

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.

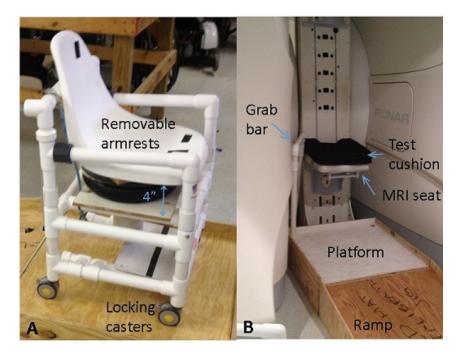


#### THE SEATED BUTTOCKS



#### MRI Studies of the Buttocks: FONAR "Stand-up" MRI

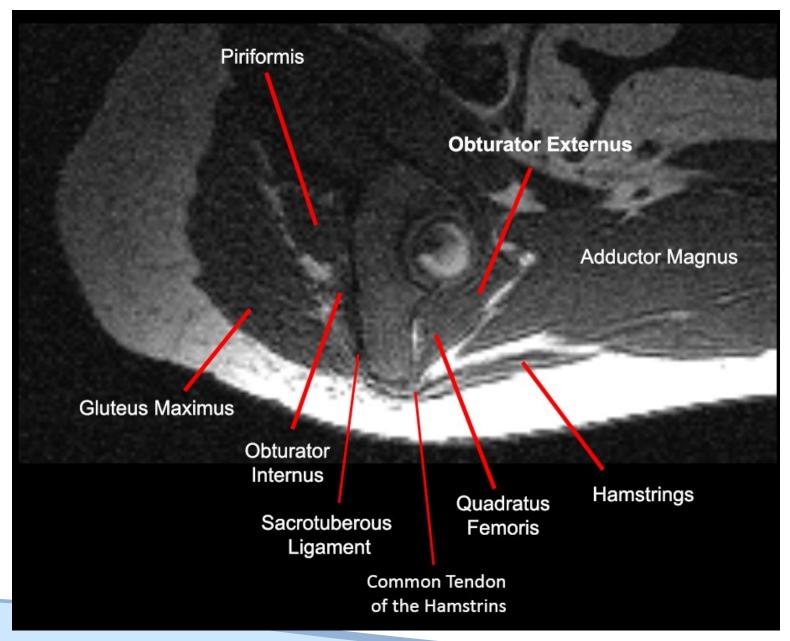






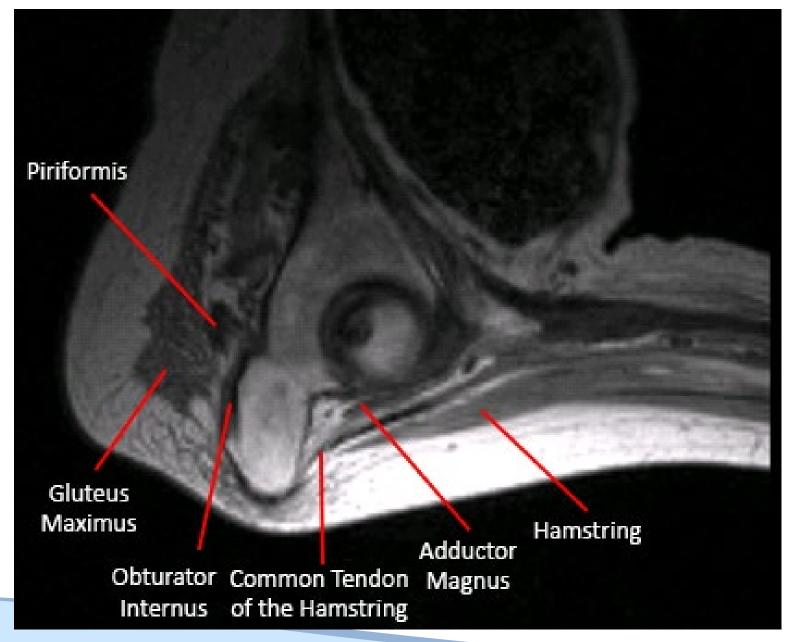


#### **Able-Bodied Buttocks**



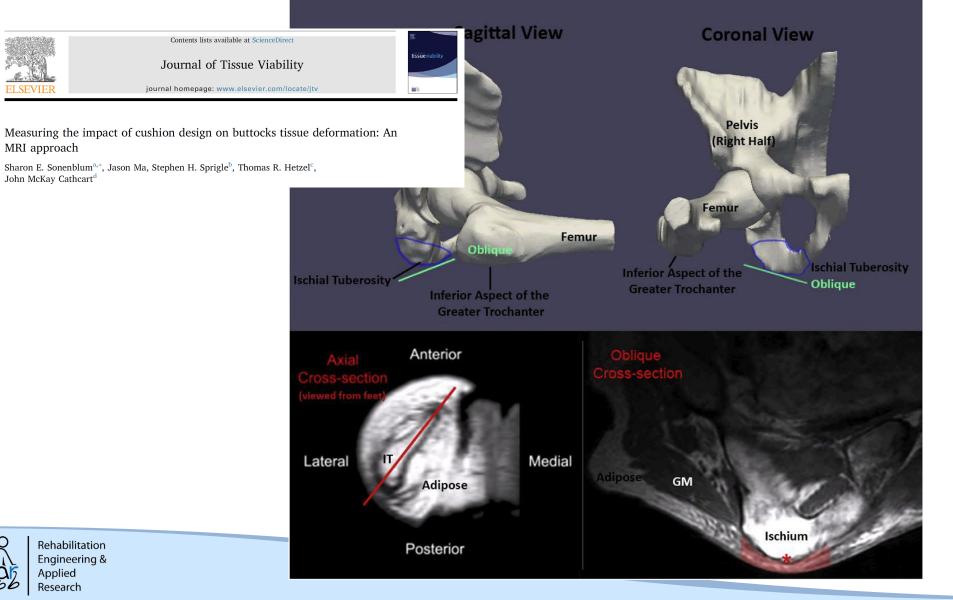


#### SCI (Atrophied) Buttocks



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#### The ischium runs at an oblique angle

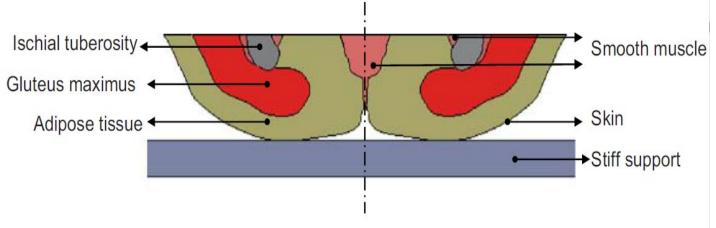


#### Question: What are you sitting on?

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



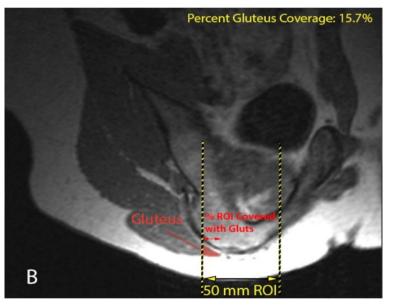
### Typical Assumption: People are Sitting on Muscle



