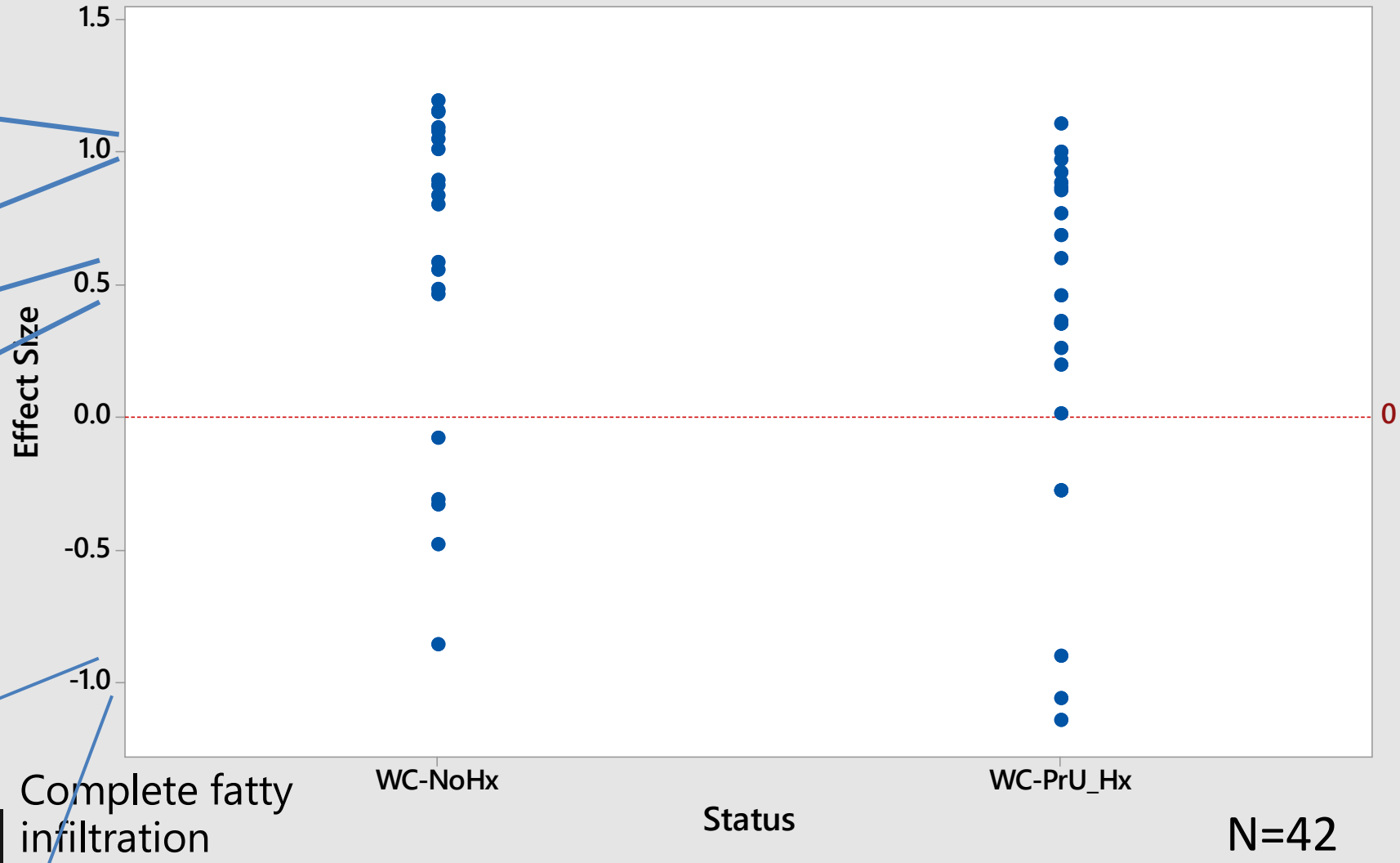
58yo, 14 years post injury
BMI = 29.6
No spasticity
No history of PrU



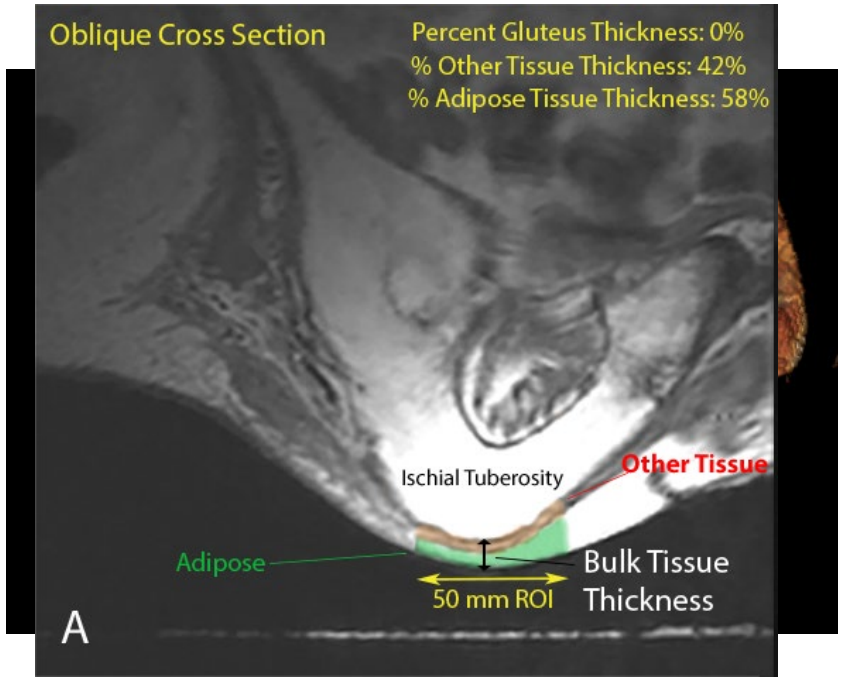




Complete fatty infiltration



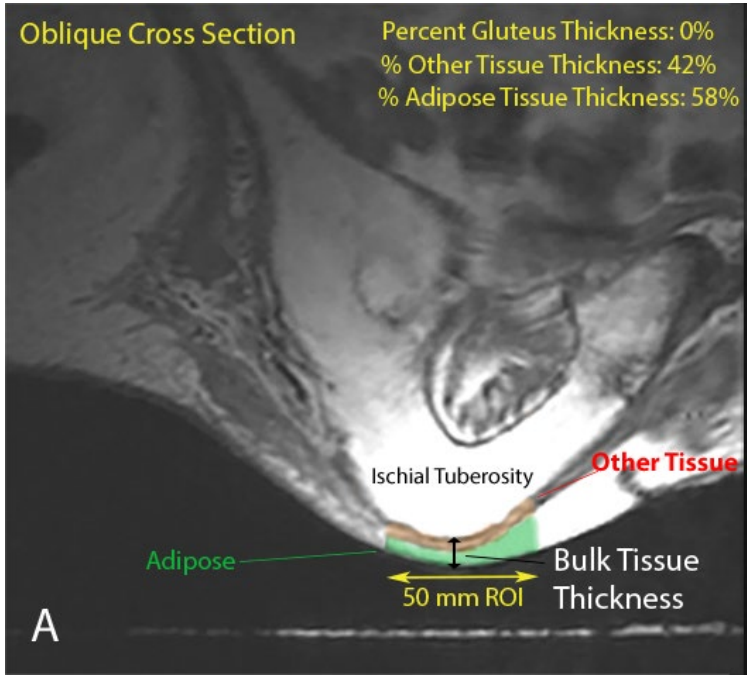
How much tissue is there under the IT when seated on a cutout (gravity loaded only)?



	Mean (SD)
Tissue Thickness	39.1 mm (12.5 mm)
% Adipose	76.2 % (17.5 %)

n=50

How much tissue is there under the IT when seated on flat foam?



	Mean (SD)
Tissue Thickness	16.2 mm (7.1 mm)
% Adipose	80.5 % (16.1 %)

n=48

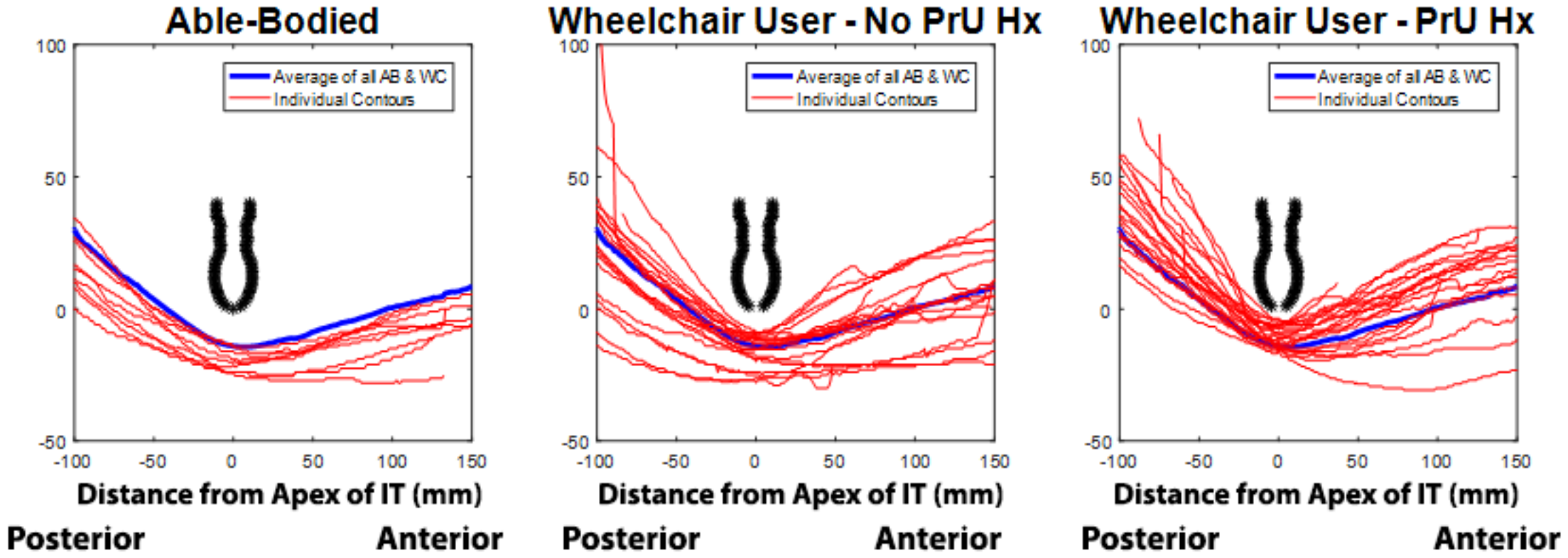
Biomechanical Risk

The intrinsic characteristic of an individual's soft tissues to deform in response to extrinsic applied forces

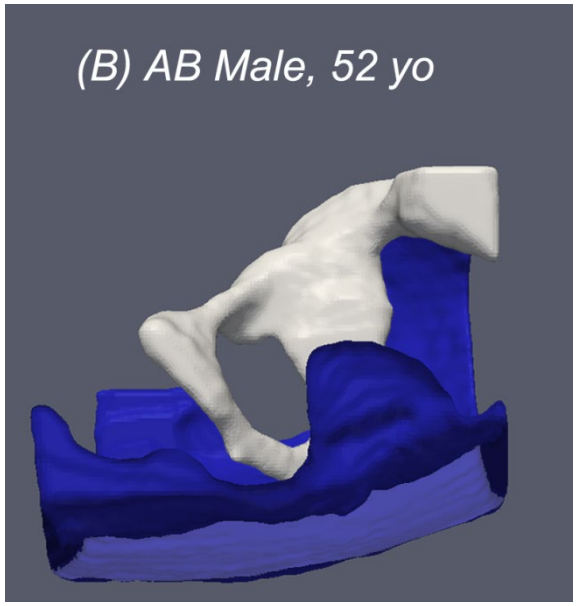
1. Sonenblum, S.E. and S.H. Sprigle, *Buttock tissue response to loading in men with spinal cord injury. PLoS One, 2018.* ***13(2): p. e0191868.***

2. Sonenblum, S.E., et al., *Measuring the impact of cushion design on buttocks tissue deformation: An MRI approach. J Tissue Viability, 2018.* ***27(3): p. 162-172.***

