Rehabilitation
Engineering &
Applied
Research

# Using Technology to Explore Seated Anatomy and its Impact on Pressure Ulcer Risk

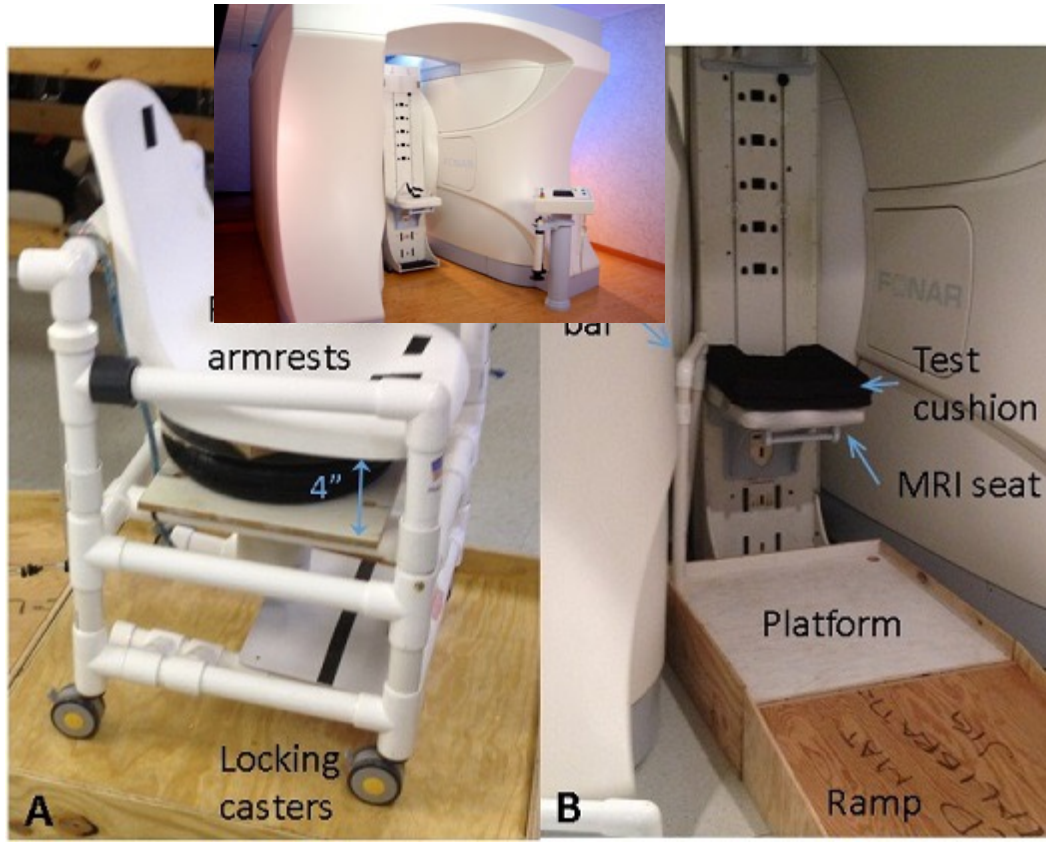
Sharon Eve Sonenblum, PhD

# Learning Objectives

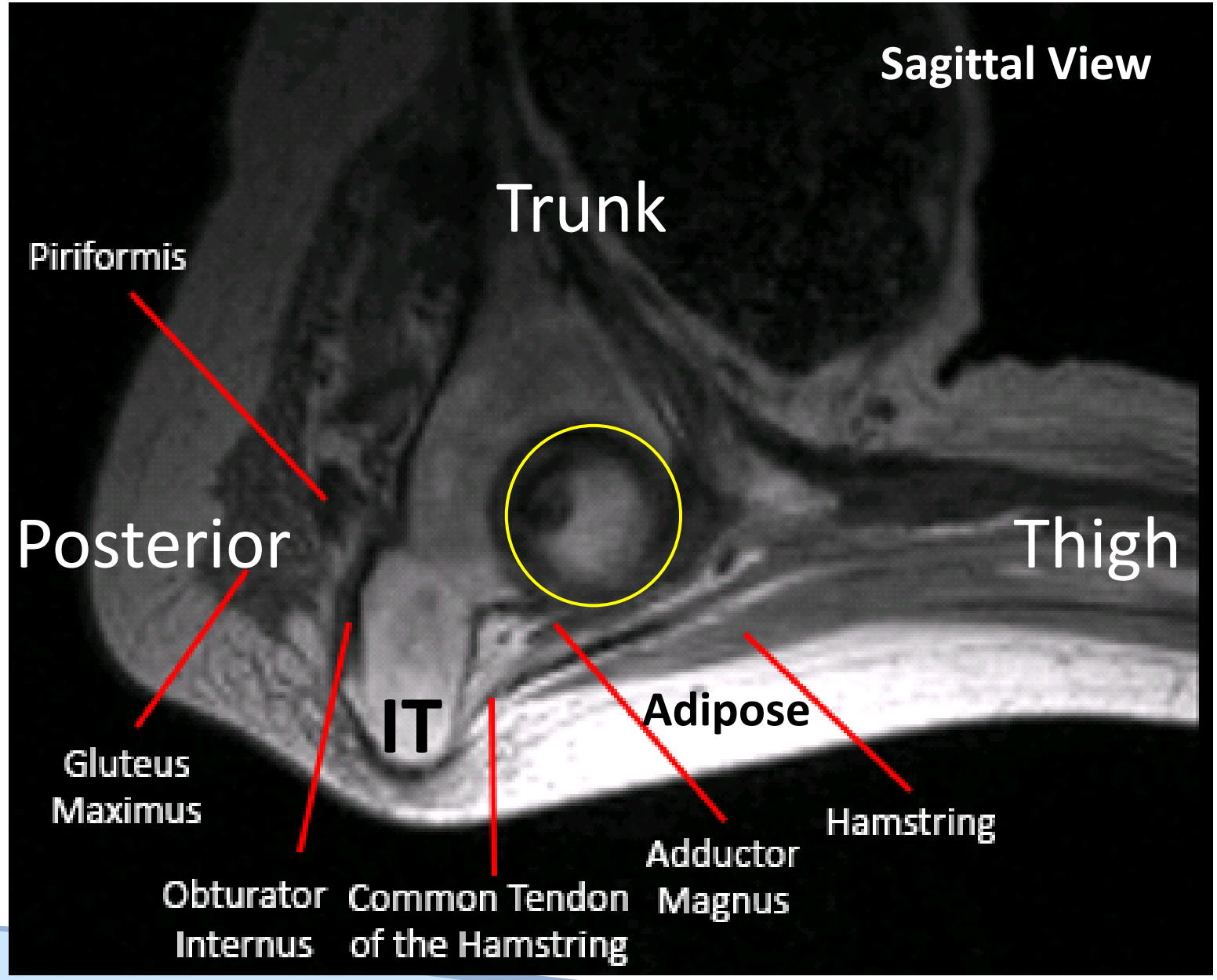
- Report the percent of individuals with gluteus maximus coverage underneath their ischium
- Identify two aspects of anatomy or skeletal morphology that are associated with pressure ulcer risk
- Describe one clinical measurement that might have value in predicting biomechanical risk.