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



#### Gluteus Maximus coverage of ischial tuberosities

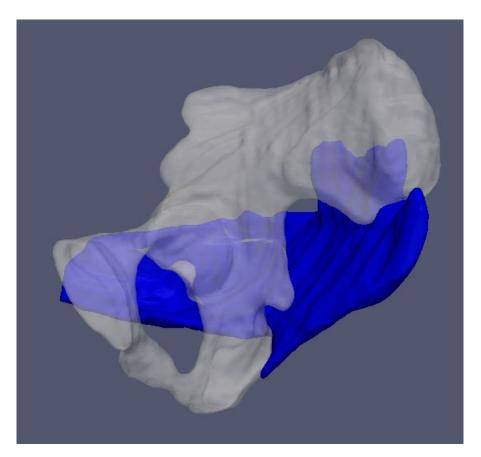


% Gluteus Coverage	Able-bodied	Wheelchair Users	% of Total
0%	3	30	61 %
1-25%	7	10	31 %
25-50%	1	1	4 %
50-75%	0	0	0 %
75-100%	1	1	4 %

n=54

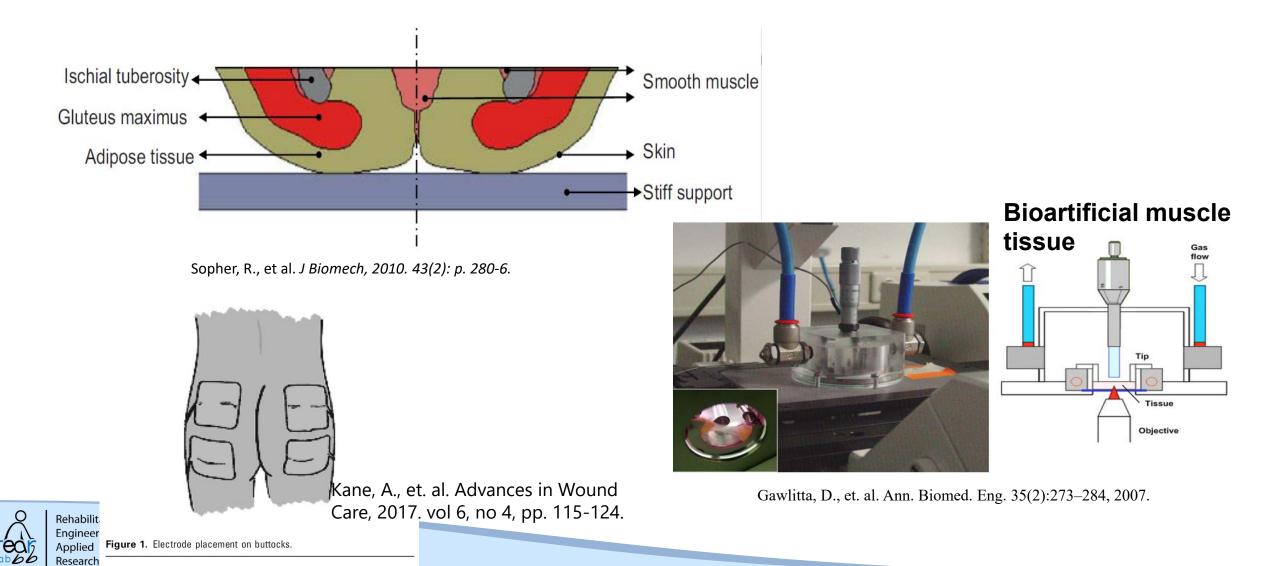


#### Example of the Gluteus Maximus While Seated T12 SCI Male, Medial View





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



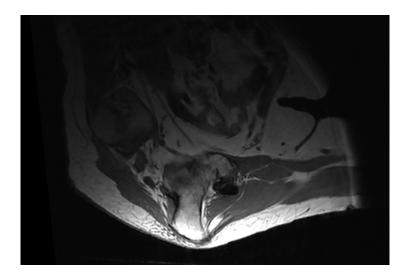
#### **Gluteus Maximus Characteristics**

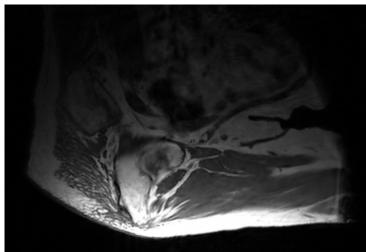
Table 3   Gluteus maximus muscle characteristics.			
Gluteus maximus	SCI [range]	AB [range]	p value
Volume (cm <sup>3</sup> )	$379 \pm 159$ [154 to 582]	667 $\pm$ 114 [504 to 892]	<0.05
CSA (cm <sup>2</sup> )	22 $\pm$ 8 [7 to 30]	40 $\pm$ 5 [30 to 43]	<0.05
Fat (%)	29 $\pm$ 23 [3 to 84]	8 ± 9 [2 to 35]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

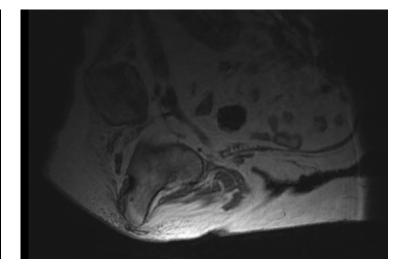
Wu & Bogie, 2013. J Tissue Viability. 2013 Aug;22(3):74-82.