Biomechanical Risk

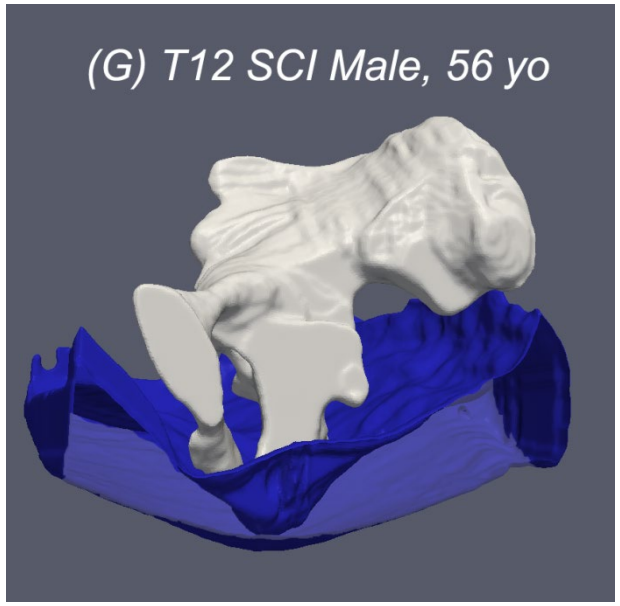


Strain: The Inner Adipose Surface



Lowest

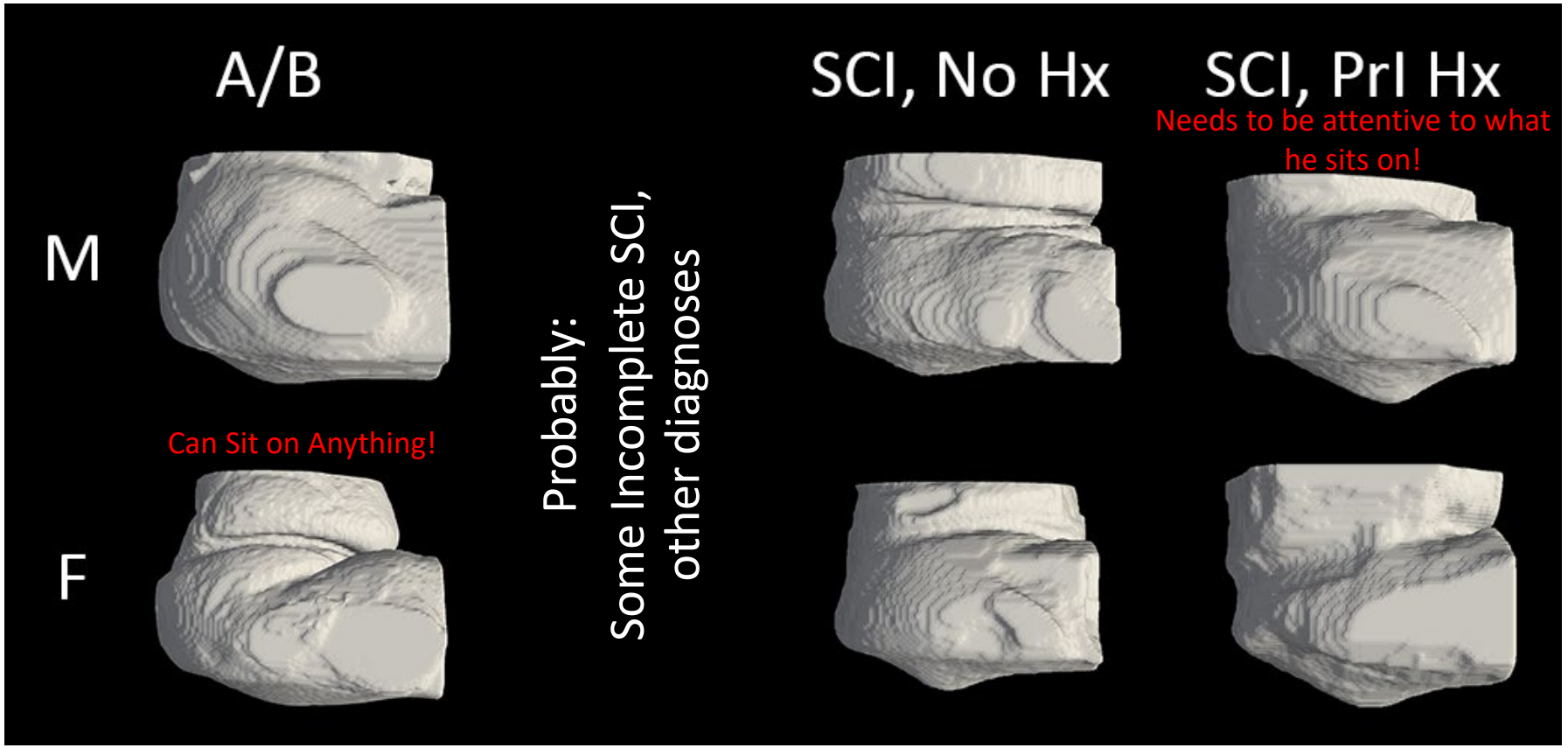
Biomechanical Risk



Highest

Biomechanical Risk

Risk Spectrum



SCI-Adjusted BMI

	No Pressure Ulcer History	Pressure Ulcer History	All
Recommended BMI (<21.9)	5	13	18
Overweight (21.9-24.9)	9	2	11
Obese (>24.9)	8	8	16
All	22	23	45

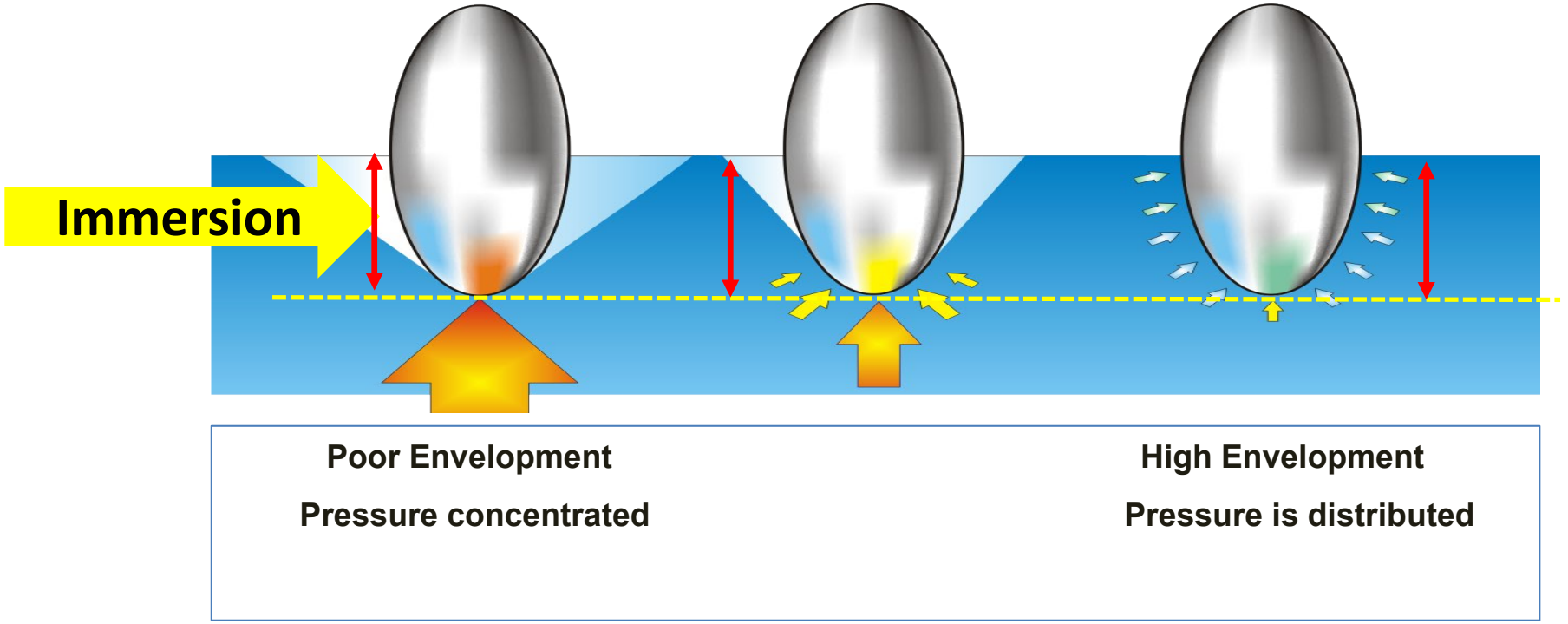
How much compressible hip tissue?

	No Pressure Ulcer History	Pressure Ulcer History
Δ Seated Hip Width > 1.75”	9	2
Δ Seated Hip Width ≤ 1.75”	10	19

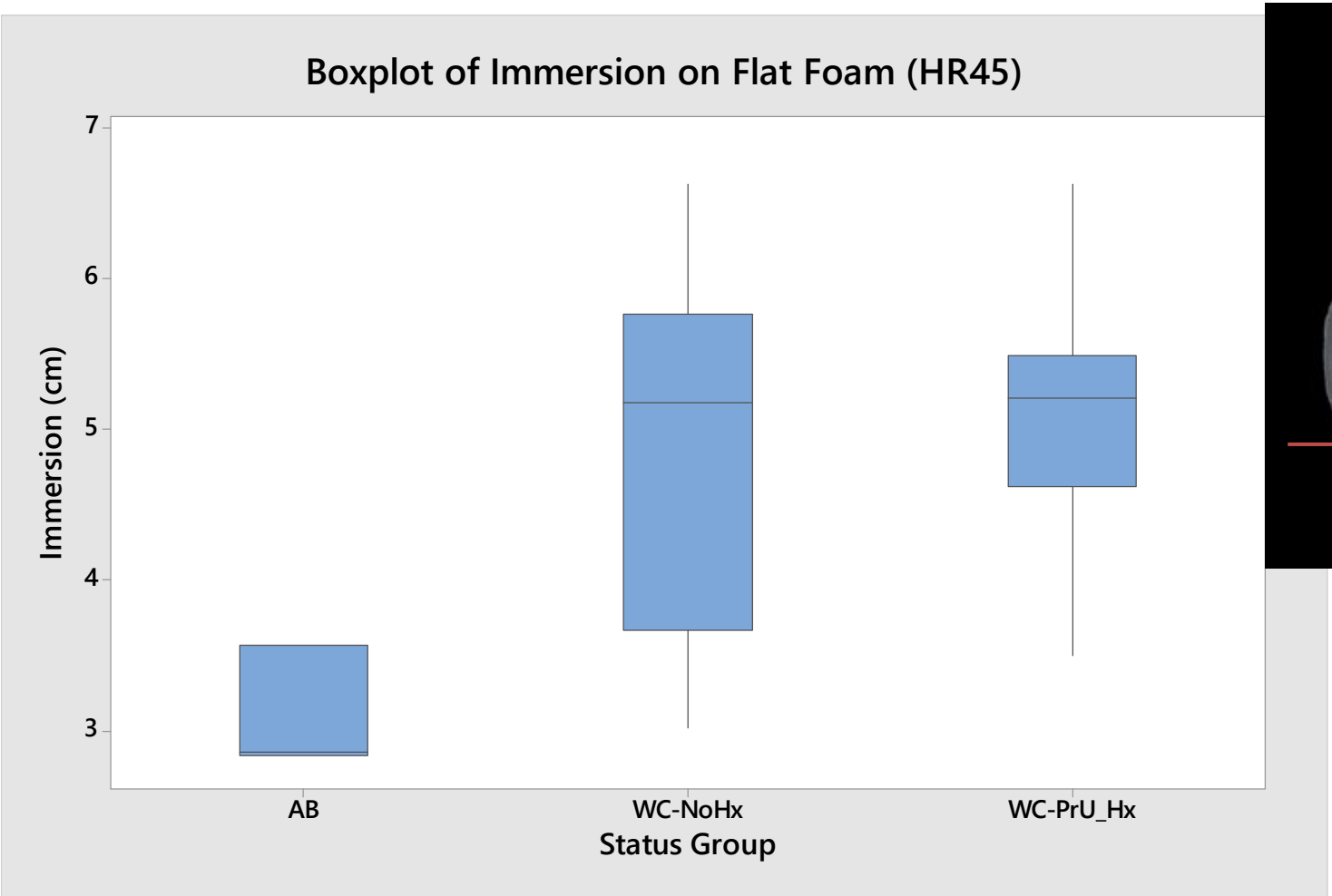
Immersion + envelopment can offer increased contact area and pressure redistribution

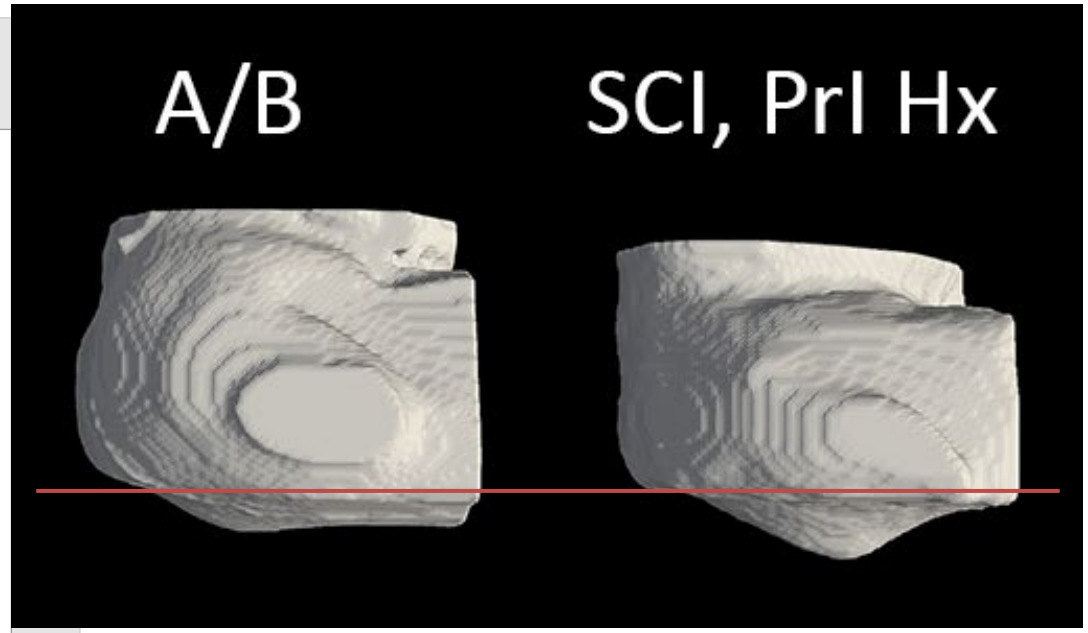
Immersion = Depth of penetration into surface

Envelopment = Ability to conform to irregularities and contact area for level of immersion



Immersion on flat foam





Coccyx Morphology

Anat Sci Int (2013) 88:204–211
DOI 10.1007/s12565-013-0181-2

ORIGINAL ARTICLE

Evaluation of coccygeal bone variability, intercoccygeal and lumbo-sacral angles in asymptomatic patients in multislice computed tomography

Piotr Przybylski · Marcin Pankowicz · Agata Boćkowska · Elżbieta Czekajska-Chehab · Grzegorz Staśkiewicz · Maria Korzec · Andrzej Drop

Table 1 Classification of coccyx proposed by Postacchini and Massobrio (1983)

	Characteristic
Type I	The coccyx is curved slightly forward, its apex pointing downward and caudally (Fig. 1a)
Type II	The curve of the coccyx is more marked and its apex points straight forward (Fig. 1b)
Type III	The coccyx is sharply angled forward between the first and second or the second and third segments (Fig. 1c)
Type IV	The coccyx is subluxated anteriorly at the level of the sacrococcygeal joint or the first or second intercoccygeal joint (Fig. 1d)