# THE SEATED BUTTOCKS

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



# SCI (Atrophied) Buttocks



# The ischium runs at an oblique angle

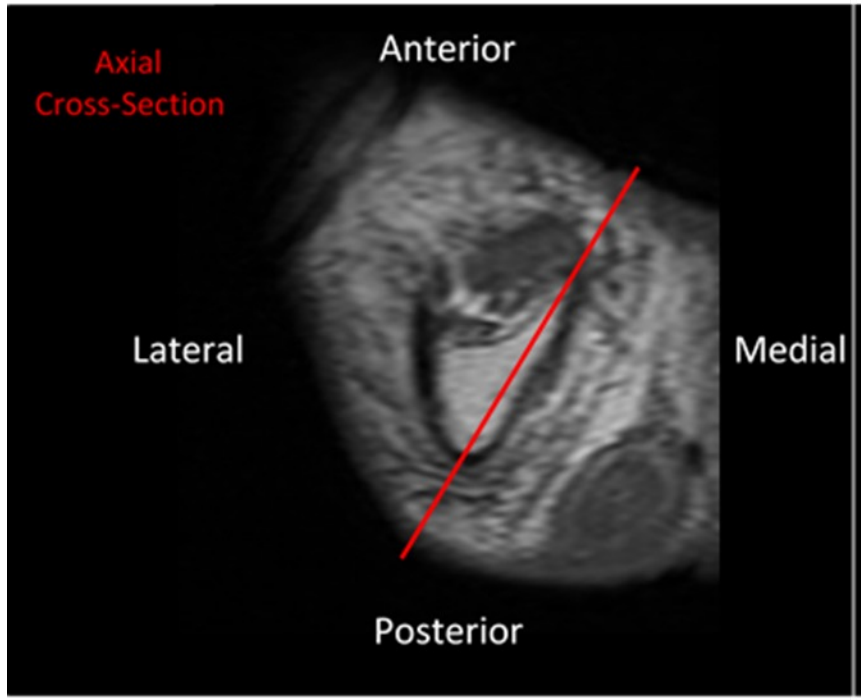
Contents lists available at ScienceDirect

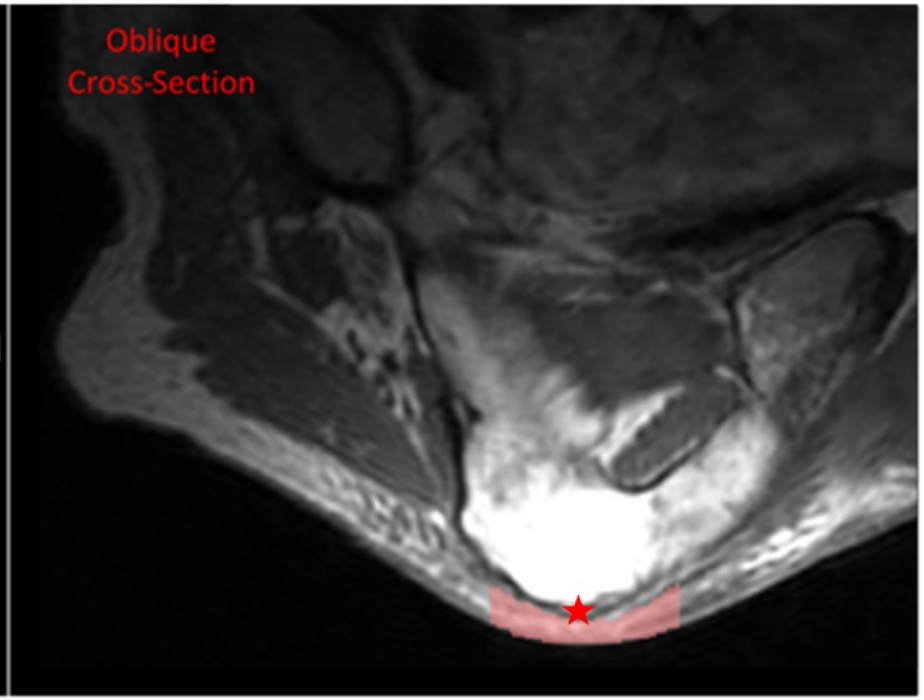
Journal of Tissue Viability

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]



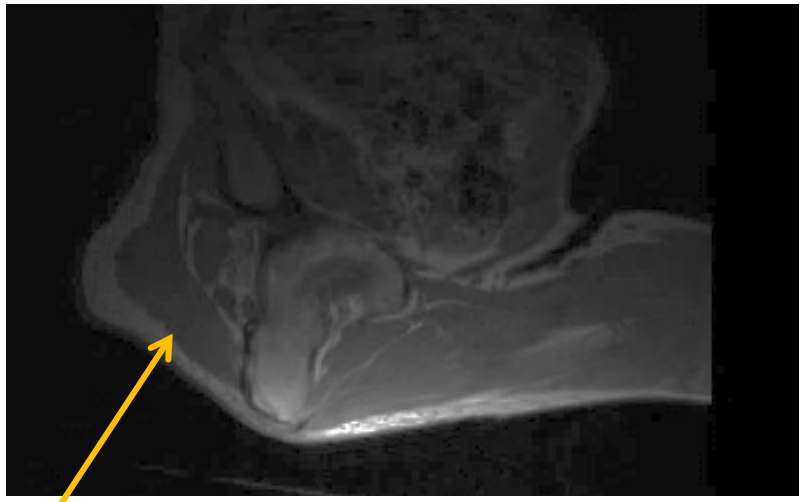
# Gluteus Maximus Characteristics

Table 3 Gluteus maximus muscle characteristics.

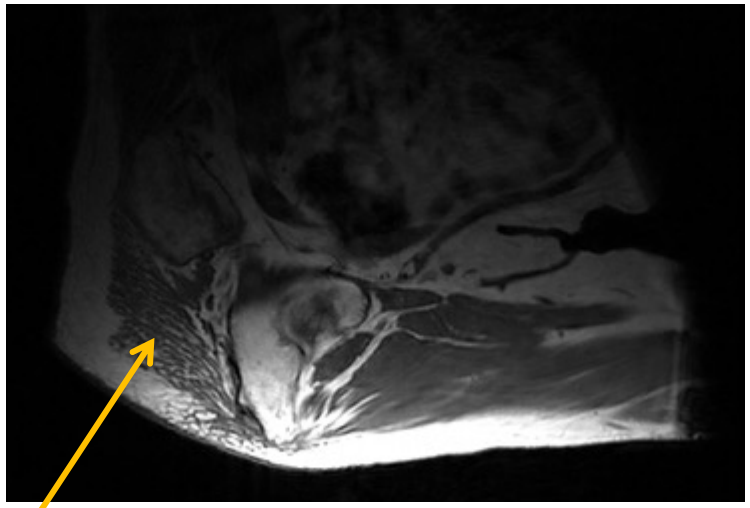
| Gluteus maximus | SCI [range] | AB [range] | *p* value |
|---|---|---|---|
| Volume ($cm^3$) | 379 ± 159 [154 to 582] | 667 ± 114 [504 to 892] | <0.05 |
| CSA ($cm^2$) | 22 ± 8 [7 to 30] | 40 ± 5 [30 to 43] | <0.05 |
| Fat (%) | 29 ± 23 [3 to 84] | 8 ± 9 [2 to 35] | <0.05 |
| Low density muscle (%) | 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.

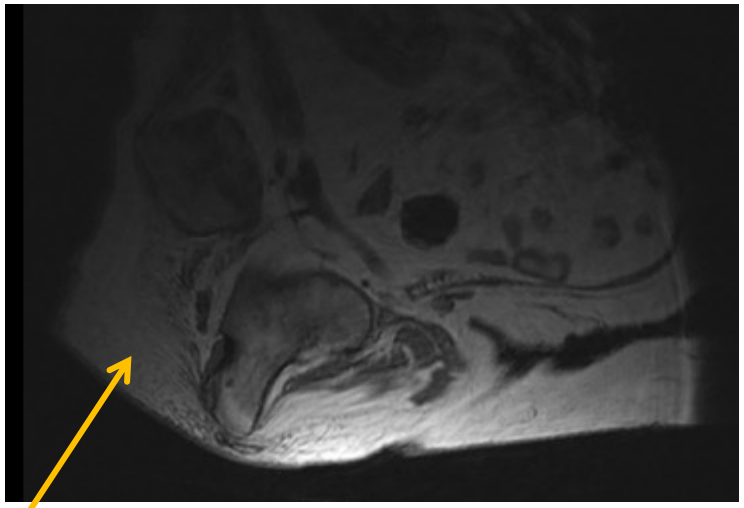
# Fatty Infiltration in Men with SCI



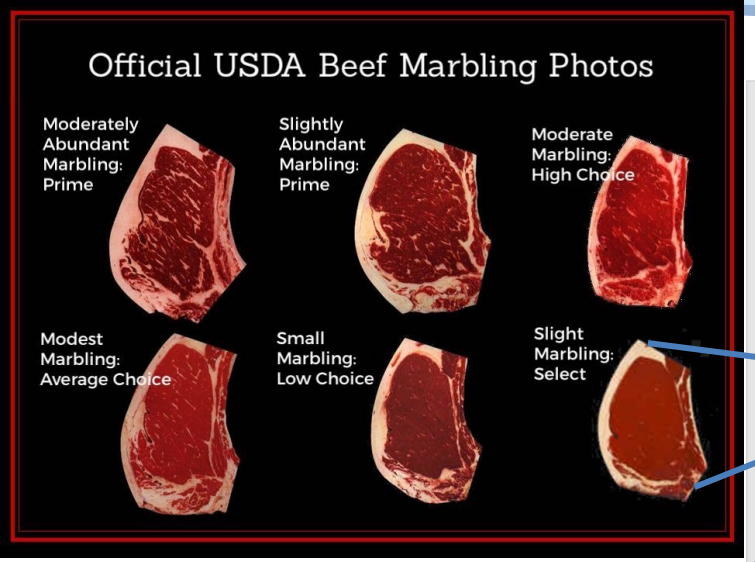
37yo, 14 years post injury
BMI = 21.4
Mild spasms induced by stimulation
History of PrU