#### Fatty Infiltration in Men with SCI

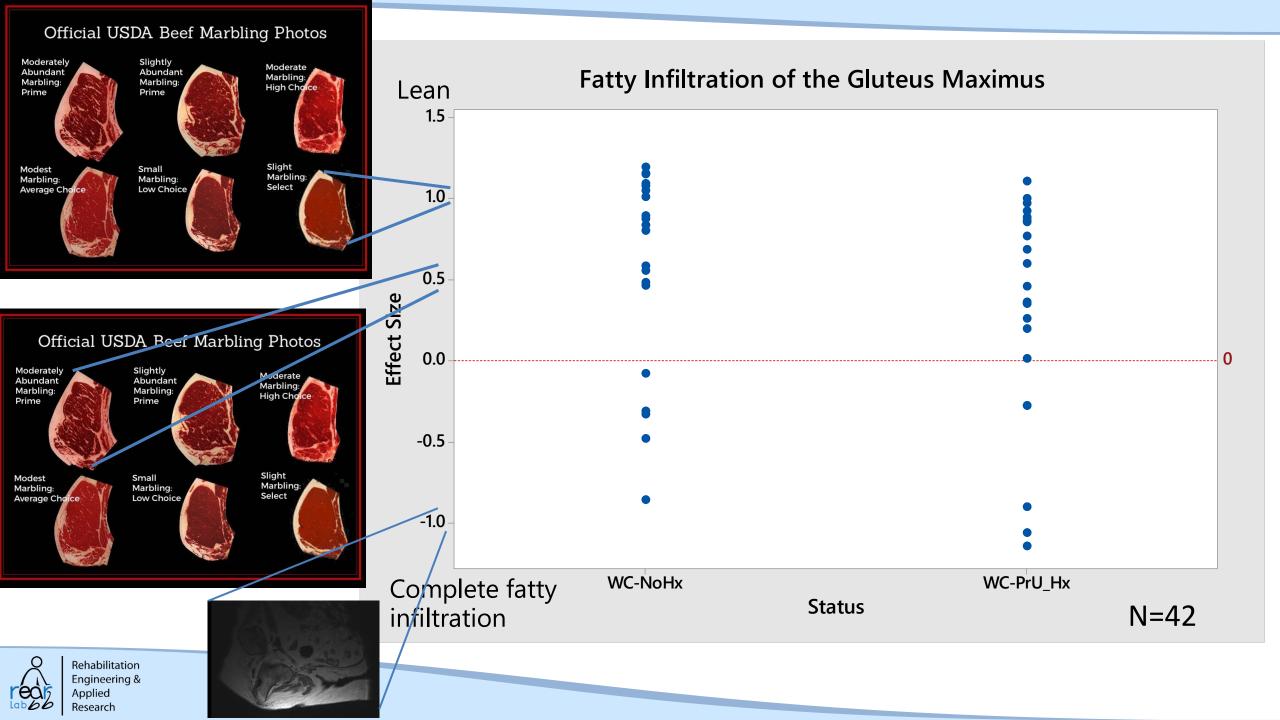




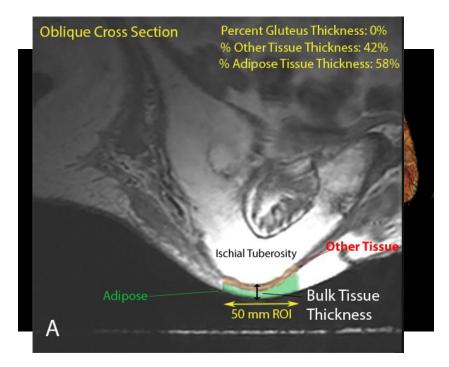


27yo, 6 years post injury BMI = 24.1 Mild spasms No history of PrU 49yo, 29 years post injury BMI = 27.3 Infrequent spasms (<1/hr) History of PrU 58yo, 14 years post injury BMI = 29.6 No spasticity No history of PrU





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

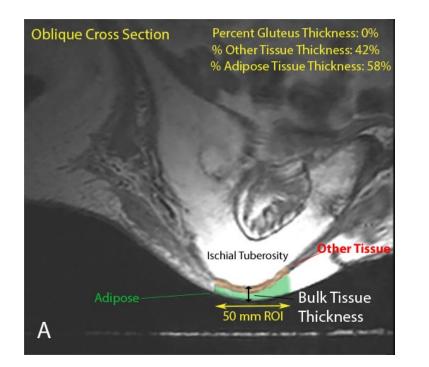


	Mean (SD)
Tissue Thickness	39.1 mm (12.5 mm)
% Adipose	76.2 % (17.5 %)

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**

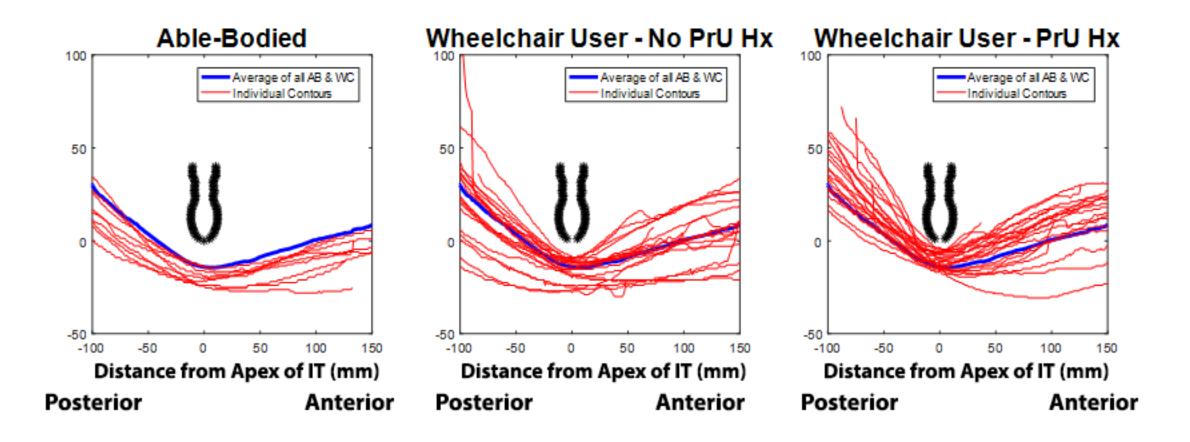
### The intrinsic characteristic of an individual's soft tissues to deform in response to extrinsic applied forces