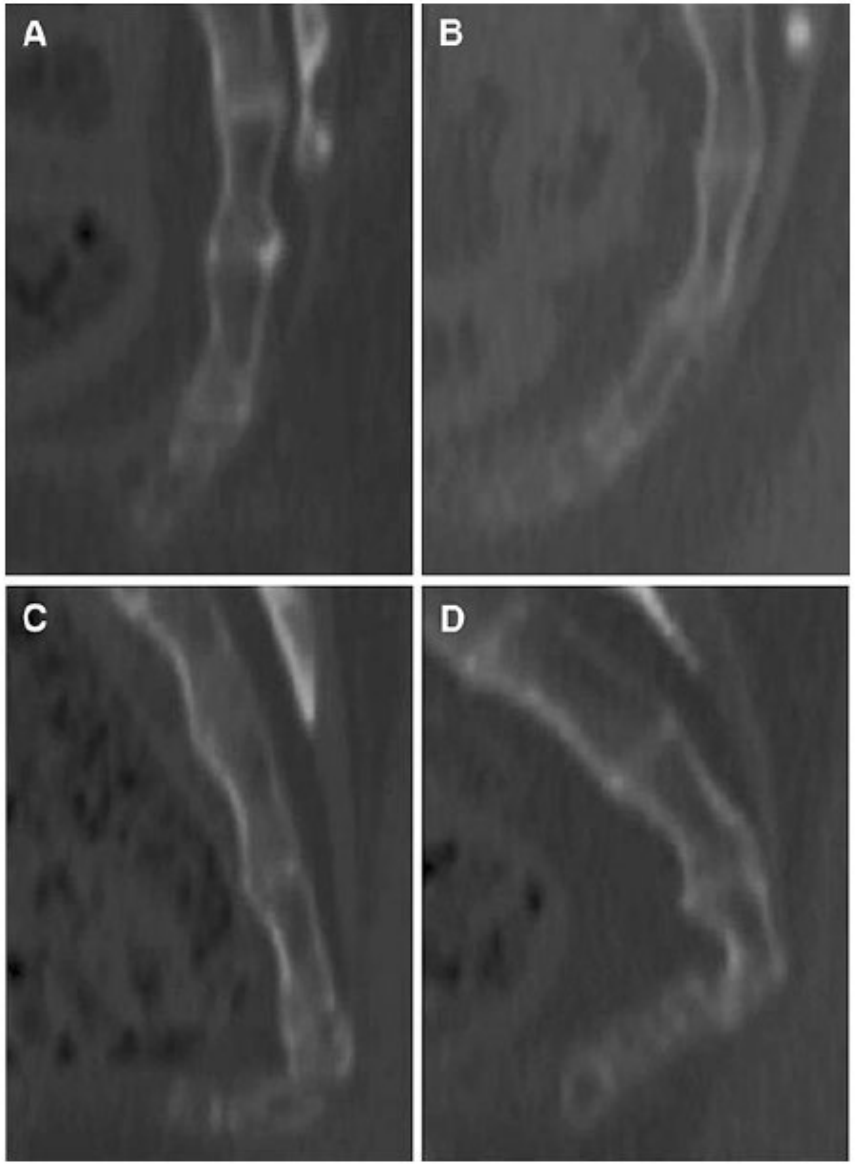
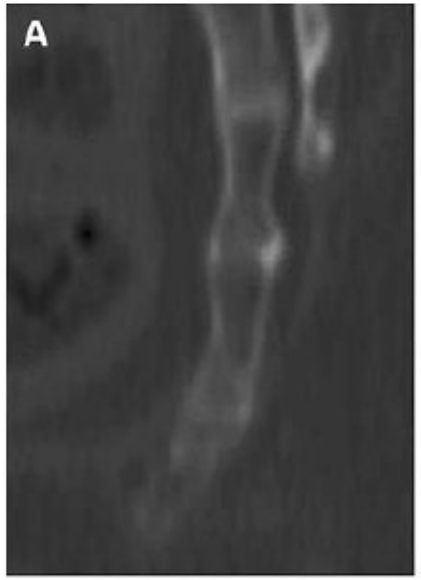
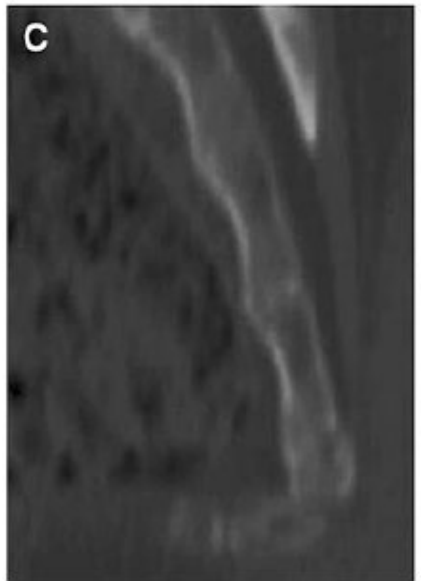


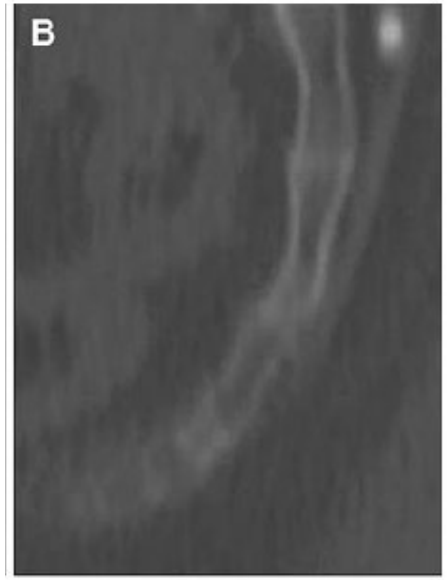
Fig. 1 Types of coccyx according to Postacchini and Massobrio (1983) classification in multislice computed tomography (MSCT). **a** Type I, **b** type II, **c** type III, **d** type IV

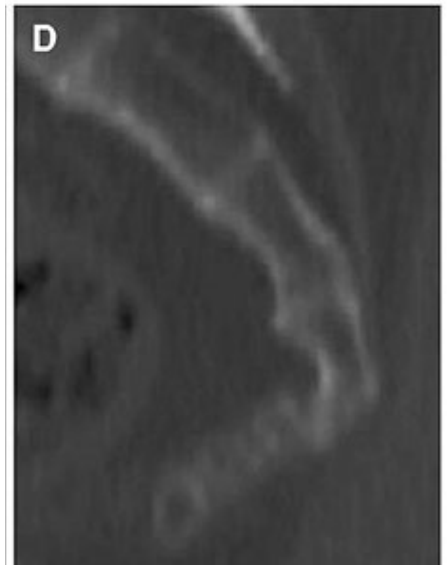




Coccyx Type	No Sacral/Coccyx Pressure Ulcer History	Sacral/Coccyx Pressure Ulcer History
I	17	2
II	8	6
III	6	1
IV	1	4
All	32	13

REARLab, Unpublished Data





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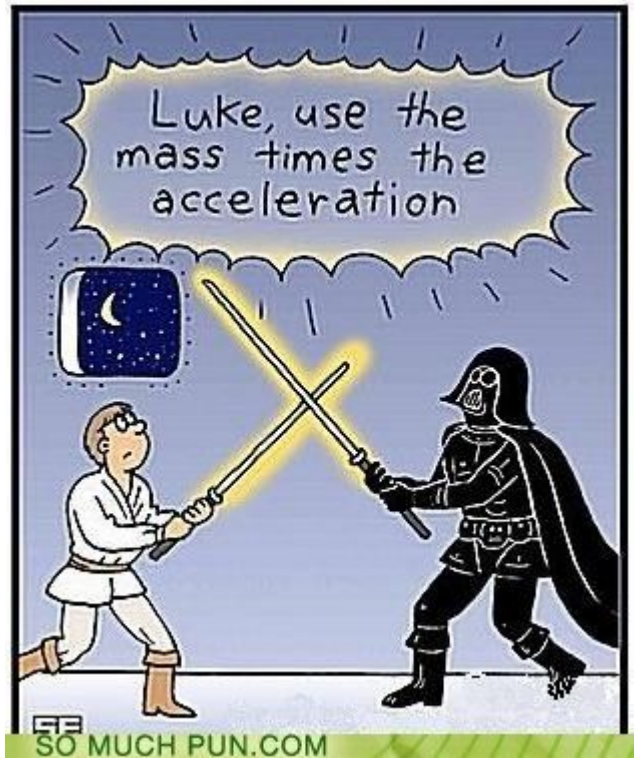
PHYSICS BACKGROUND



Compression!

Body weight

Soft Tissue

Support surface

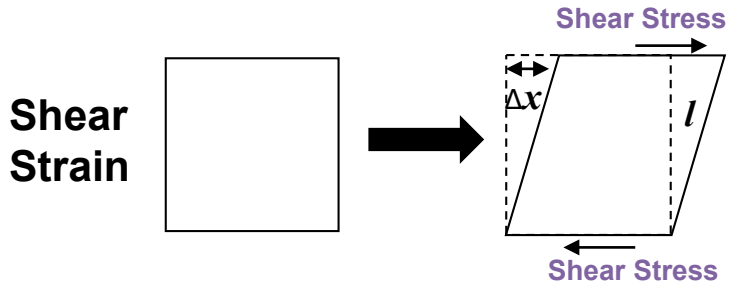
Body weight

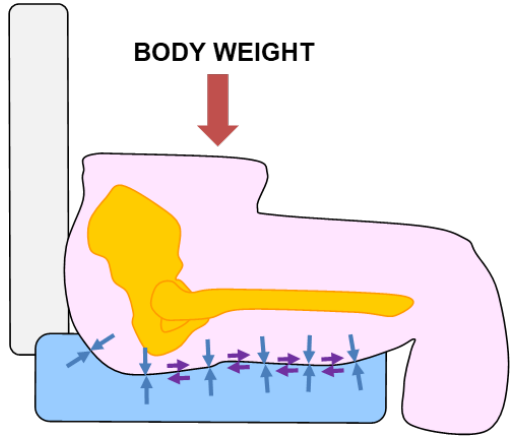
Soft Tissue

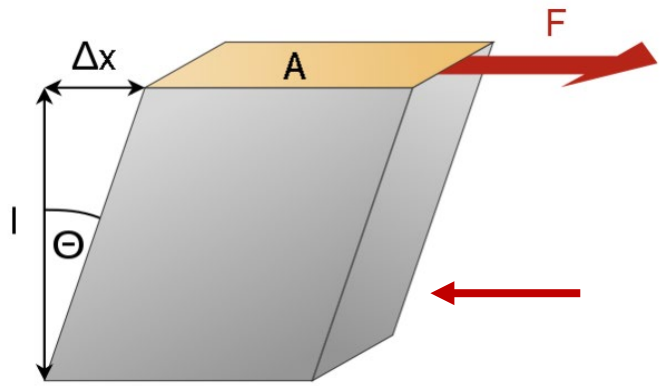
Support surface

Basic Terminology: Shear Force & Shear Stress

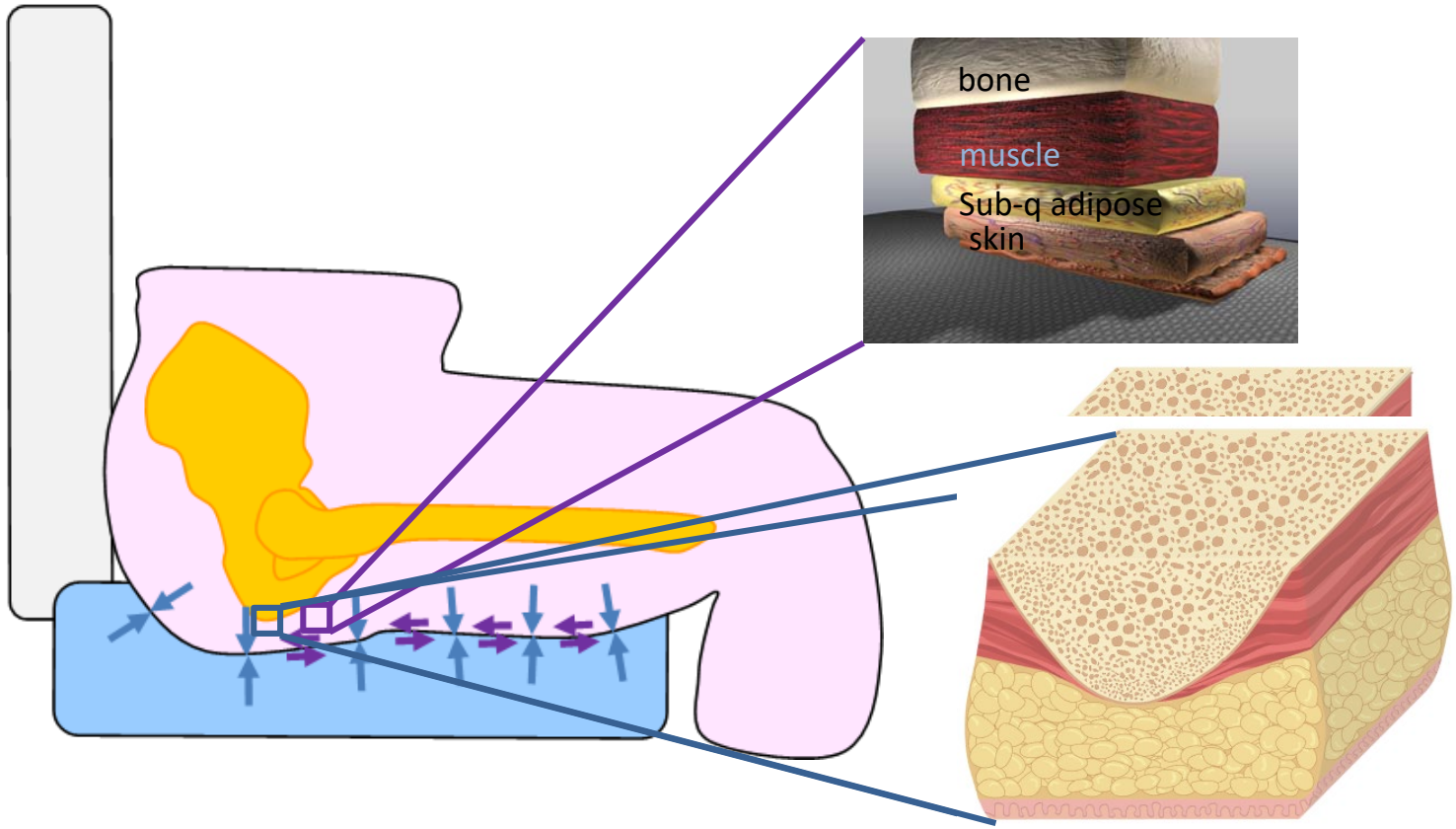
- **Shear forces** act parallel to the body-support surface interface
- When a **Shear Force** is distributed over the contact surface of area **A**, **shear stress** can be defined.
- Shear stress → Shear strain