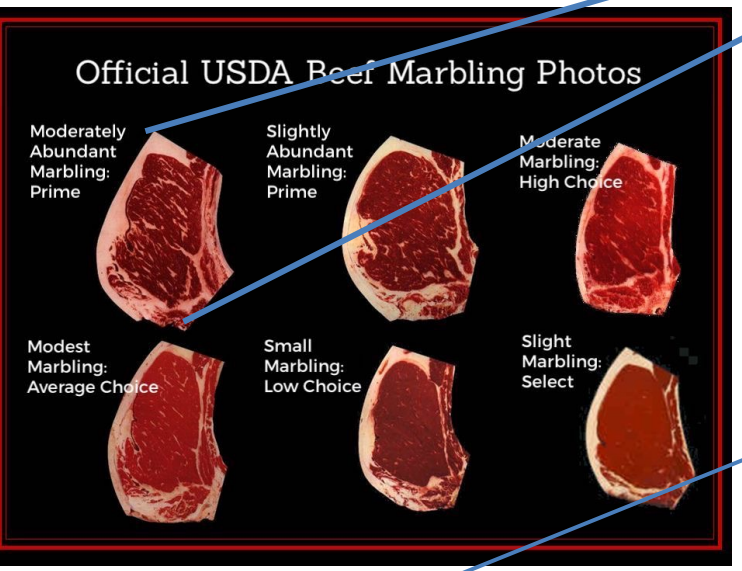


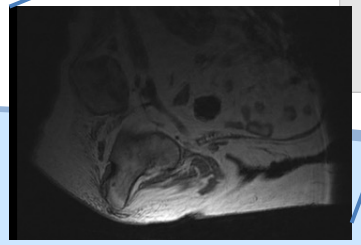
49yo, 29 years post injury
BMI = 27.3
Infrequent spasms (<1/hr)
History of PrU

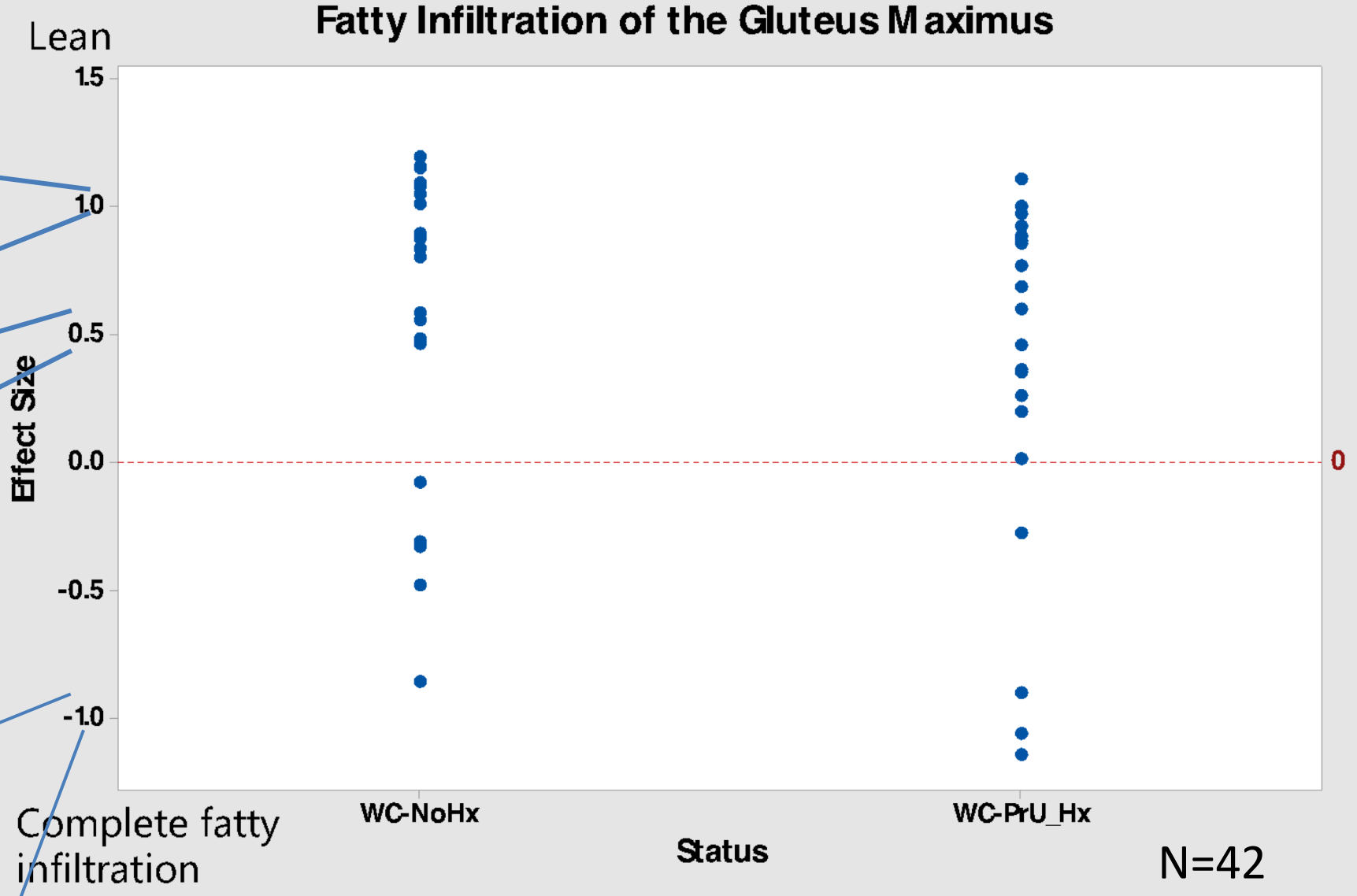


58yo, 14 years post injury
BMI = 29.6
No spasticity
No history of PrU






Complete fatty infiltration

ACRM
AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2019;100:1042-9

ORIGINAL RESEARCH

# What Lies Beneath: Why Some Pressure Injuries May Be Unpreventable for Individuals With Spinal Cord Injury

David P. Lemmer, BS,[a] Nannette Alvarado, MD,[a] Kristi Henzel, MD, PhD,[a,b] Mary Ann Richmond, MD,[a] John McDaniel, PhD,[a,c] Jennifer Graebert, BS,[a] Katelyn Schwartz, BA,[a] Jiayang Sun, PhD,[d] Kath M. Bogie, DPhil[a,e]