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.** 

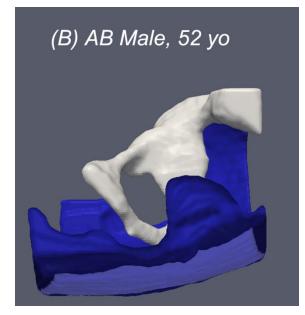


#### **Biomechanical Risk**





#### Strain: The Inner Adipose Surface



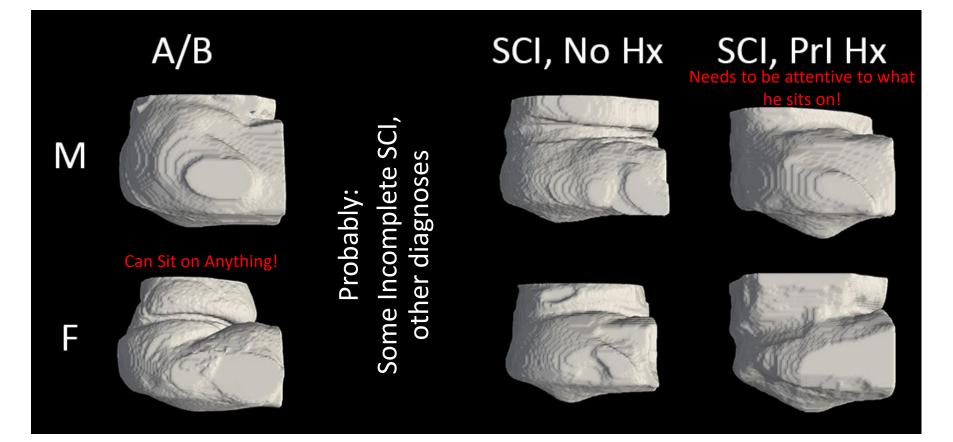
Lowest Biomechanical Risk



Highest Biomechanical Risk



#### **Risk Spectrum**



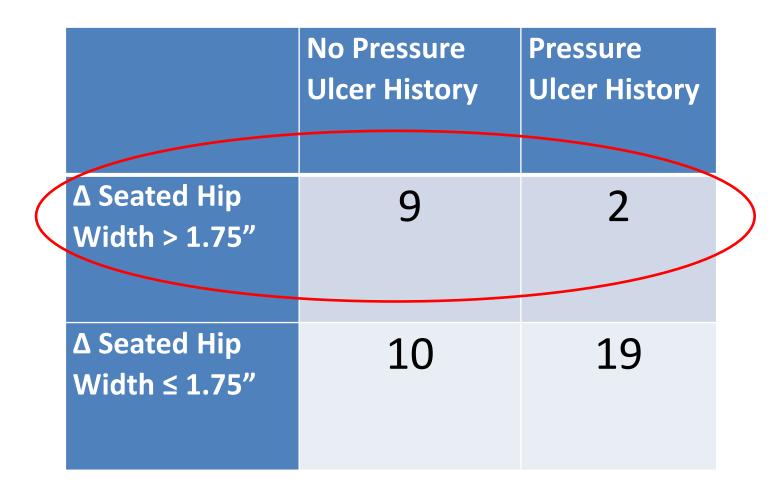
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### **SCI-Adjusted BMI**

	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?

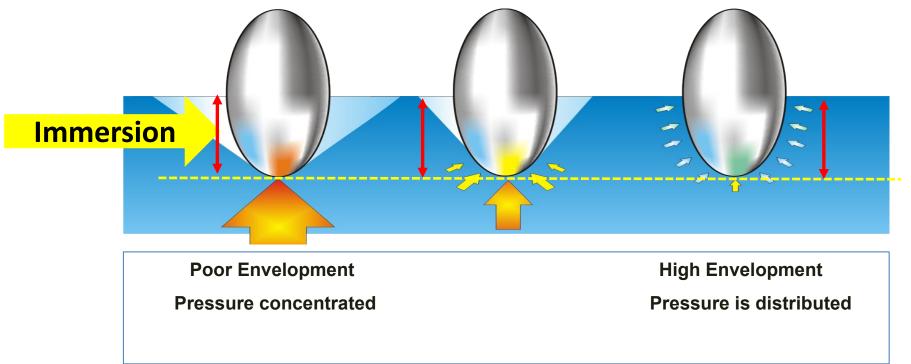




# Immersion + envelopment can offer increased contact area and pressure redistribution

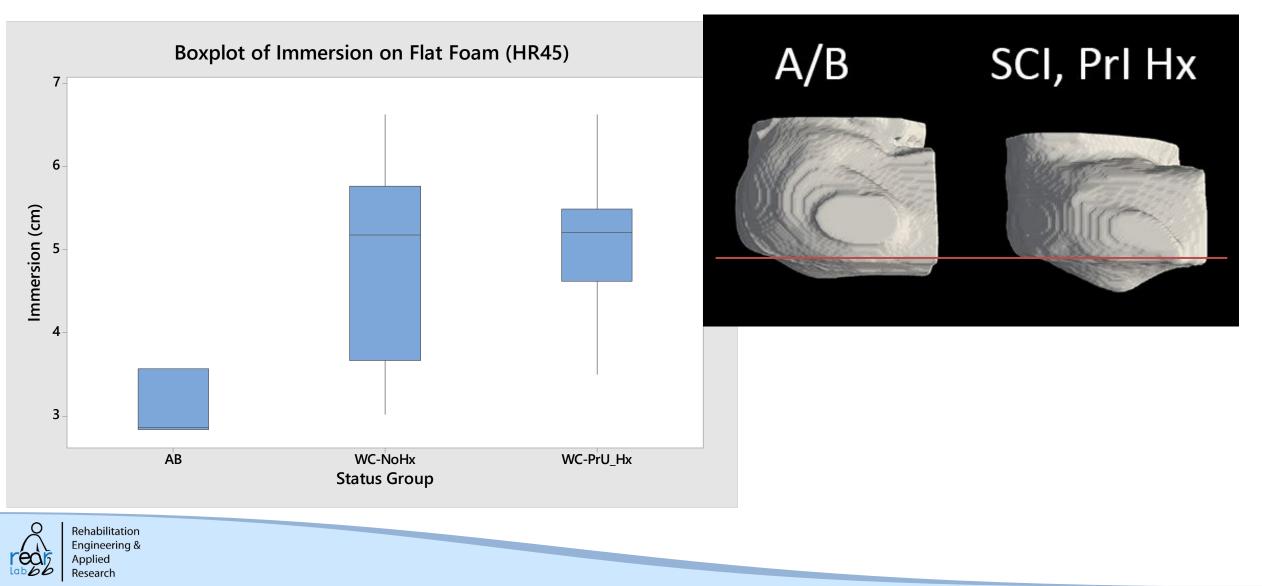
*Immersion* = Depth of penetration into surface

*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)

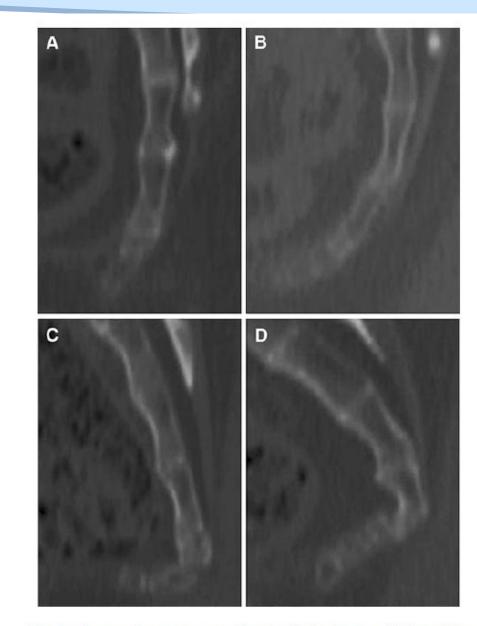
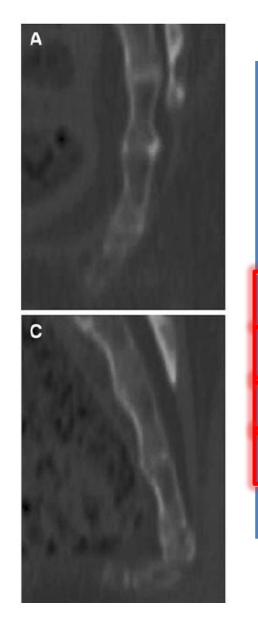