ALL forces on tissue (normal, friction, shear) can induce shear strain in tissue



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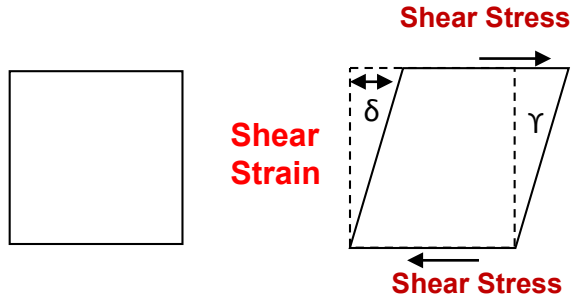
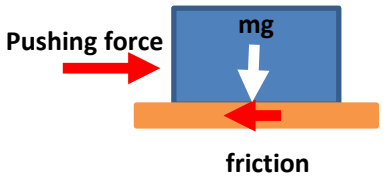
Shear Strain and Friction

- Shear Strain
  - Shear stress induces shear strain
  - Deformation or change in shape
  - Movement of tissues in relation to bony structures; tissue deformation



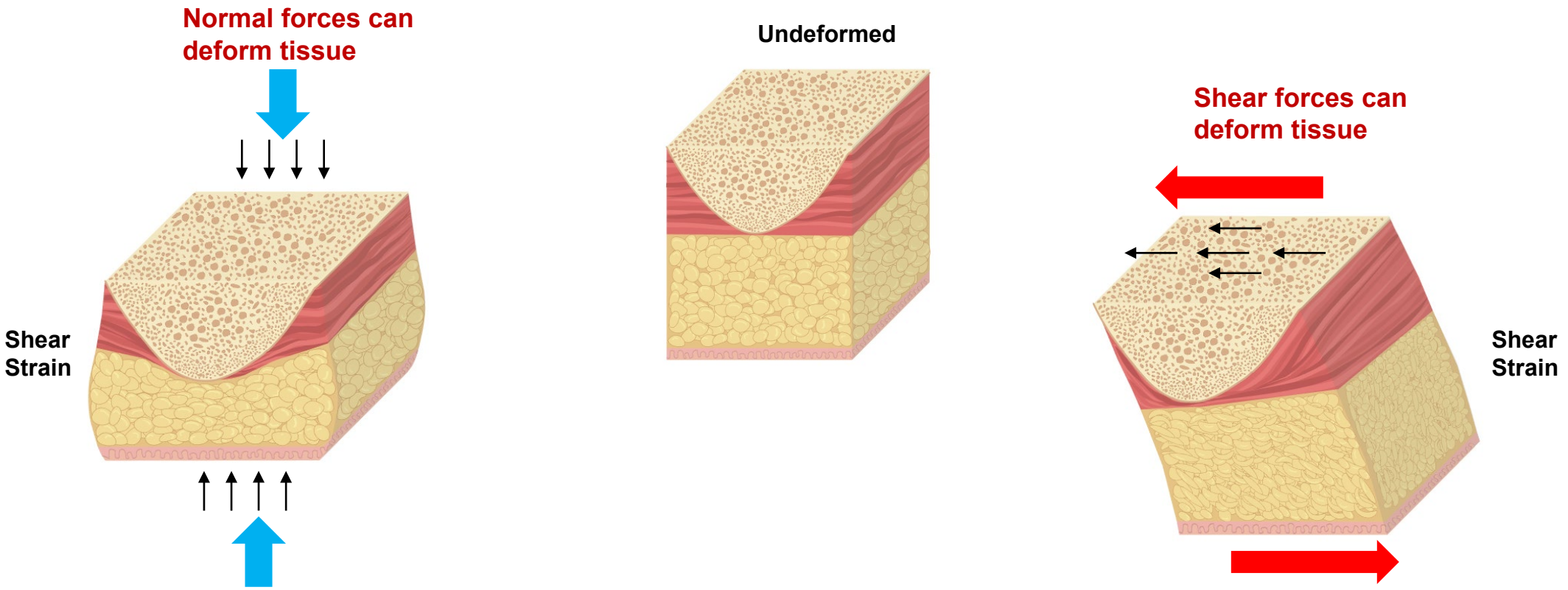
- Friction
  - a force resisting the relative motion of two bodies in contact
  - impedes sliding
  - frictional forces are proportional to normal forces
  - clinically, often refers to damaging forces caused by sliding



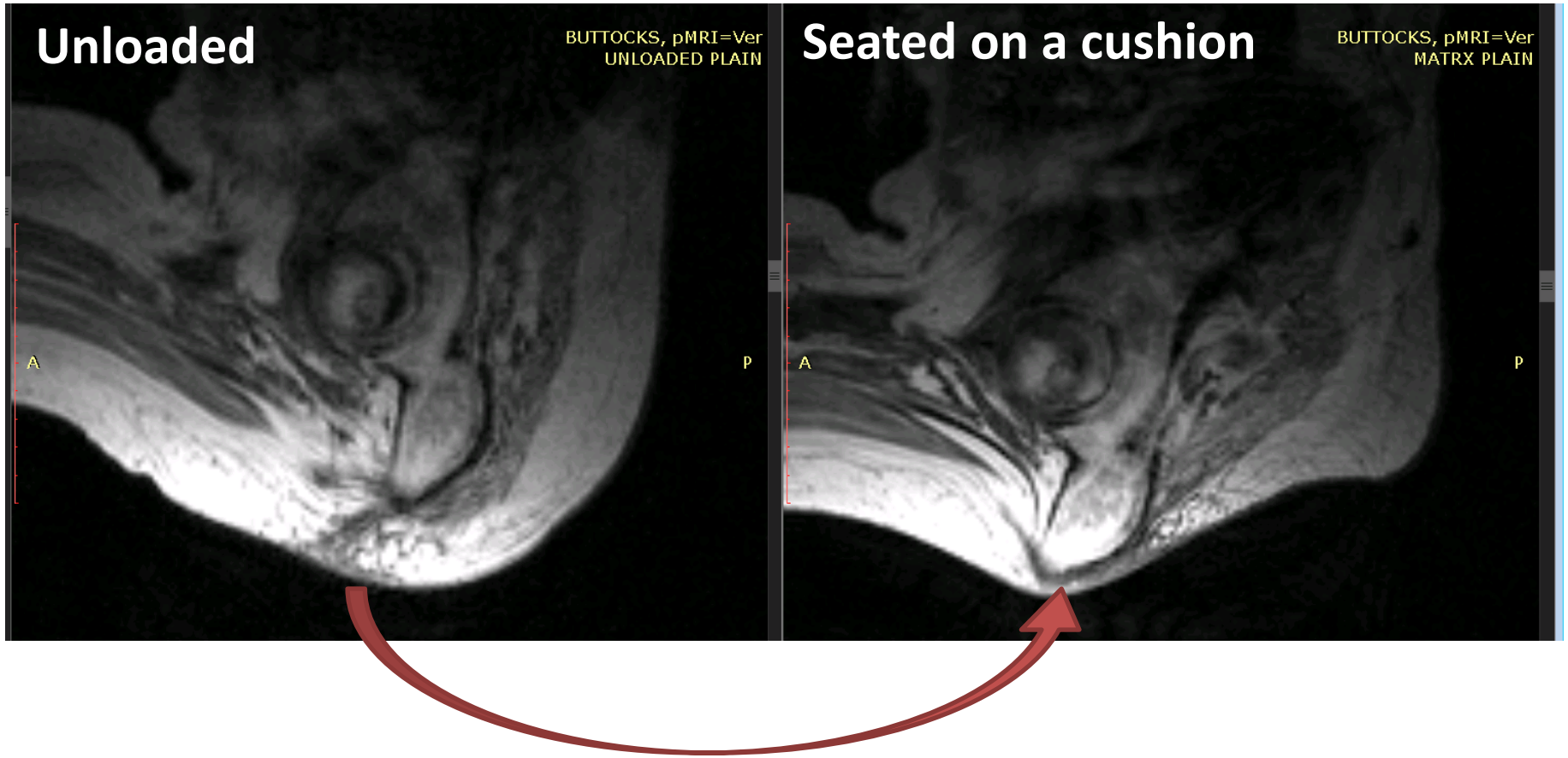
- Friction occurs at interfaces and may induce a shear force within tissue
- Not all shear forces and shear strains are caused by friction
  - Press your finger into your thenar eminence

SEATED TISSUE DEFORMATION ON DIFFERENT CUSHIONS

Soft tissues at the Support Surfaces



Evidence of shear strain during upright sitting (gravitational loads)

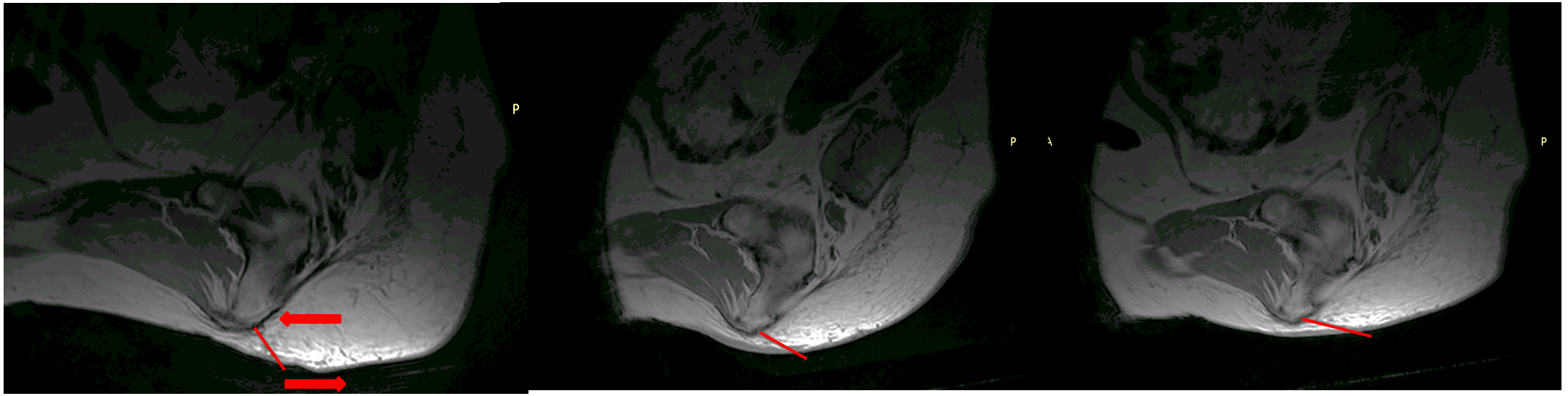


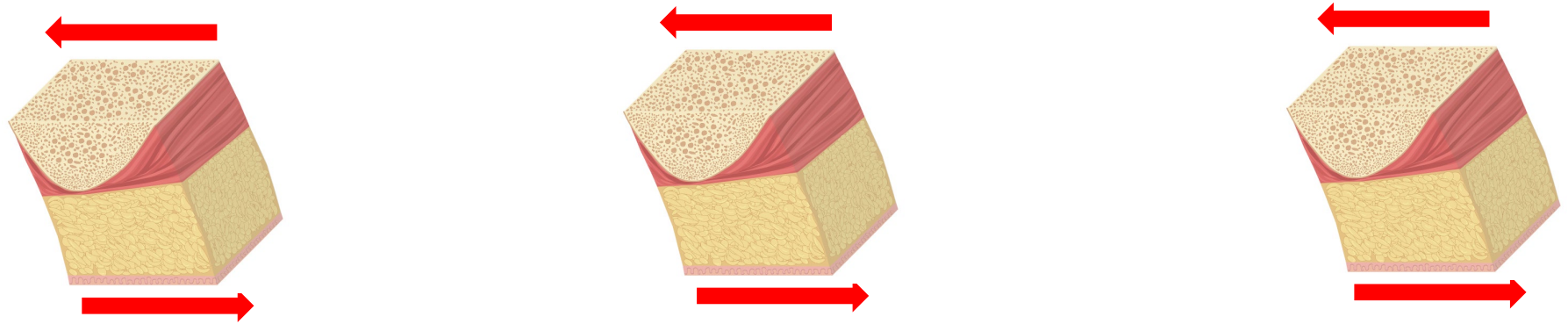
Surface friction in combination with gravitational loads can impart shear strain