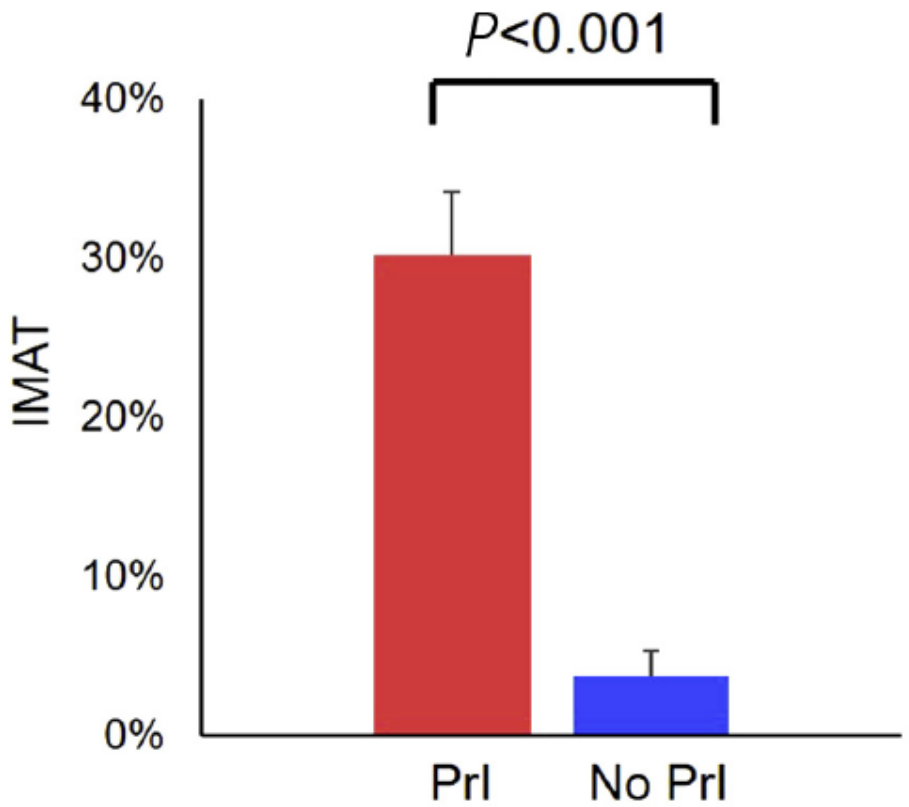
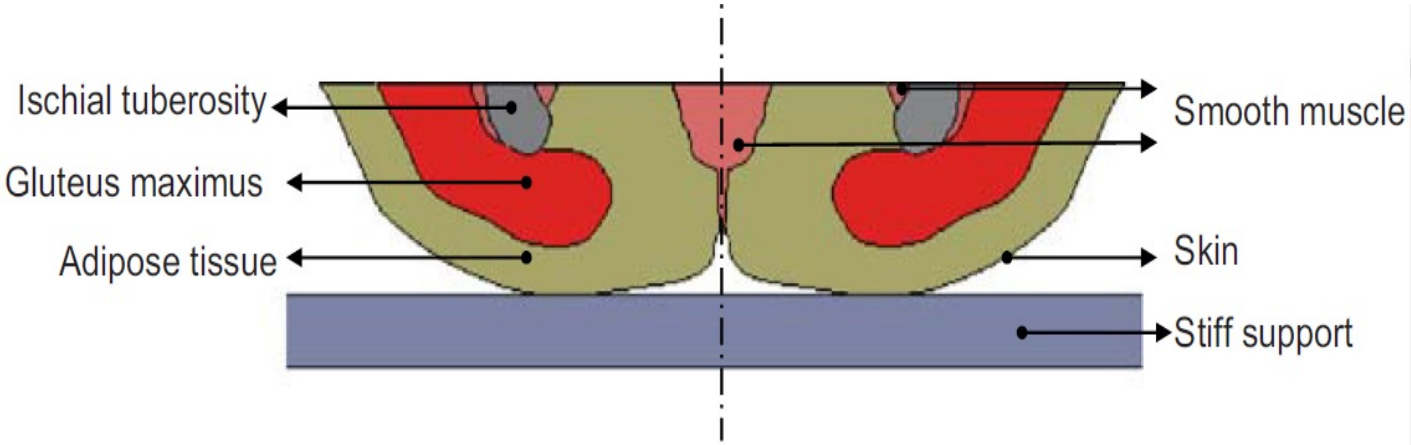


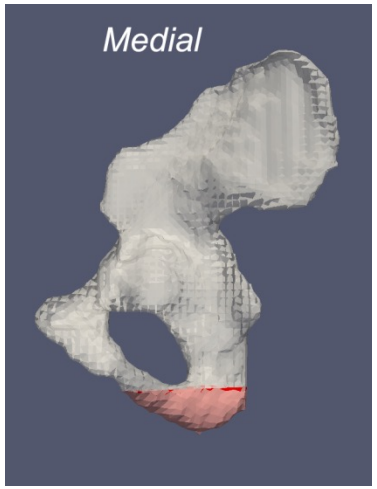

**Fig 4** Gluteal muscle area IMAT content. The vertical axis shows the percentage of IMAT in the gluteal muscle.

# Typical Assumption: People are Sitting on Muscle




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

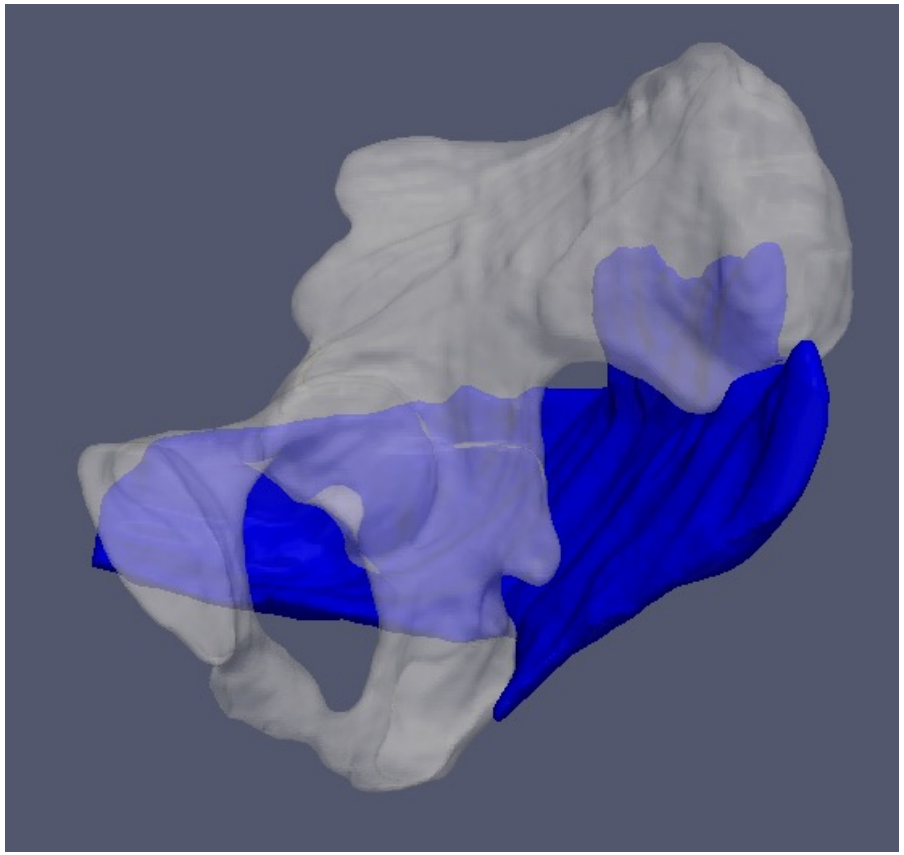
# Gluteus Maximus coverage of ischial tuberosities