Fig. 1 Types of coccyx according to Postacchini and Massobrio (1983) classification in multislice computed tomography (MSCT). a Type I, b type II, c type III, d type IV





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

в

D

REARLab, Unpublished Data

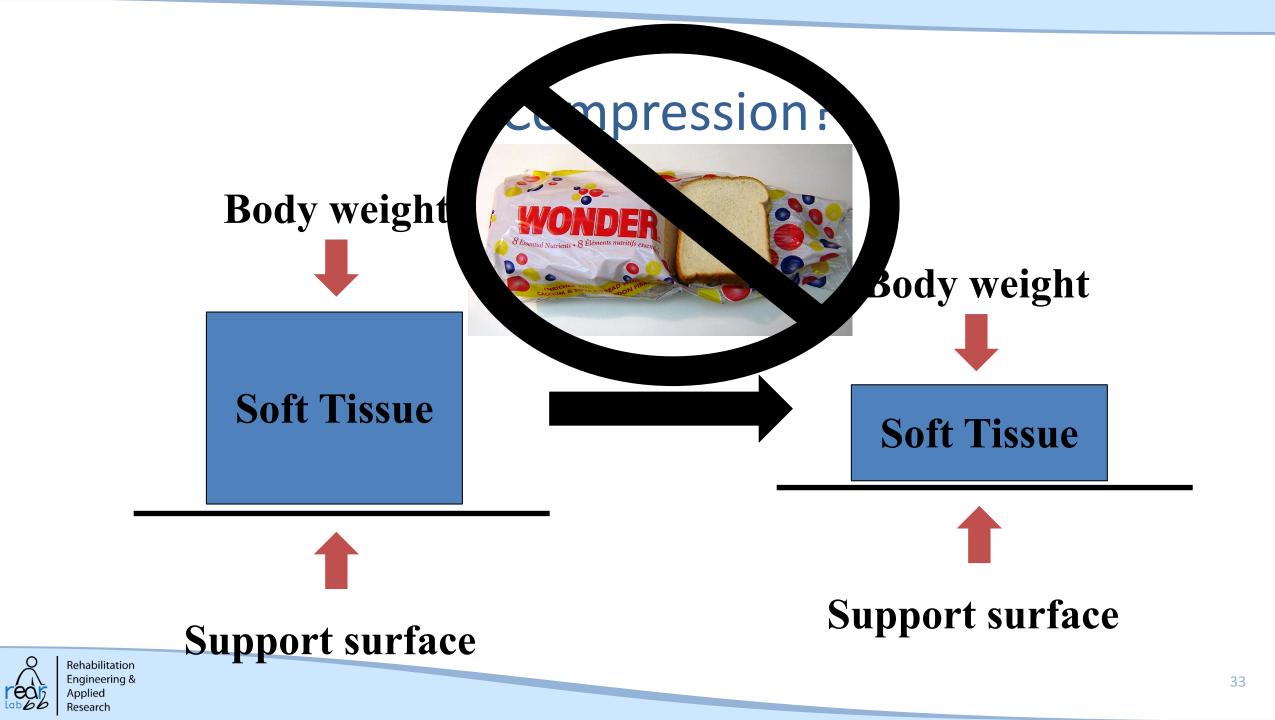




#### **PHYSICS BACKGROUND**

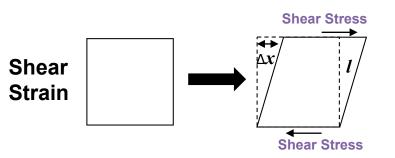




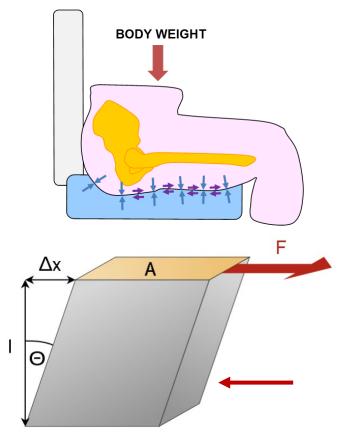


### Basic Terminology: Shear Force & Shear Stress

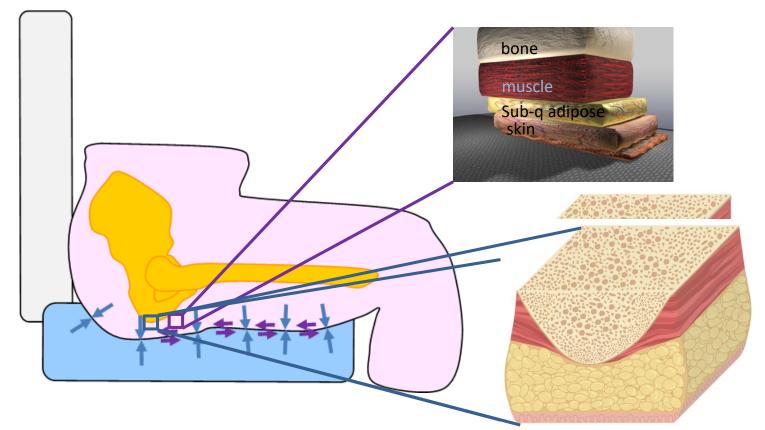
- Shear forces act parallel to the body-support surface interface
- When a <u>Shear Force</u> is distributed over the contact surface of area A, <u>shear stress</u> can be defined.
- Shear stress  $\rightarrow$  Shear strain







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

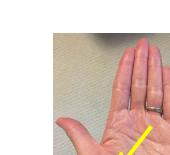


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### **Shear Strain and Friction**

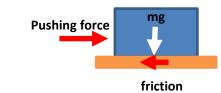
- Shear Strain
  - Shear stress induces shear strain
  - Deformation or change in shape
  - Movement of tissues in relation to bony structures; tissue deformation
- Friction
  - a force resisting the relative motion of two bodies in contact
  - impedes sliding
  - frictional forces are proportional to 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





#### Shear Stress

Shear Stress



Shear

Strain



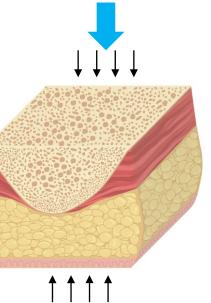
#### SEATED TISSUE DEFORMATION ON DIFFERENT CUSHIONS



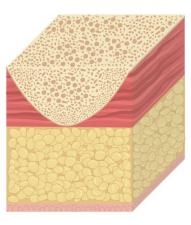
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#### Soft tissues at the Support Surfaces