Unloaded

J2 Deep Contour

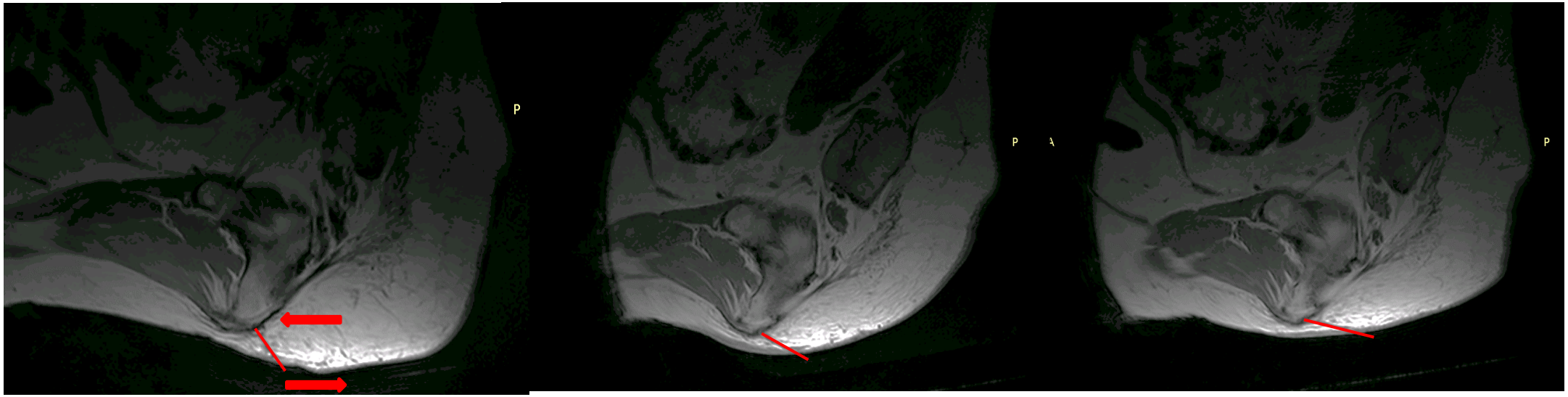
Matrx Vi





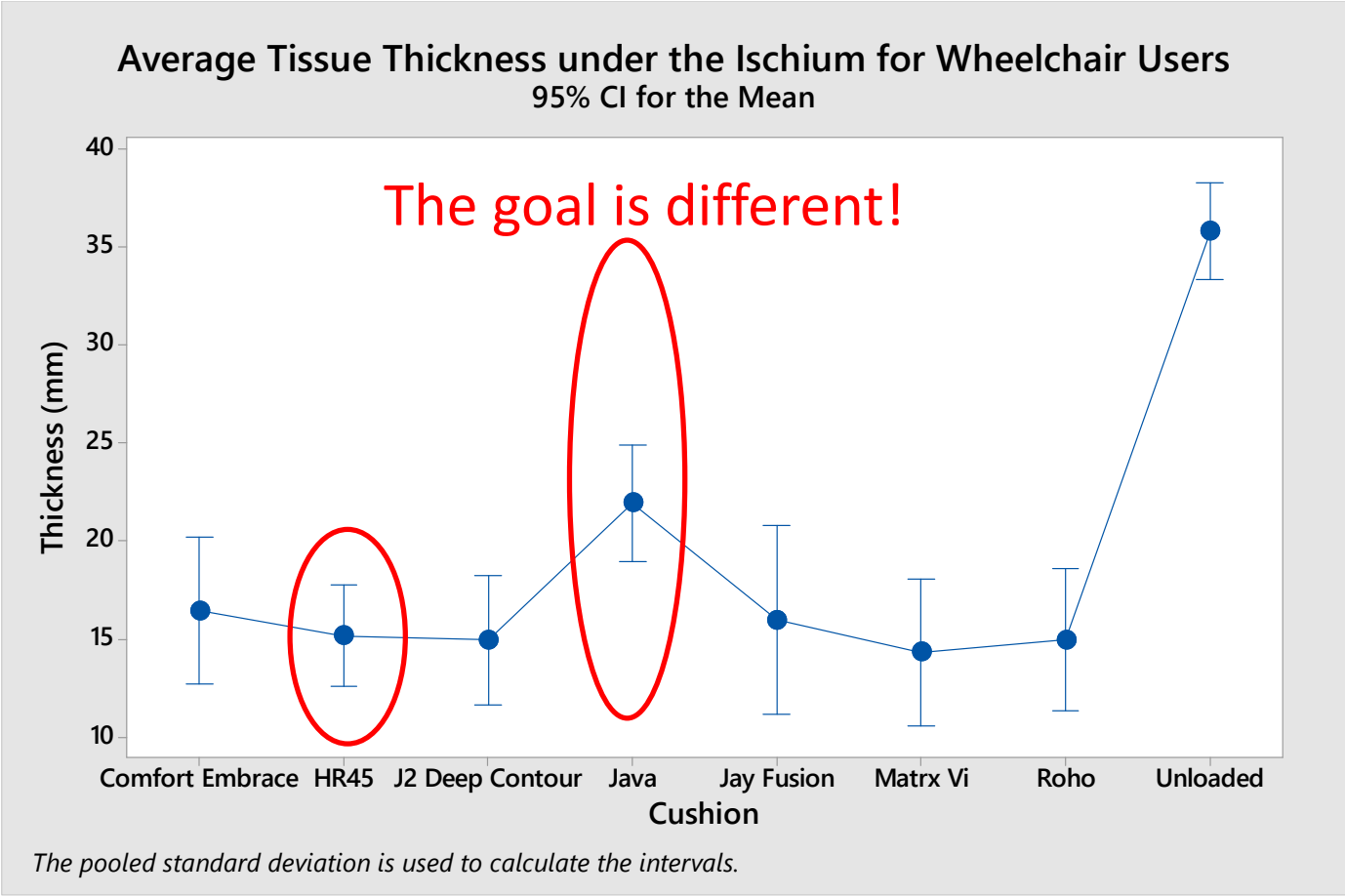
Surface friction in combination with gravitational loads can impart shear strain

Unloaded | **J2 Deep Contour** | **Matrx Vi**



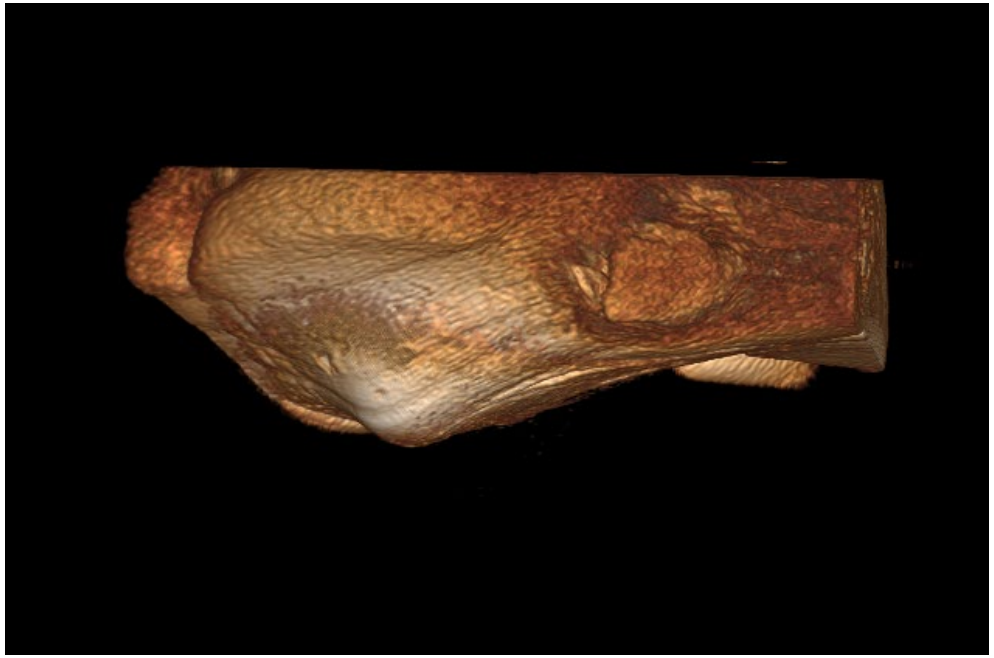
48° | 25° | 13°

Tissue Thickness Under the Ischium



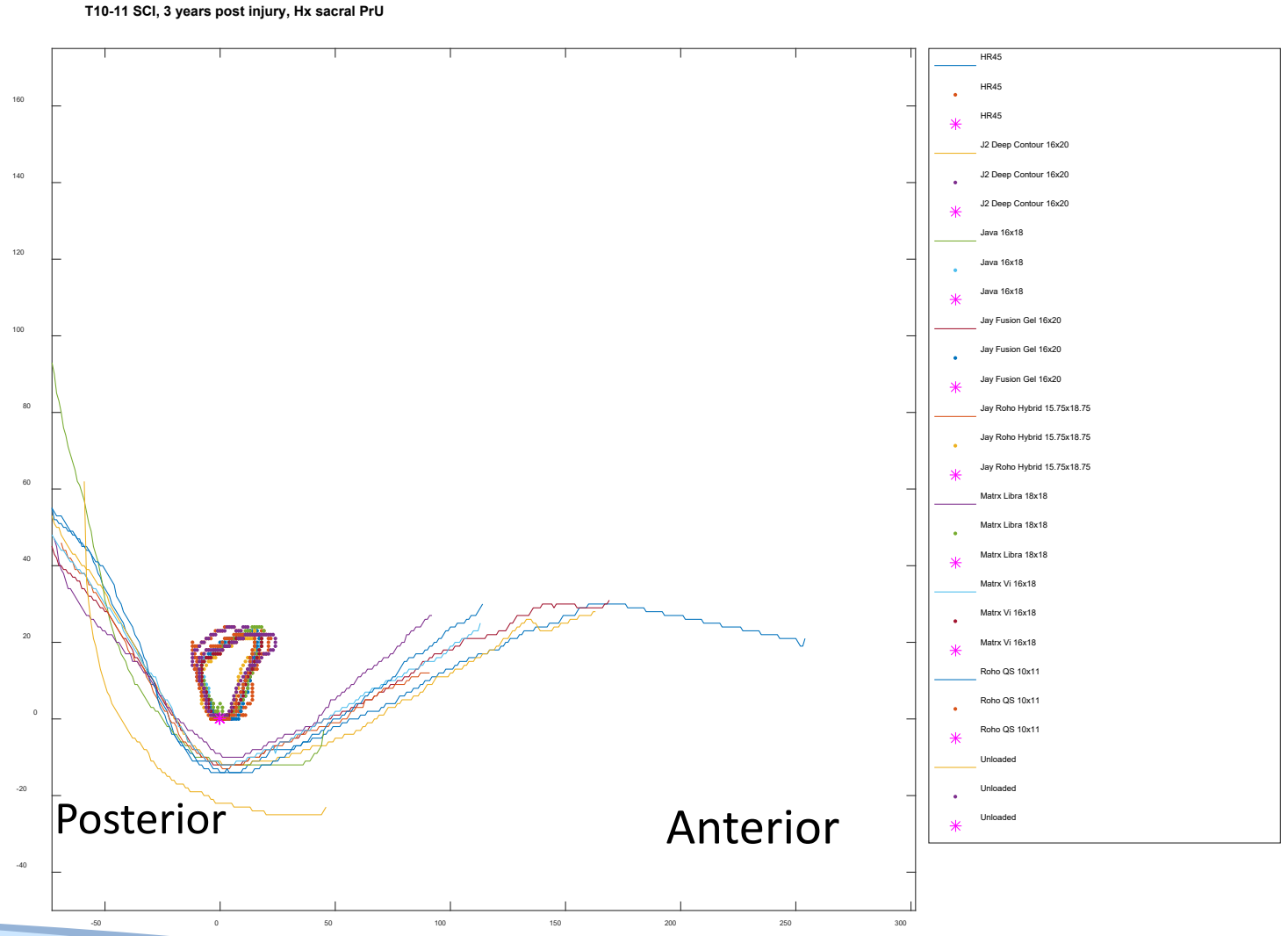
The pooled standard deviation is used to calculate the intervals.