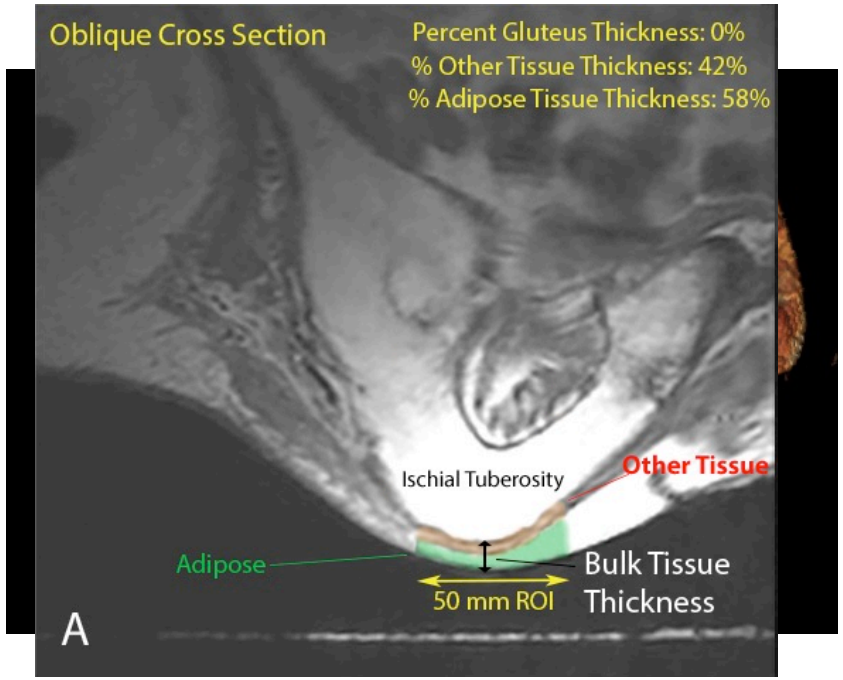

| % Gluteus Coverage | Able-bodied | Wheelchair Users |
|---|---|---|
| 0% | 3 | 30 |
| 1-25% | 7 | 10 |
| 25-50% | 1 | 1 |
| 50-75% | 0 | 0 |
| 75-100% | 1 | 1 |

n=54

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



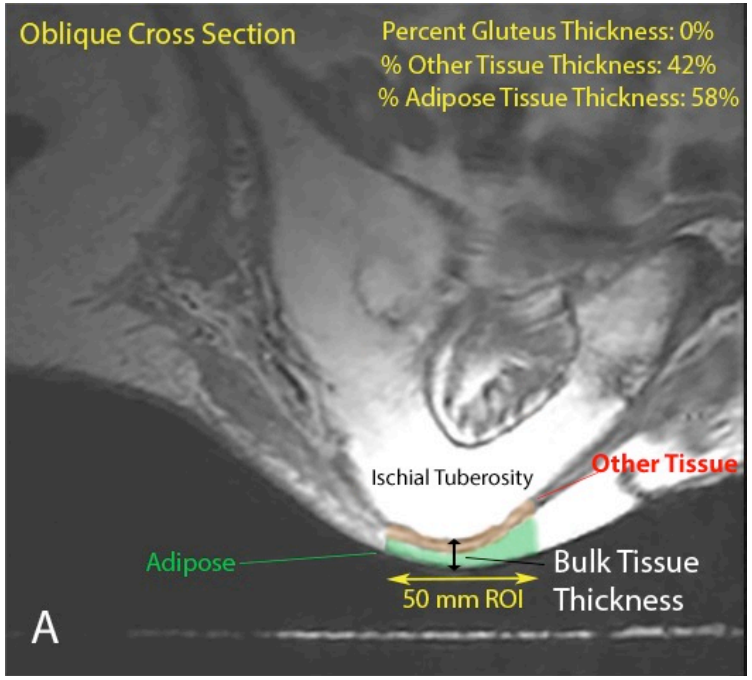
# How much tissue is there under the IT when seated on a cutout (gravity loaded only)?




| | 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

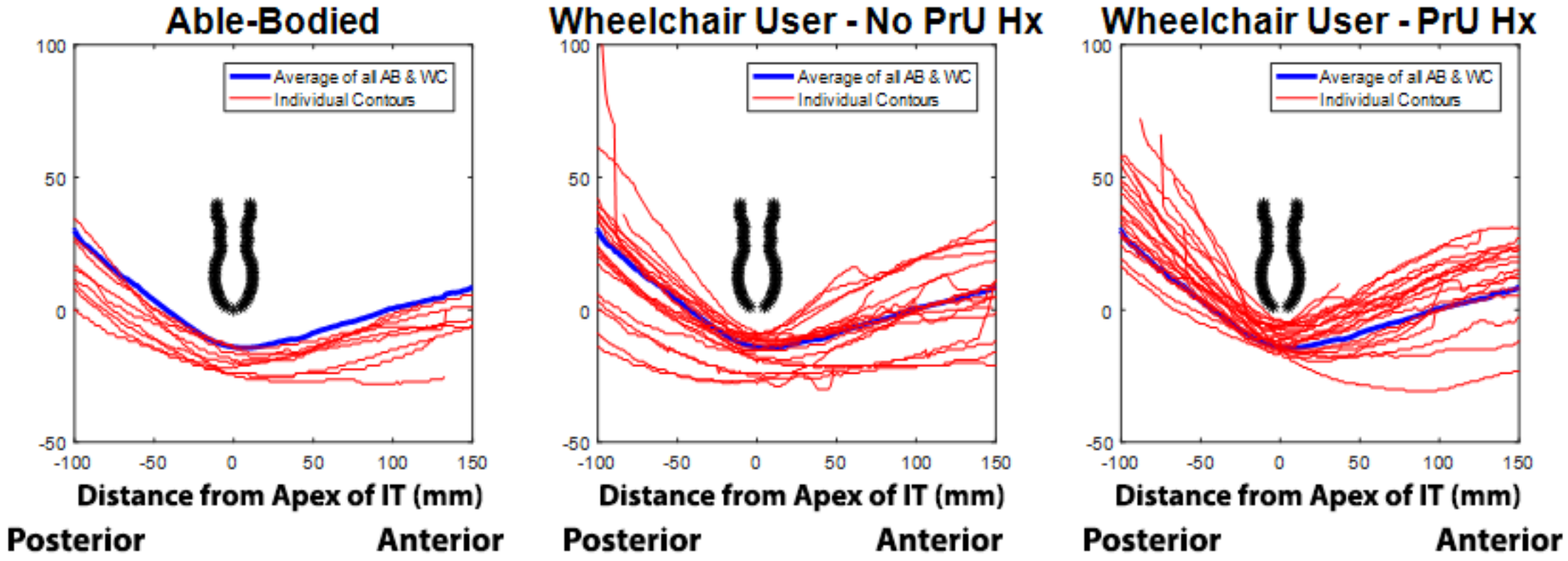
# Biomechanical Risk

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.***

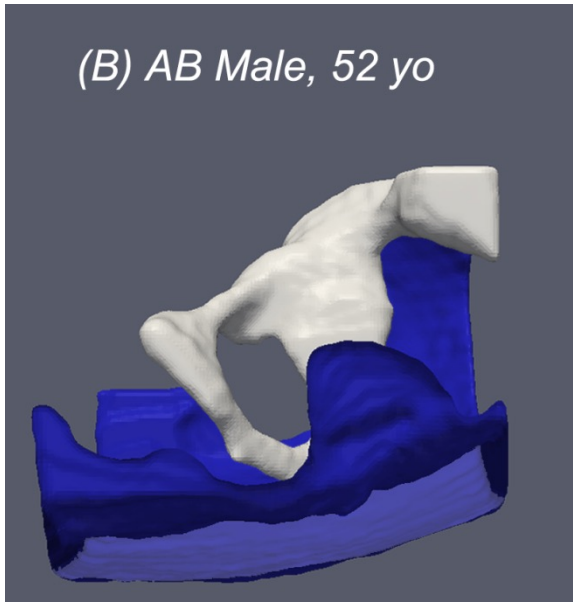
# Biomechanical Risk





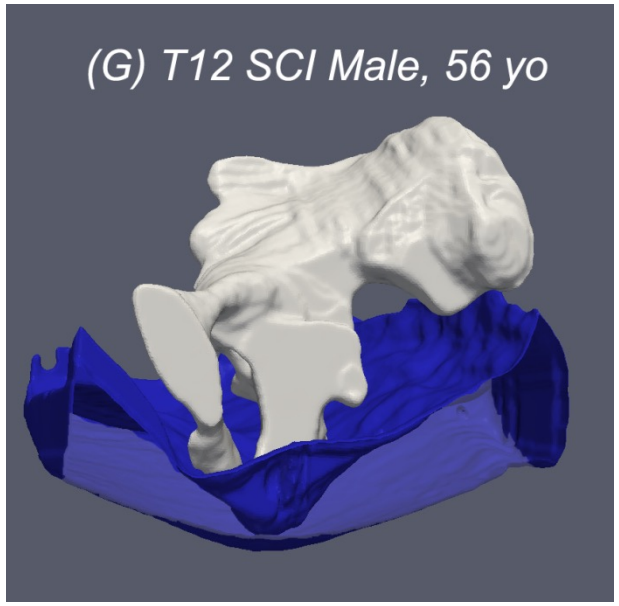

Sonenblum SE, Seol D, Sprigle SH, Cathcart JM. Seated buttocks anatomy and its impact on biomechanical risk. J Tissue Viability. 2020 May;29(2):69-75