Undeformed



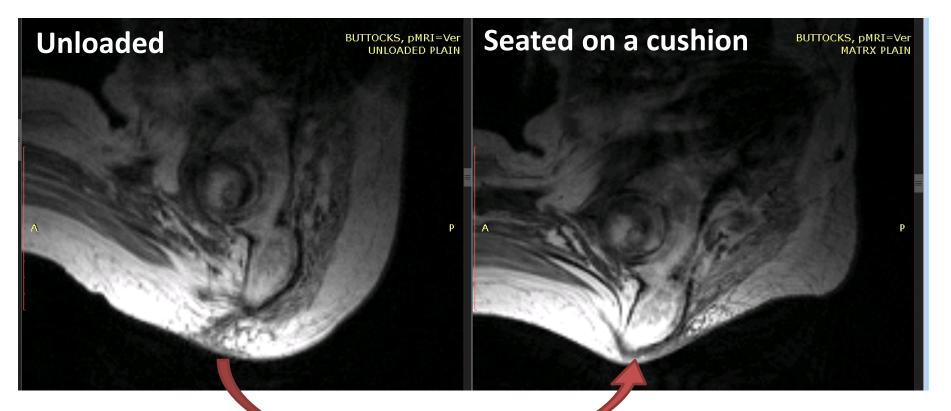
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Shear

Strain

# Evidence of shear strain during upright sitting (gravitational loads)



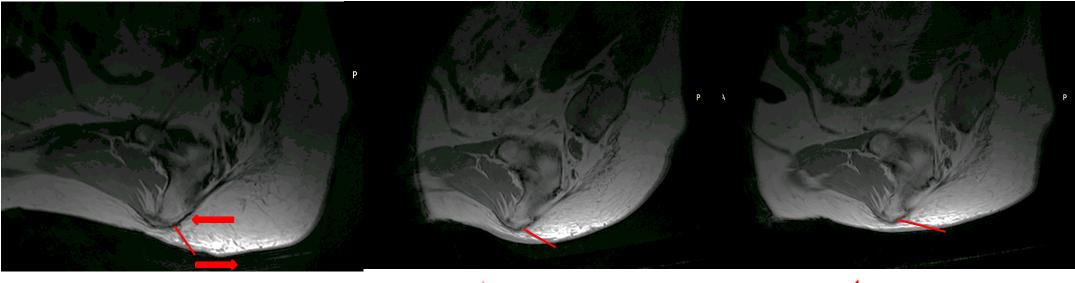


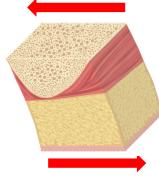
# Surface friction in combination with gravitational loads can impart shear strain

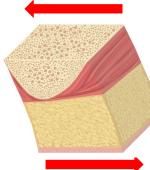
Unloaded

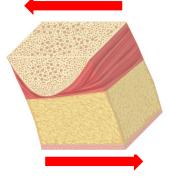
#### J2 Deep Contour

#### Matrx Vi







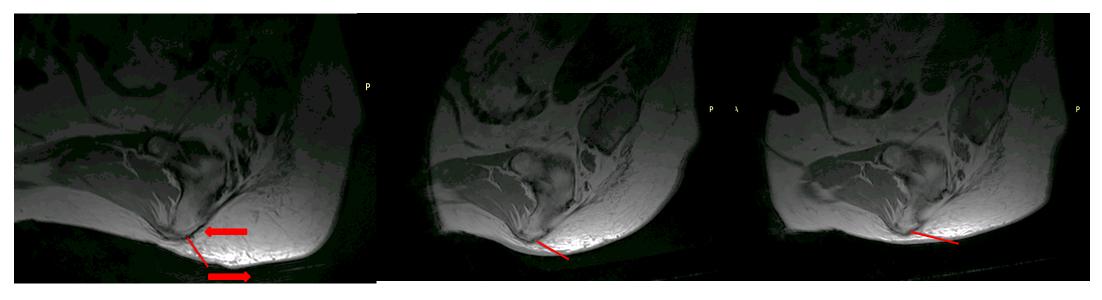


# Surface friction in combination with gravitational loads can impart shear strain

Unloaded

J2 Deep Contour

#### Matrx Vi



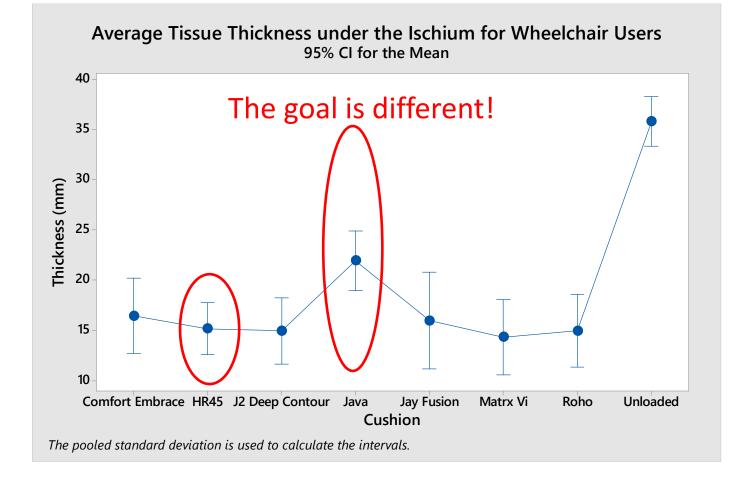
48°

25°

13°

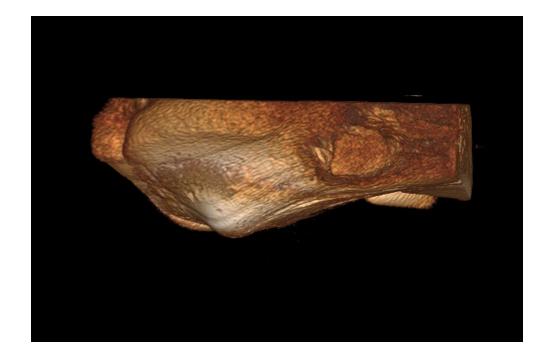


#### **Tissue Thickness Under the Ischium**





# Meet our subject

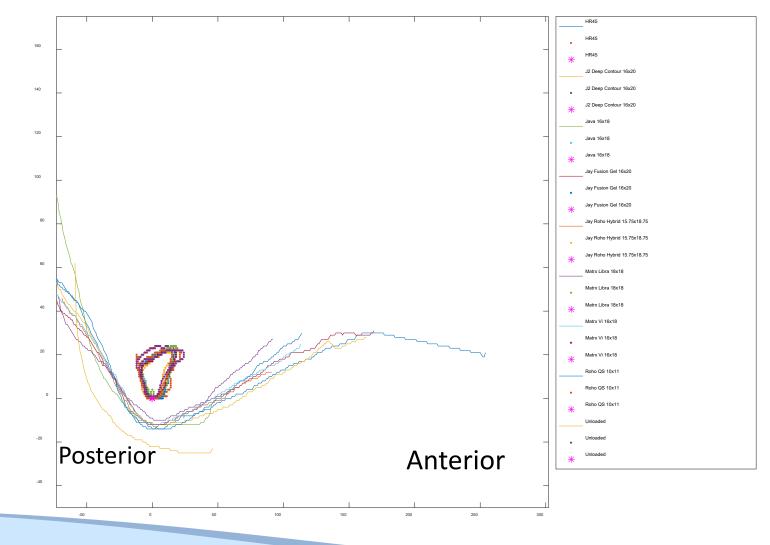


- 54 yo Male
- 172 lbs
- T10-11 SCI
- 3 years post injury
- History of a sacral ulcer
- No spasticity
- Lean muscle (limited fatty infiltration)