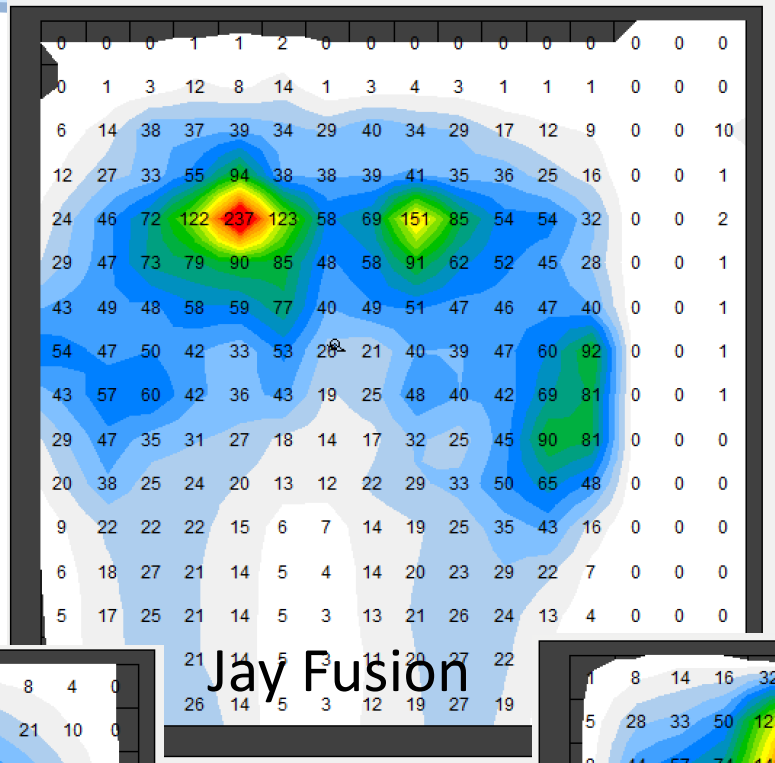
Meet our subject

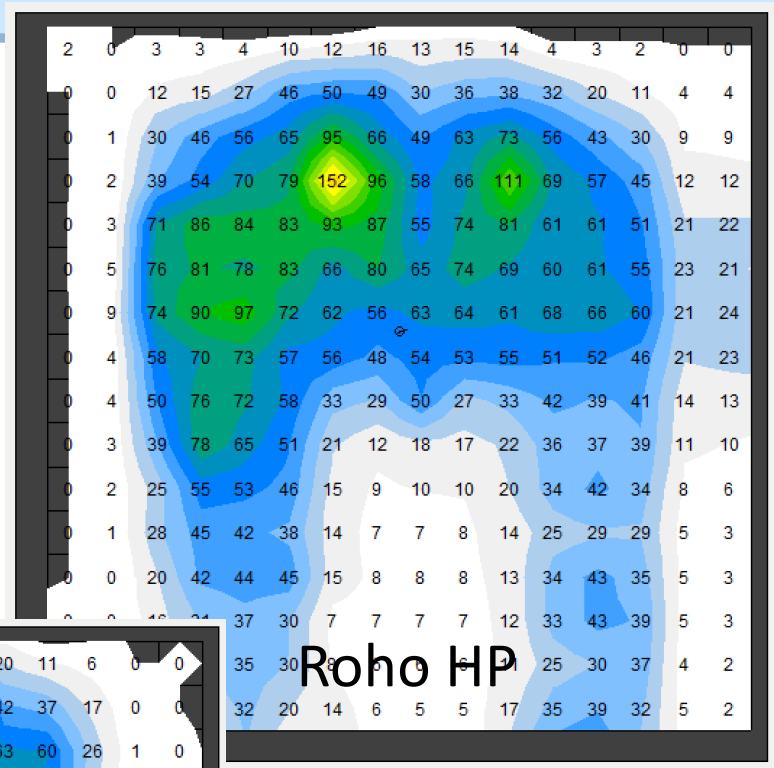


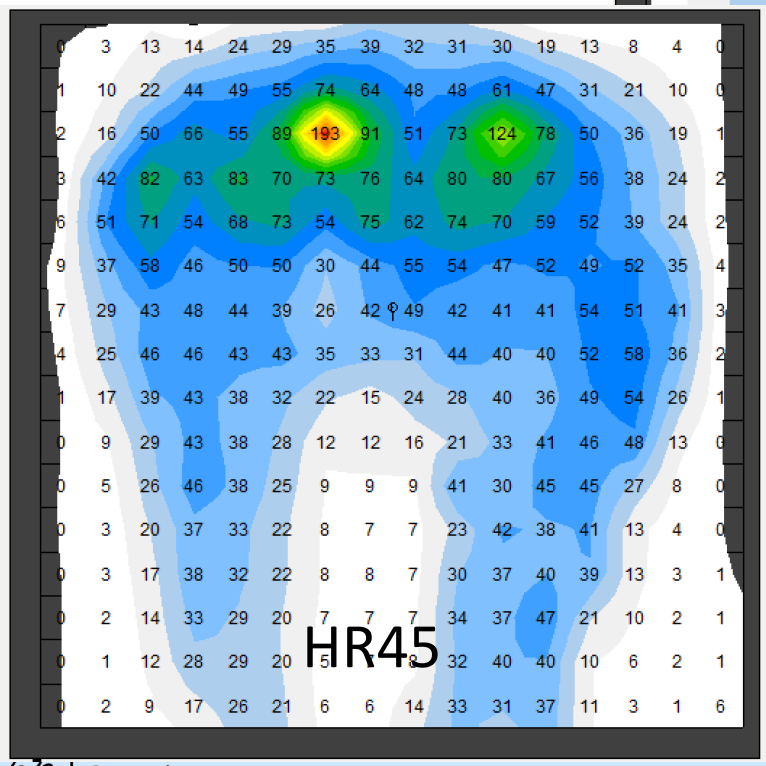
- 54 yo Male
- 172 lbs
- T10-11 SCI
- 3 years post injury
- History of a sacral ulcer
- No spasticity
- Lean muscle (limited fatty infiltration)

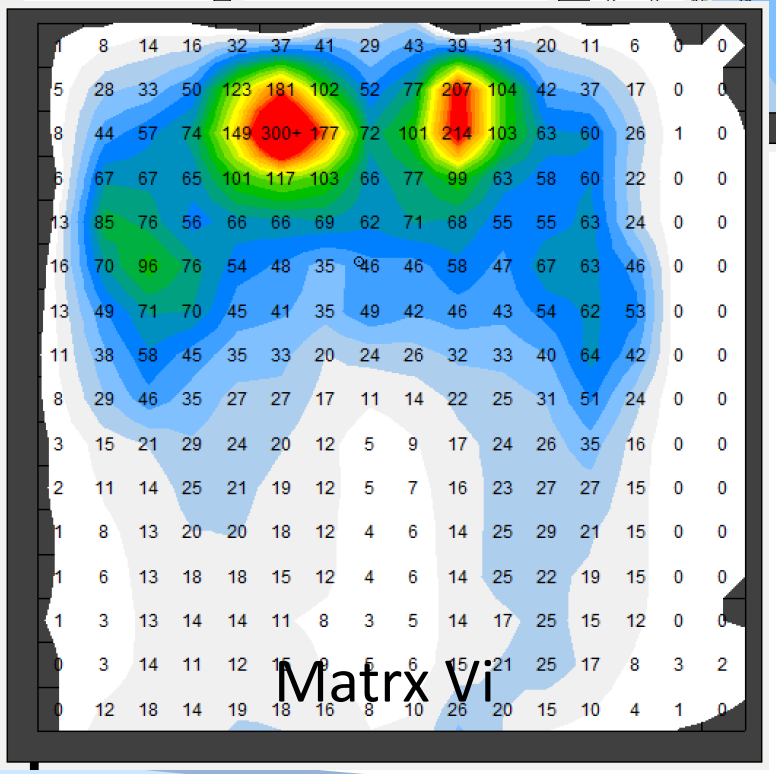
Some people sit the same on every surface




Jay Fusion


Roho HP

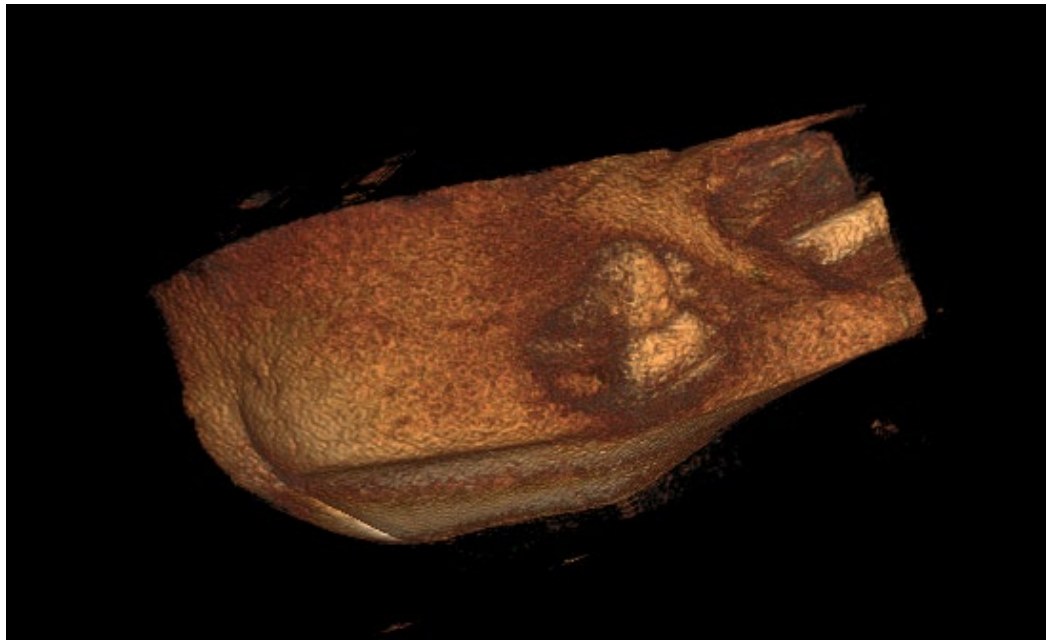

HR45


Matrx Vi

High Biomechanical Risk
High Deformation on ALL Surfaces

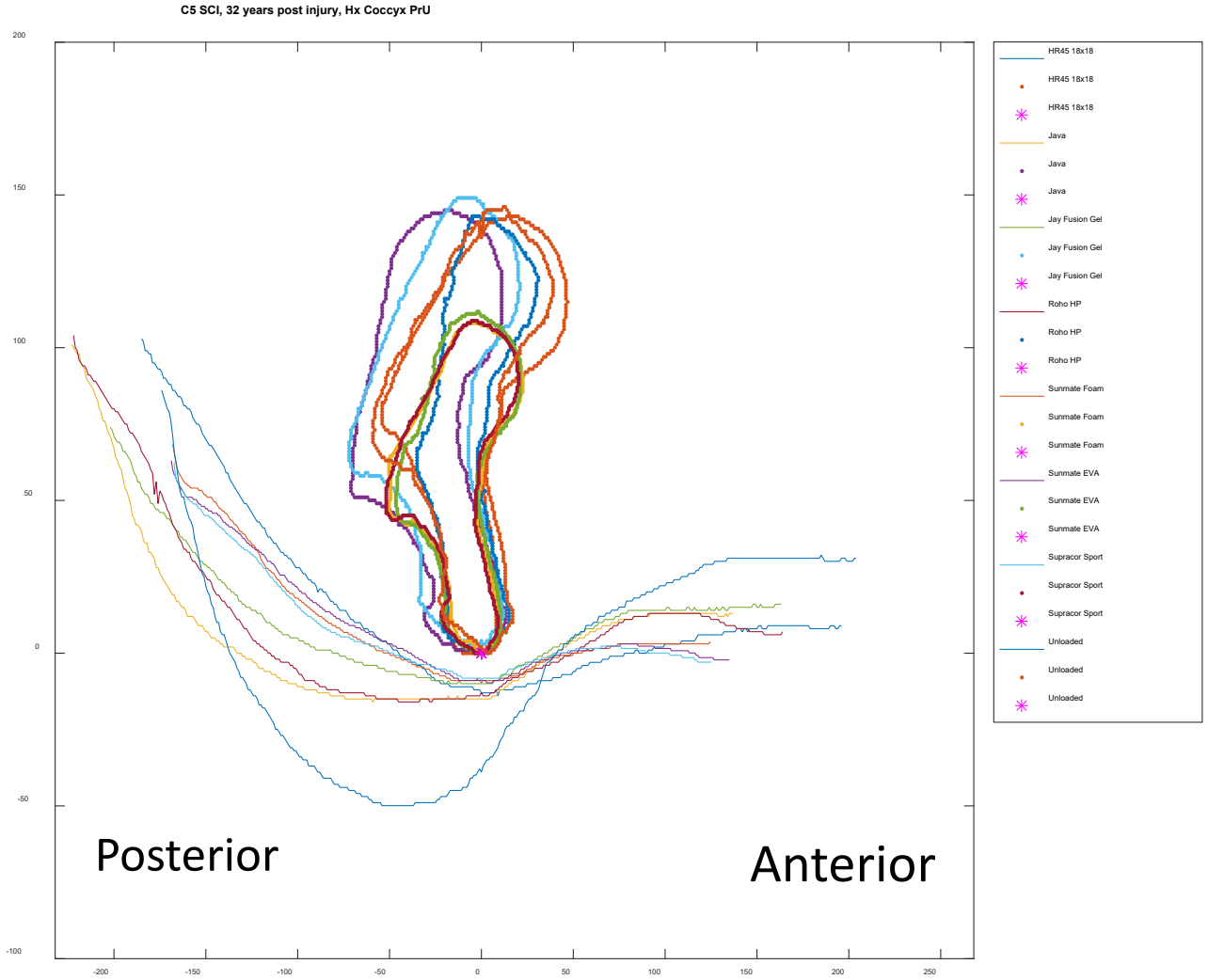
- Internal strain?
- Internal pressure?
- Blood flow?

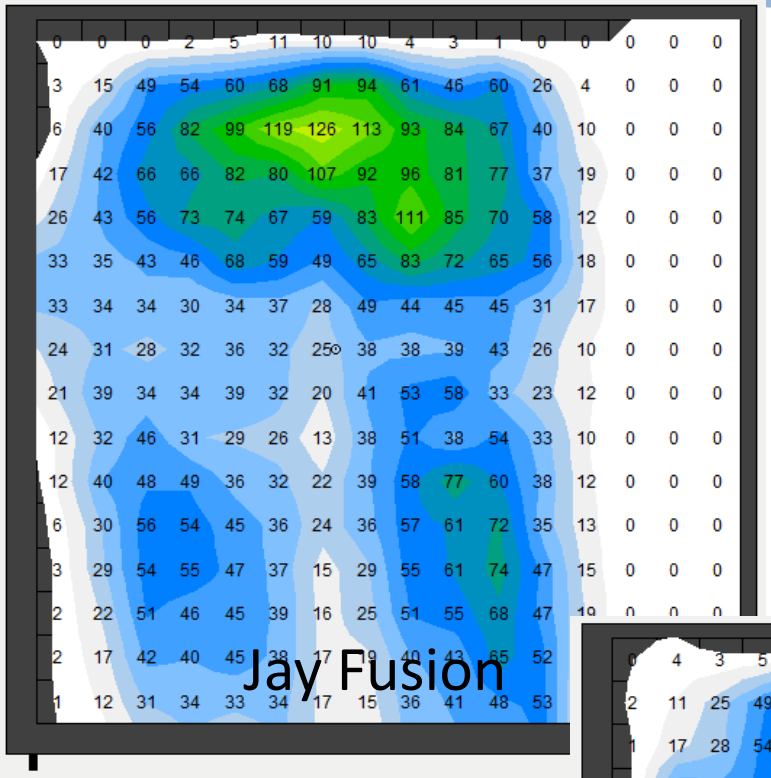
Meet another subject

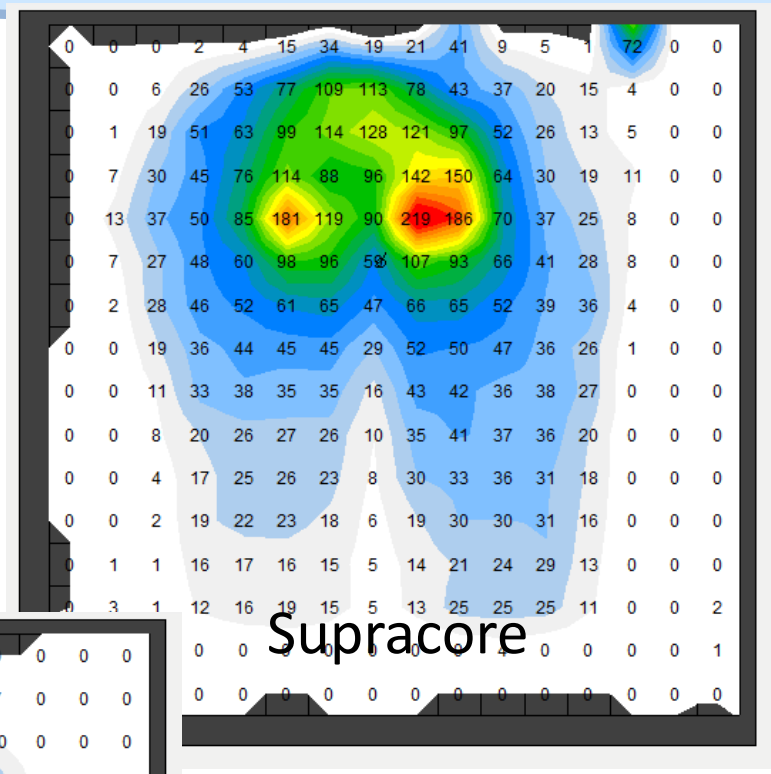


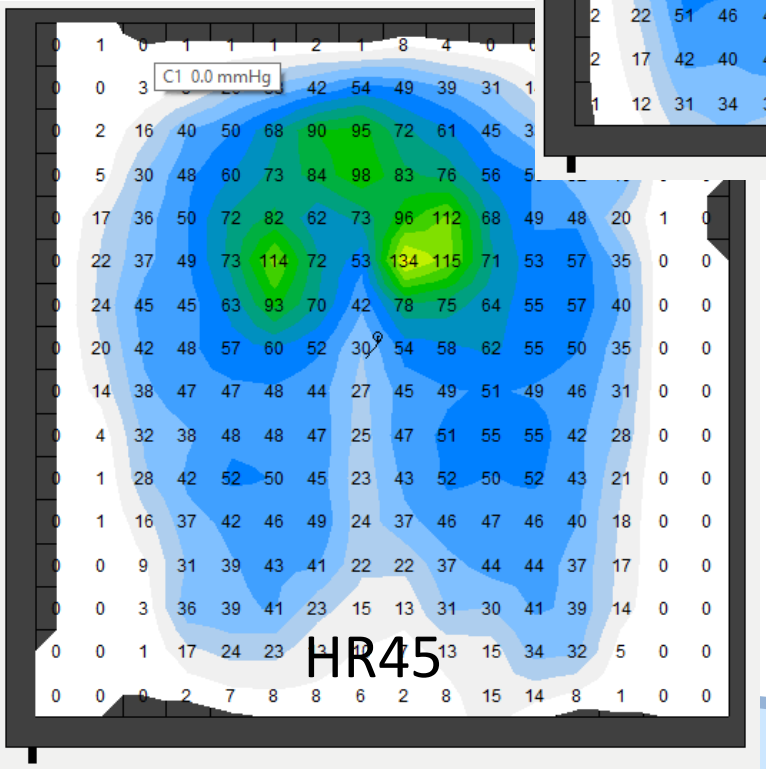
- 58 yo Male
- 160 lbs
- C5 SCI
- 32 years post injury
- History of a coccyx ulcer
- Spasticity
- Lean muscle (no fatty infiltration)