# The Inner Adipose Surface




Lowest

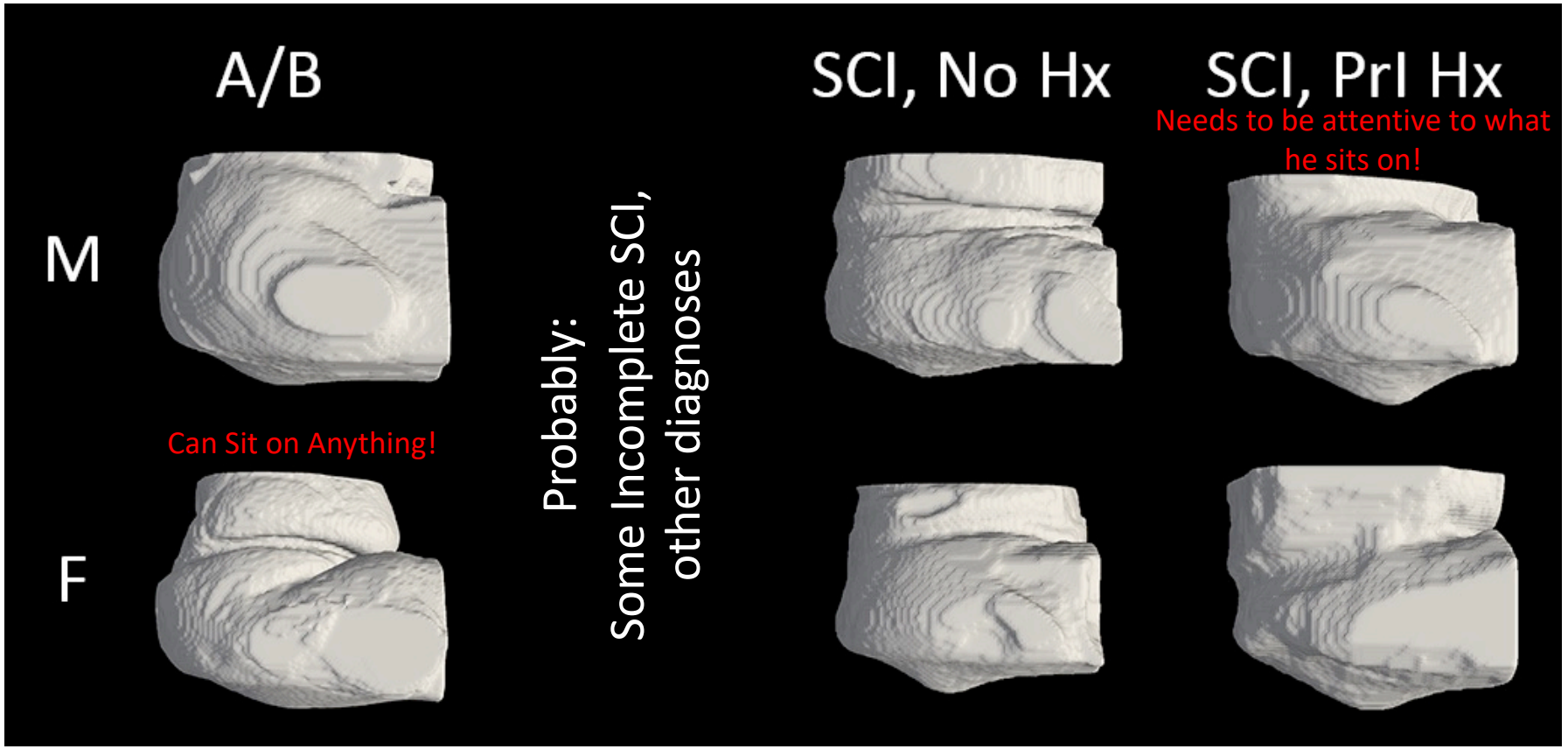
Biomechanical Risk



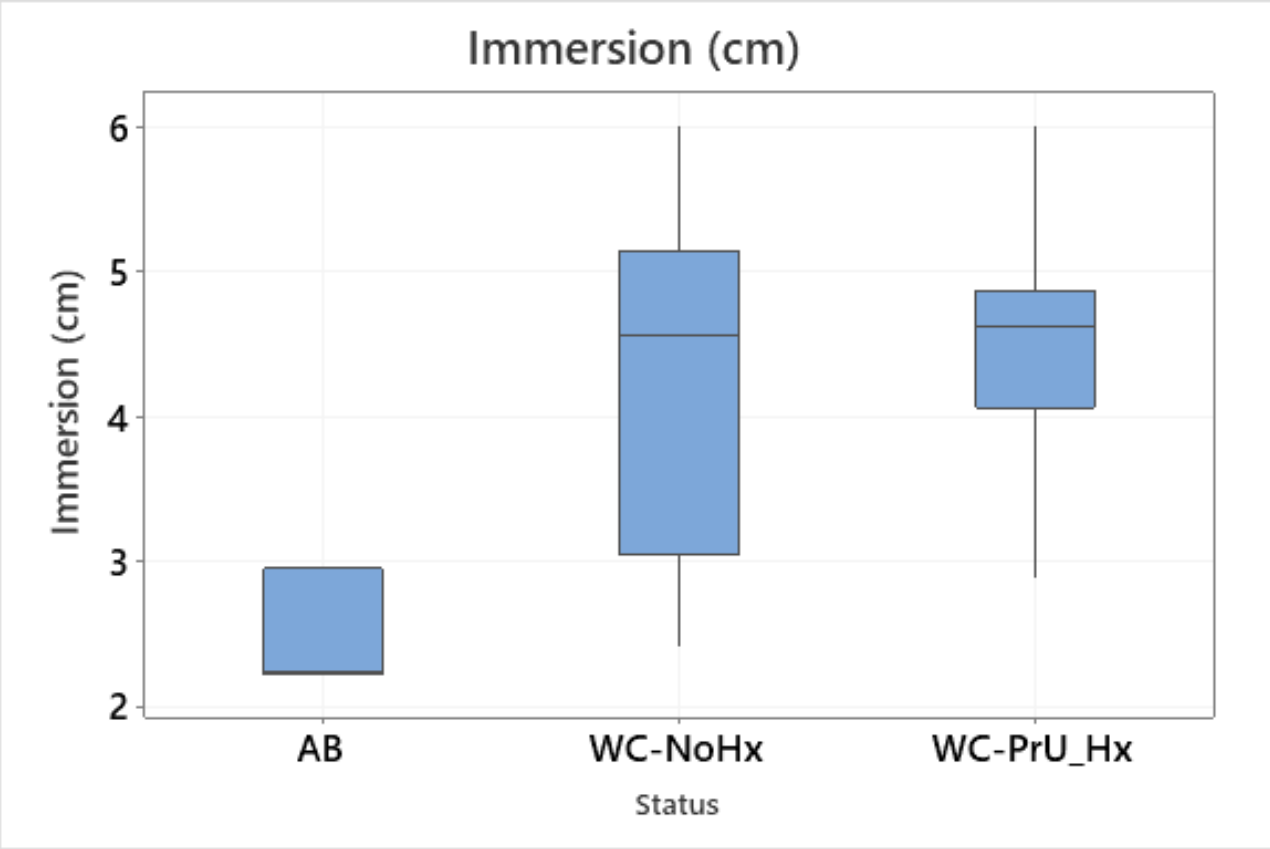

Highest

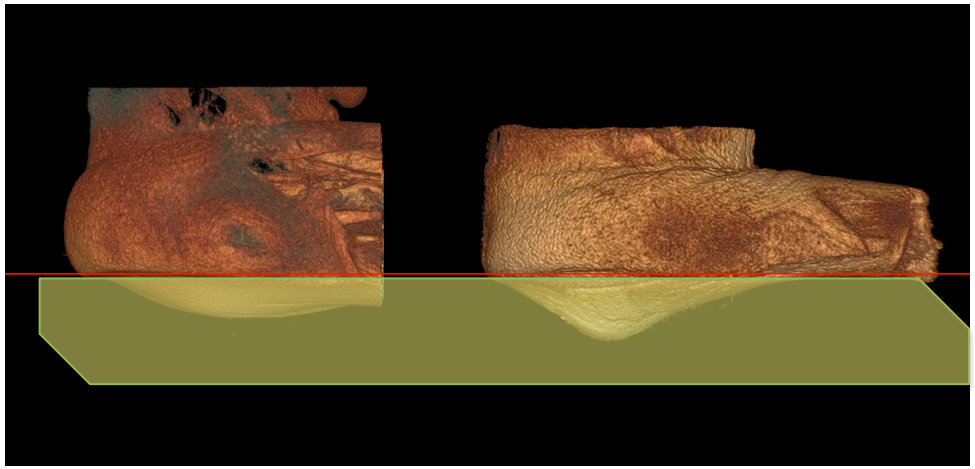
Biomechanical Risk

# Risk Spectrum



# Immersion Into Foam Varies by Risk



# Skin Stiffness

| PrU History | No PrU Hisotry |
|---|---|
| 227 (67) N/m | 185 (28) N/m |

PrU History = Stiffer Skin

# Compressible Hip Tissue

| PrU History | No PrU Hisotry |
|---|---|
| 1.1 (0.8) inches | 1.7 (0.8) inches |
| 2.8 cm | 4.3 cm |