#### Some people sit the same on every surface

#### T10-11 SCI, 3 years post injury, Hx sacral PrU





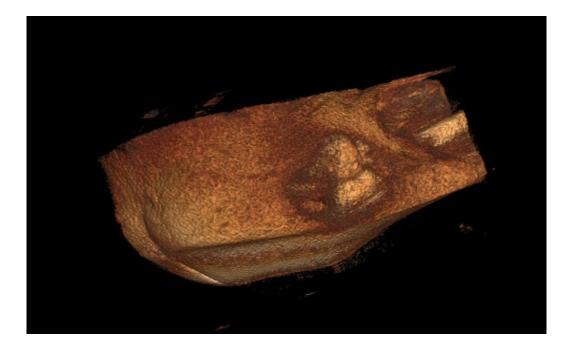
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High Biomechanical Risk High Deformation on ALL Surfaces

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



# Meet another subject

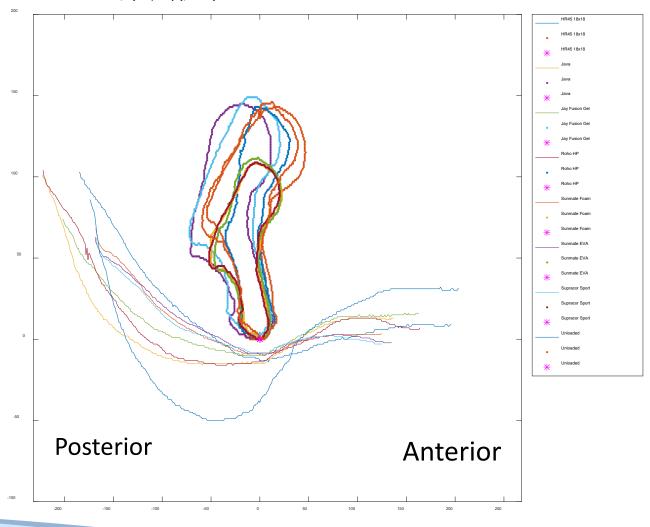


- 58 yo Male
- 160 lbs
- C5 SCI
- 32 years post injury
- History of a coccyx ulcer
- Spasticity
- Lean muscle (no fatty infiltration)



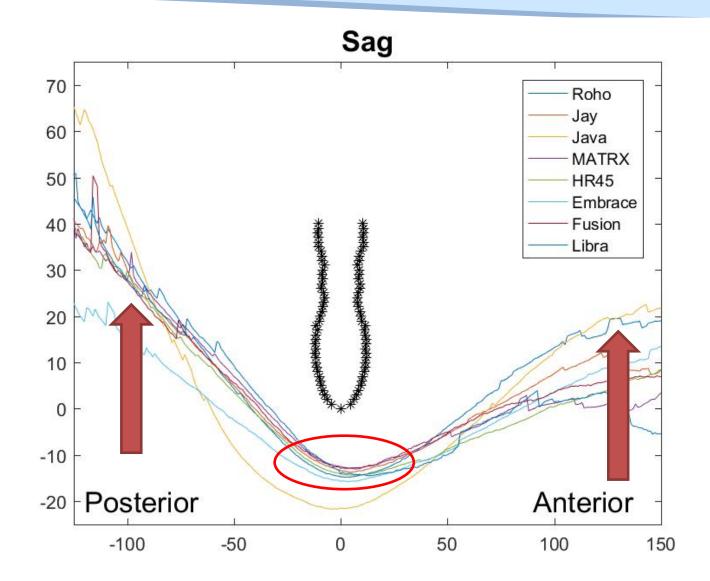
# Others sit very differently on different surfaces