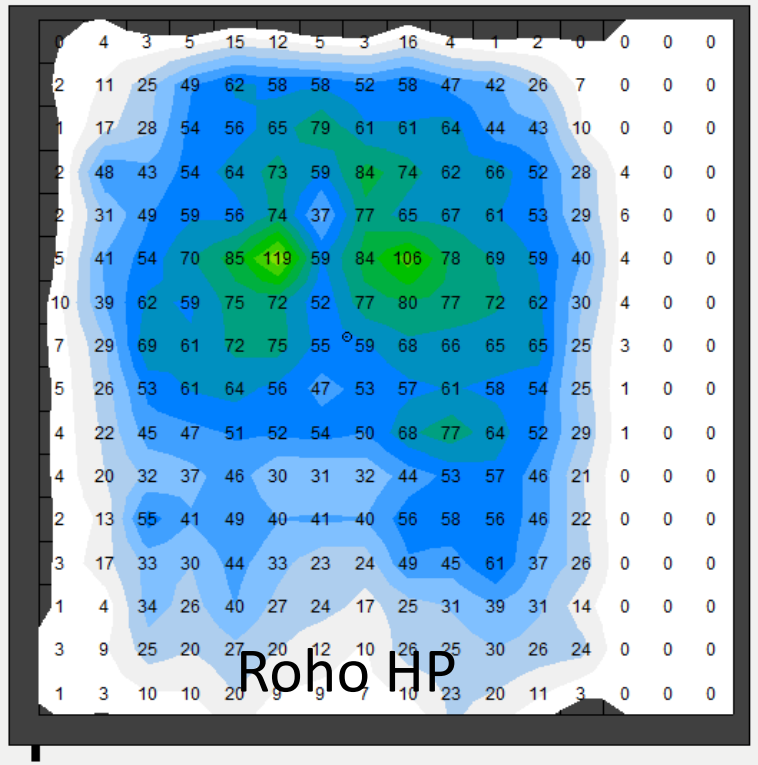
Others sit very differently on different surfaces

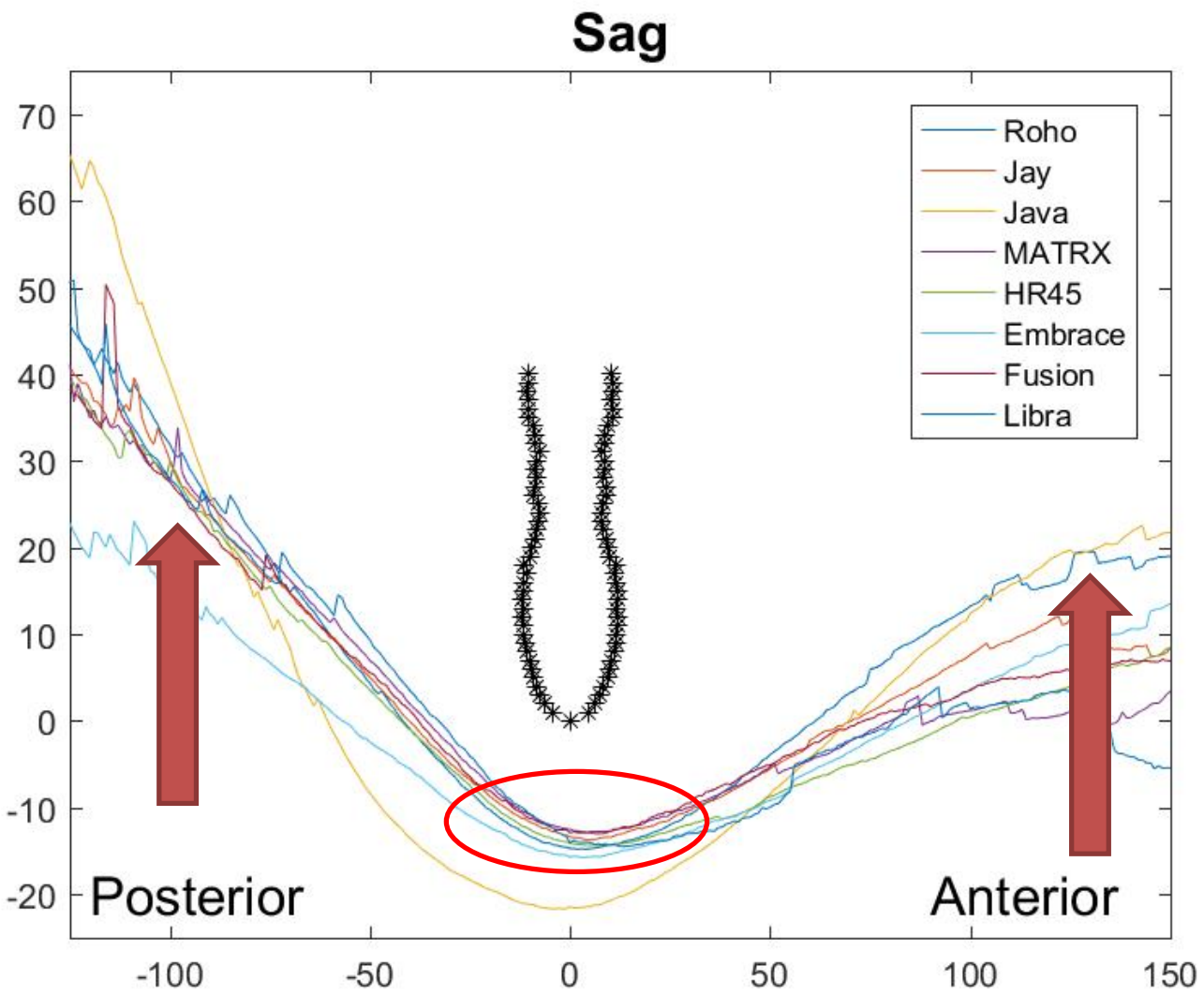



Jay Fusion

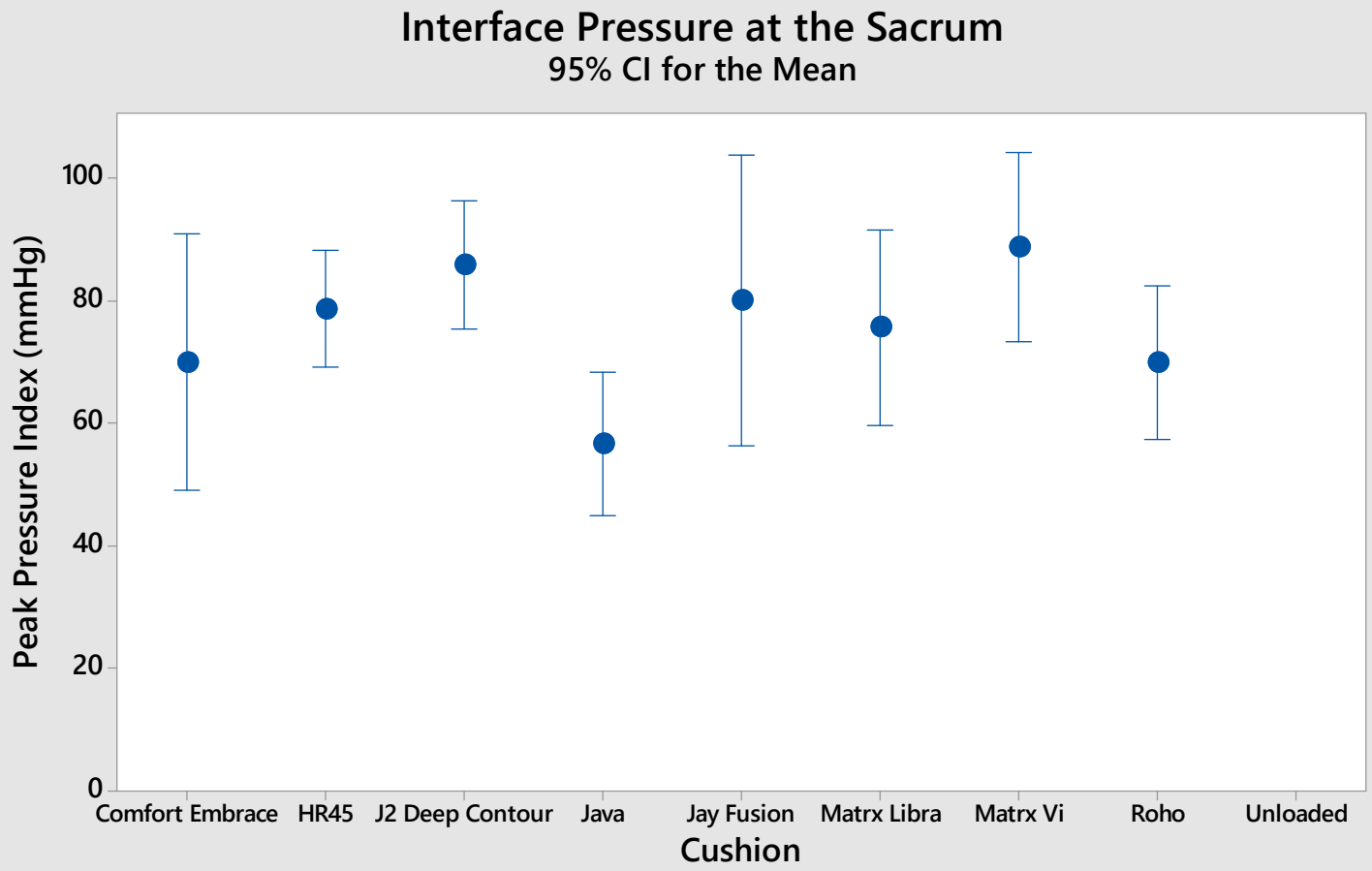

Supracore


C1 0.0 mmHg
HR45


Roho HP


Sag
70
60
50
40
30
20
10
0
-10
-20
-100
-50
0
50
100
150
Roho
Jay
Java
MATRX
HR45
Embrace
Fusion
Libra
Posterior
Anterior

Interface pressure at the Sacrum

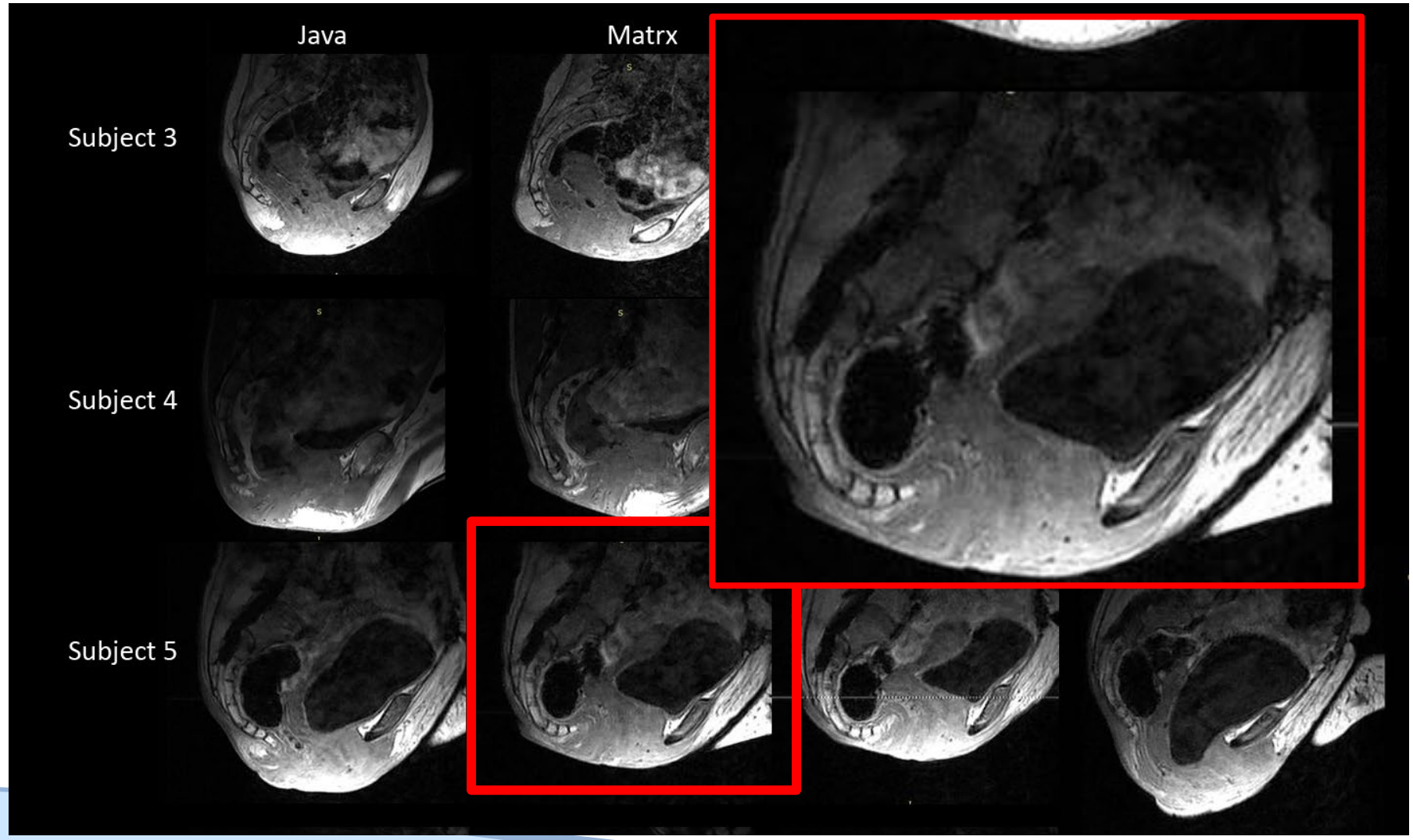


Individual standard deviations are used to calculate the intervals.