More compressible tissue = protective

Less compressible tissue = more biomechanical risk

# 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) |

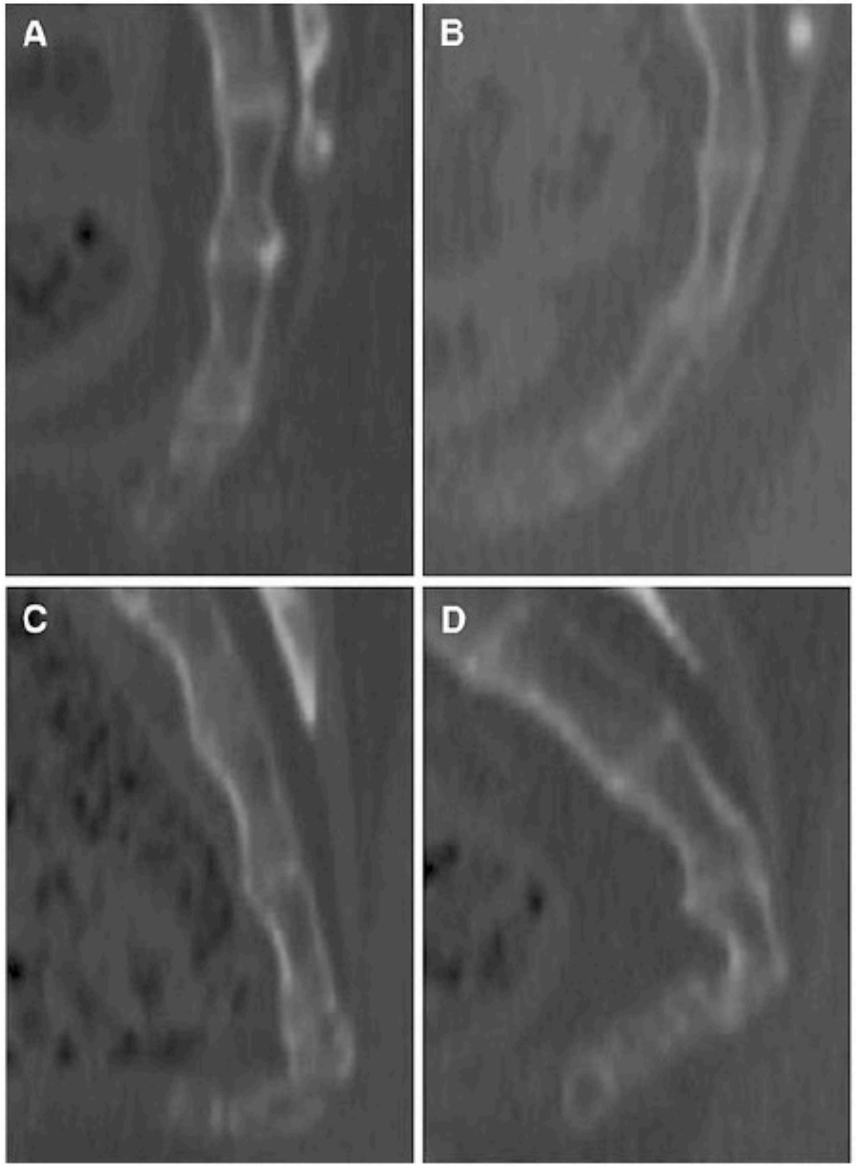
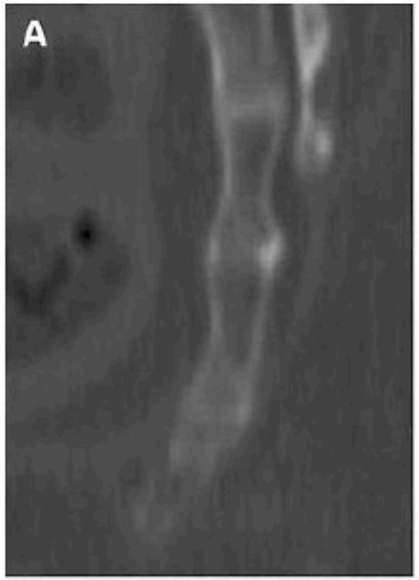
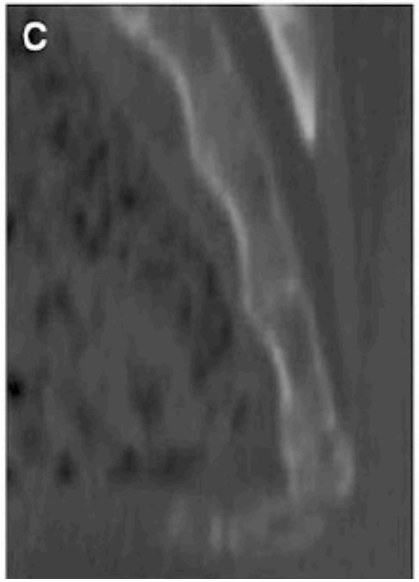


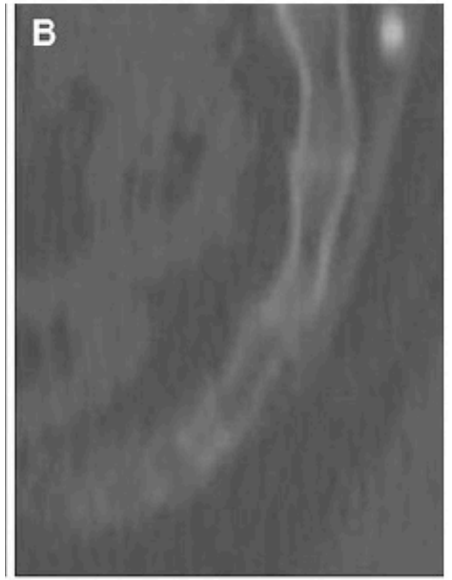

**Fig. 1** Types of coccyx according to Postacchini and Massobrio (1983) classification in multislice computed tomography (MSCT). **a** Type I, **b** type II, **c** type III, **d** type IV