C5 SCI, 32 years post injury, Hx Coccyx PrU



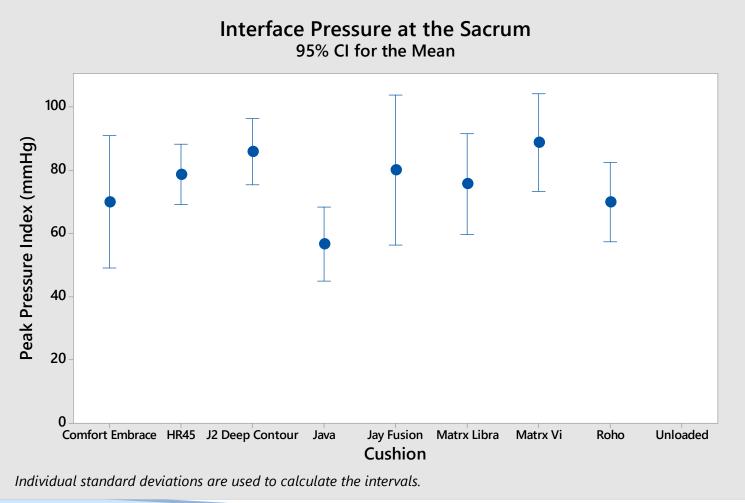


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Lap D Research				





#### Interface pressure at the Sacrum

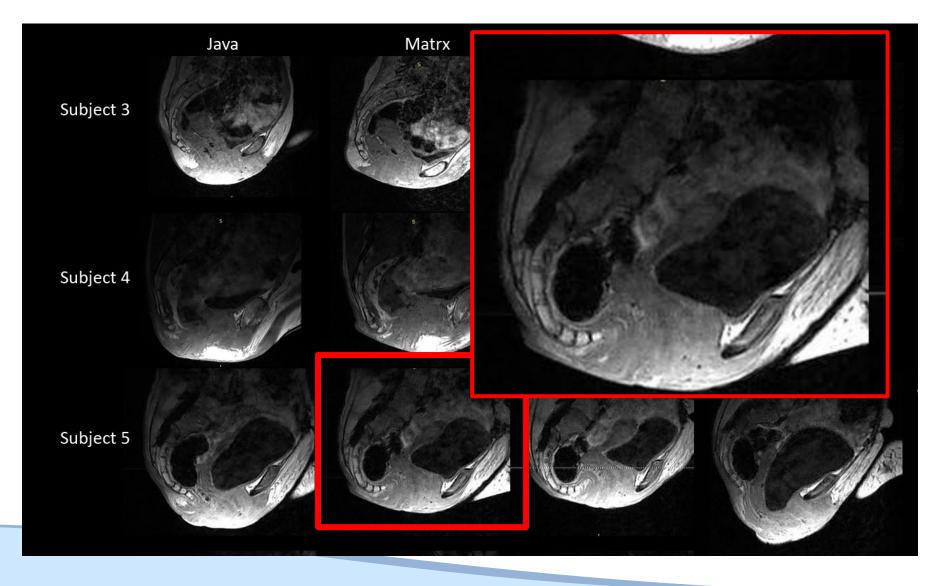


- Does NOT measure shear force
- Posture dependent

#### **SPEAKING OF POSTURE...**

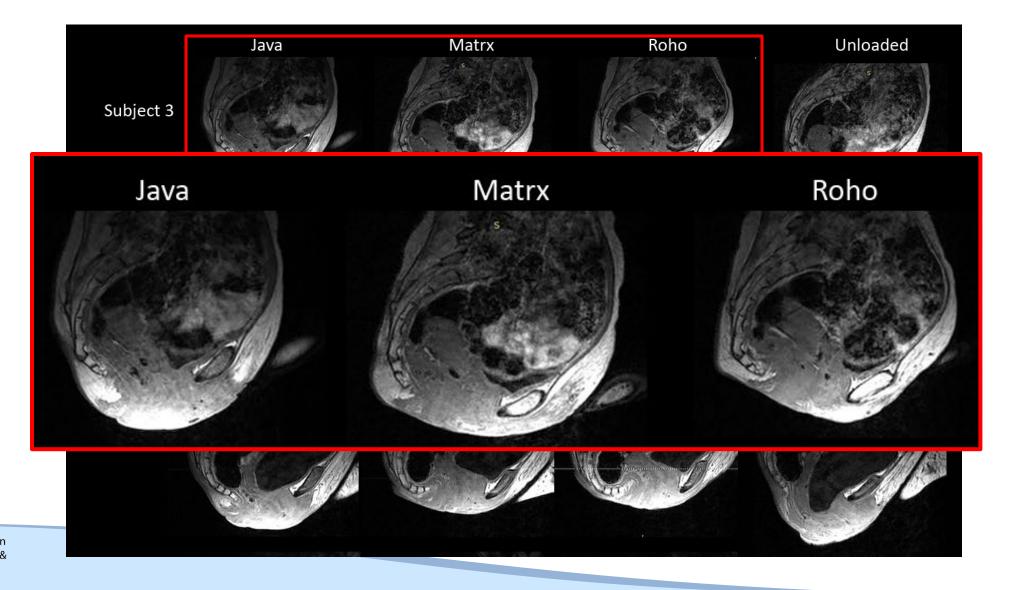


#### Sacrum and Coccyx



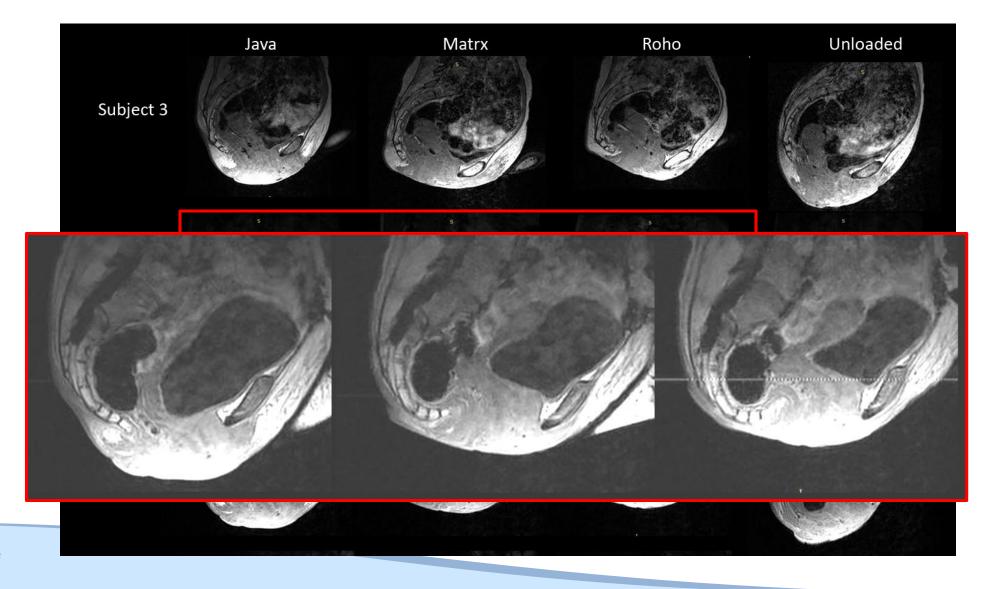


#### Sacrum and Coccyx



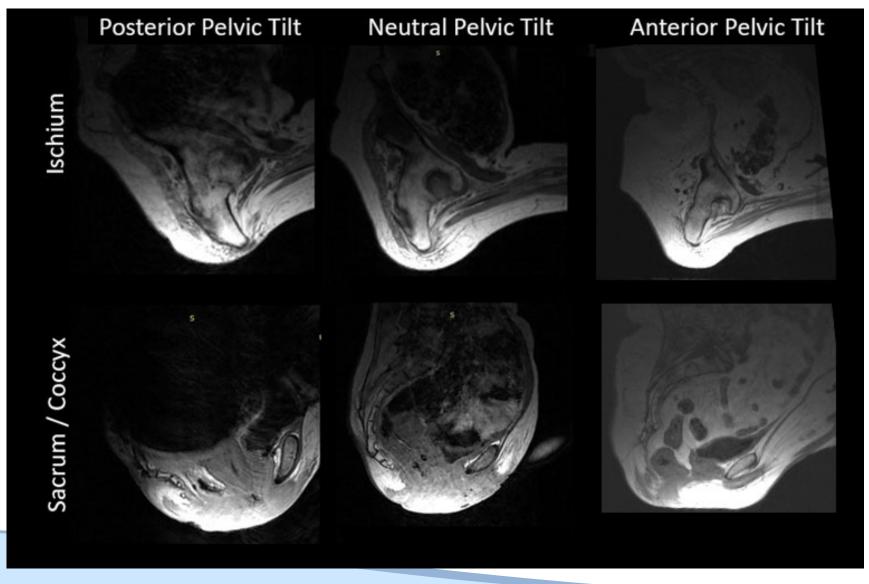


#### Sacrum and Coccyx





### 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
- UC Denver Kelly Waugh, PT, MAPT, ATP
- FONAR (John Greenhalgh)
- Stephen Sprigle, PhD, PT
- Students!
- University of Ulster
- Robert H. Graebe Foundation

The research presented in this talk was supported by many sources including grants from National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR) and donations from various companies and foundations.

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#### **QUESTIONS?**