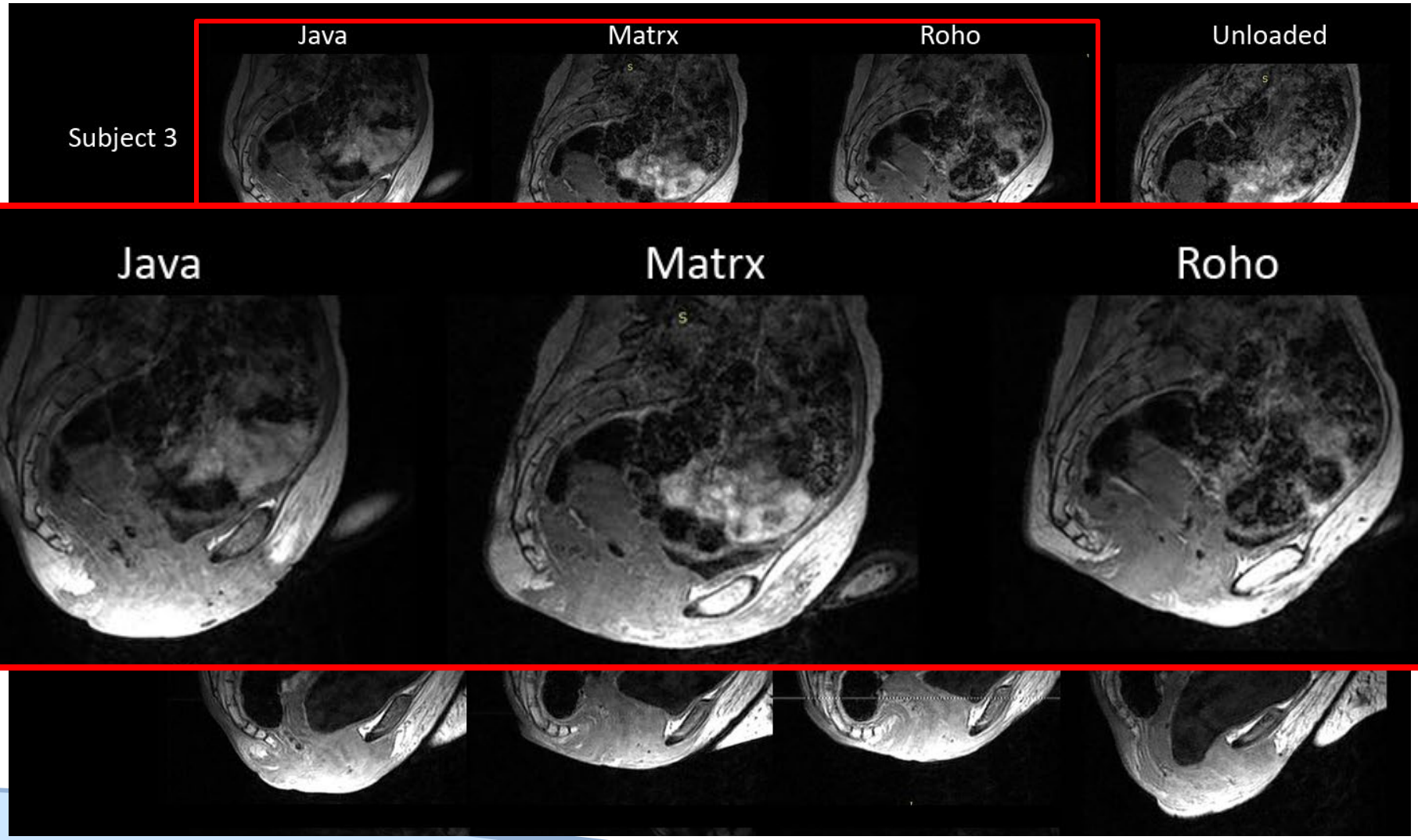
- Does NOT measure shear force
- Posture dependent

SPEAKING OF POSTURE…

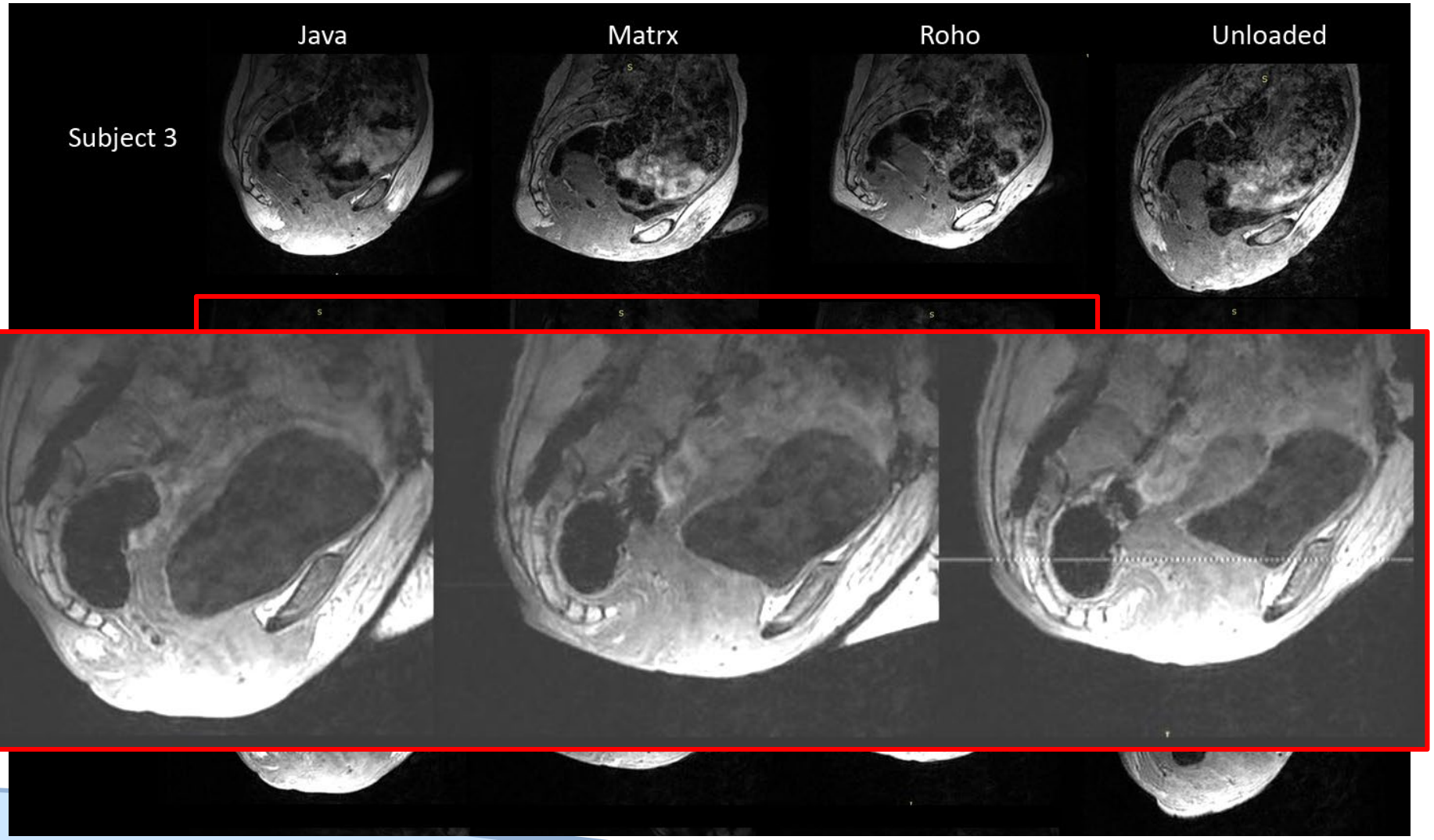
Sacrum and Coccyx



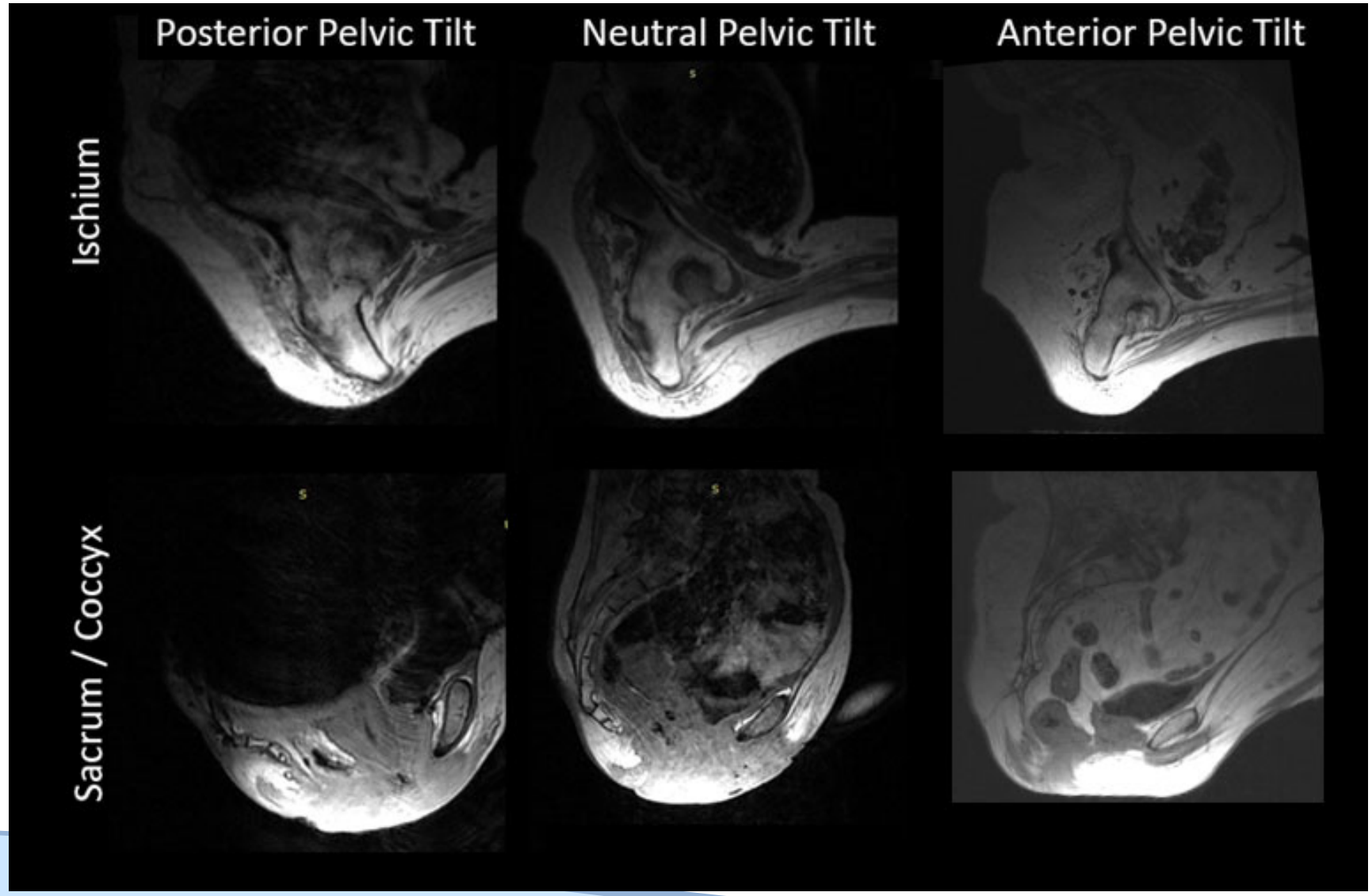
Sacrum and Coccyx



Sacrum and Coccyx



Pelvic Tilt on the Java



Posture Impacts:

- Contact with cushion
- Force on sacrum and coccyx (normal/perpendicular and shear)
- IT position on cushion
- Loaded aspect of IT

Summary

- We do NOT sit on our gluts
- Biomechanical risk
  - Tissue thickness and curvature are different in those at highest risk
  - BMI and delta hip thickness could predict risk – we need more data
  - Coccyx morphology may impact risk of sacral/coccyx ulcers!
- Differences across cushions
  - Amount of tissue under the ischium is similar for most immersion/envelopment cushions
  - Evidence of shear strain in the tissue during sitting
  - Some people experience the same deformation across all cushions
    - Who?
    - Why?
    - Does it matter?

Acknowledgements

- The butts (i.e., participants)
- Kessler Rehab – Mary Shea, MA, OTR, ATP & Trevor Dyson-Hudson, MD
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- Stephen Sprigle, PhD, PT
- Students!
- University of Ulster
- Robert H. Graebe Foundation

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Contact Information

Sharon Sonenblum:
ss427@gatech.edu
http://rearlab.gatech.edu

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QUESTIONS?