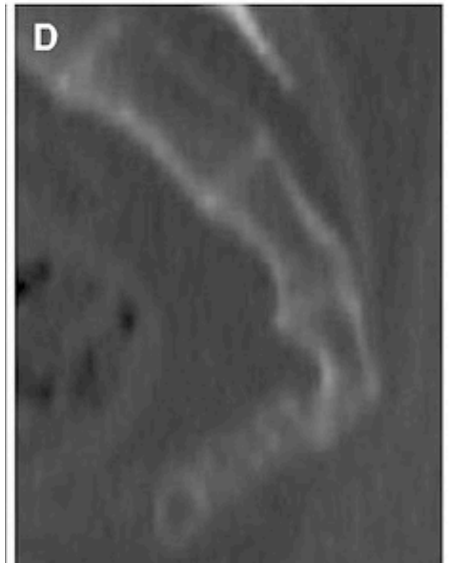



| Coccyx Type | No Sacral/Coccyx Pressure Ulcer History | Sacral/Coccyx Pressure Ulcer History |
|---|---|---|
| I | 17 | 2 |
| II | 8 | 6 |
| III | 6 | 1 |
| IV | 1 | 4 |
| All | 32 | 13 |

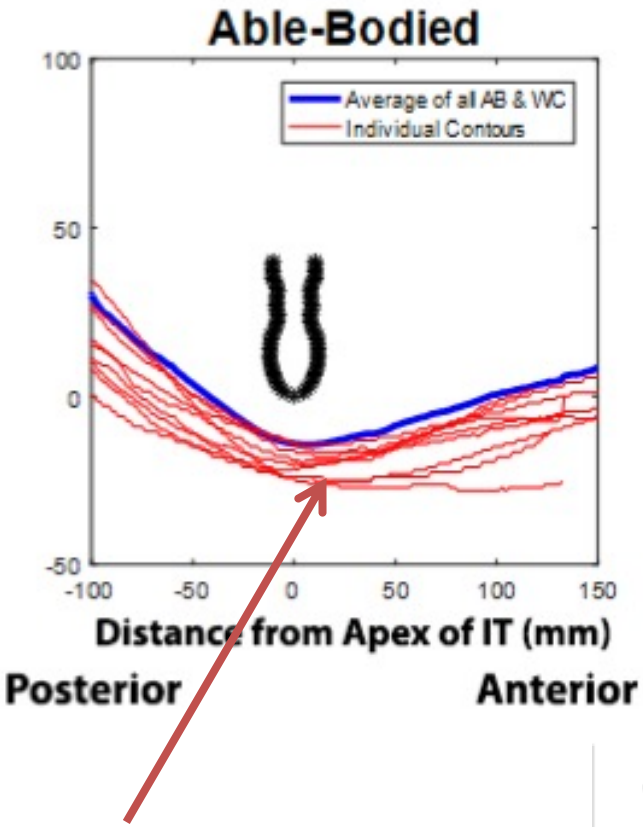
REARLab, Unpublished Data



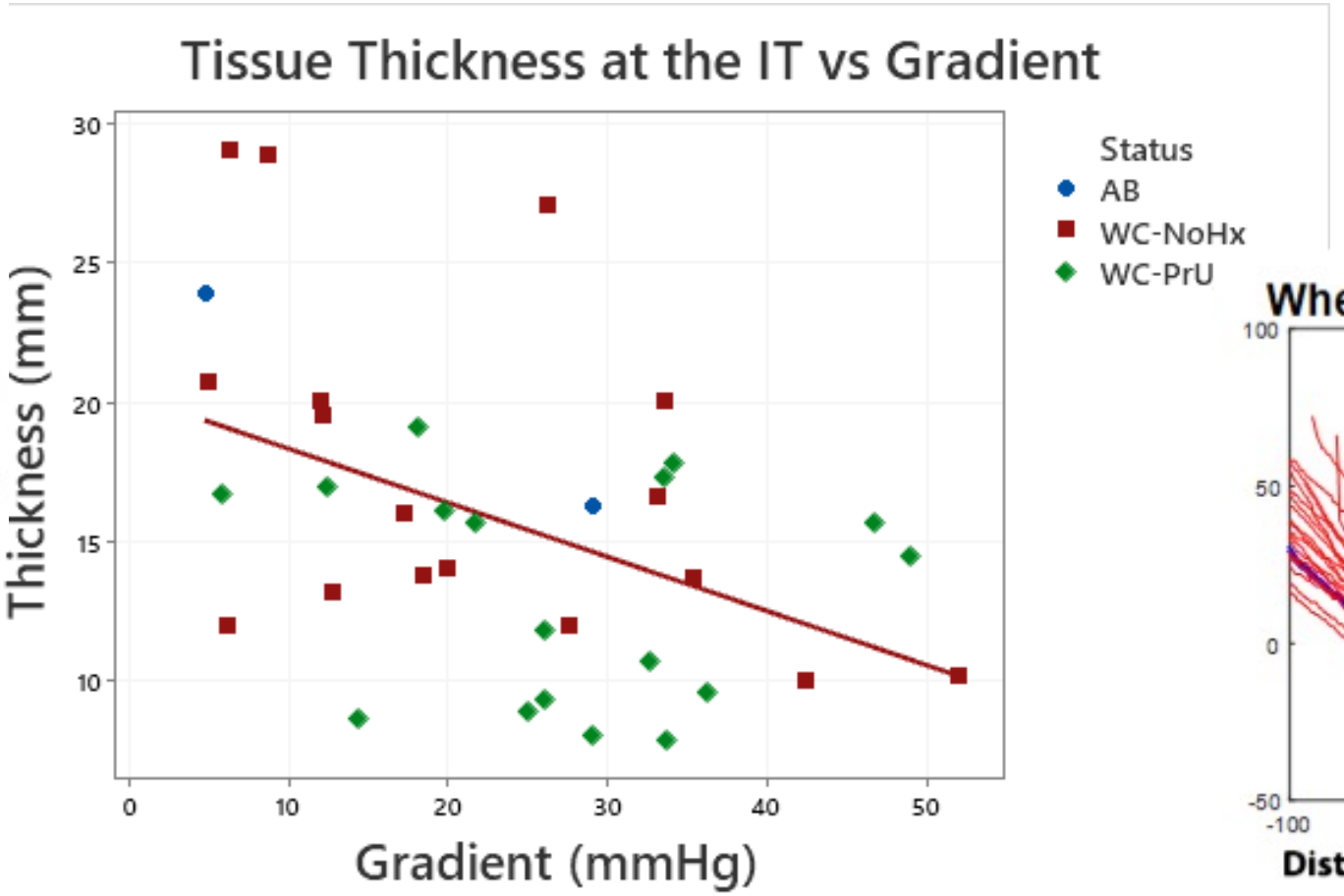



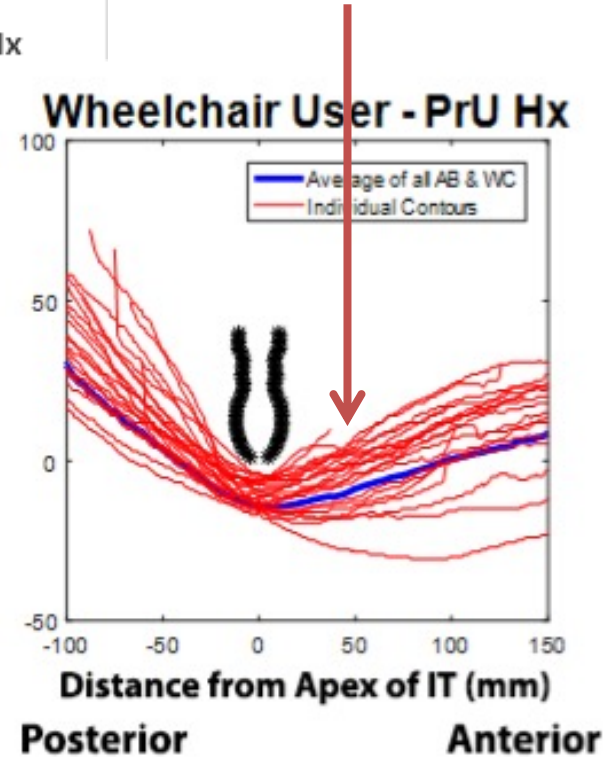
# CAN WE USE TECHNOLOGY TO MEASURE THE BUTTOCKS RESPONSE?

# Pressure Mapping Gradient



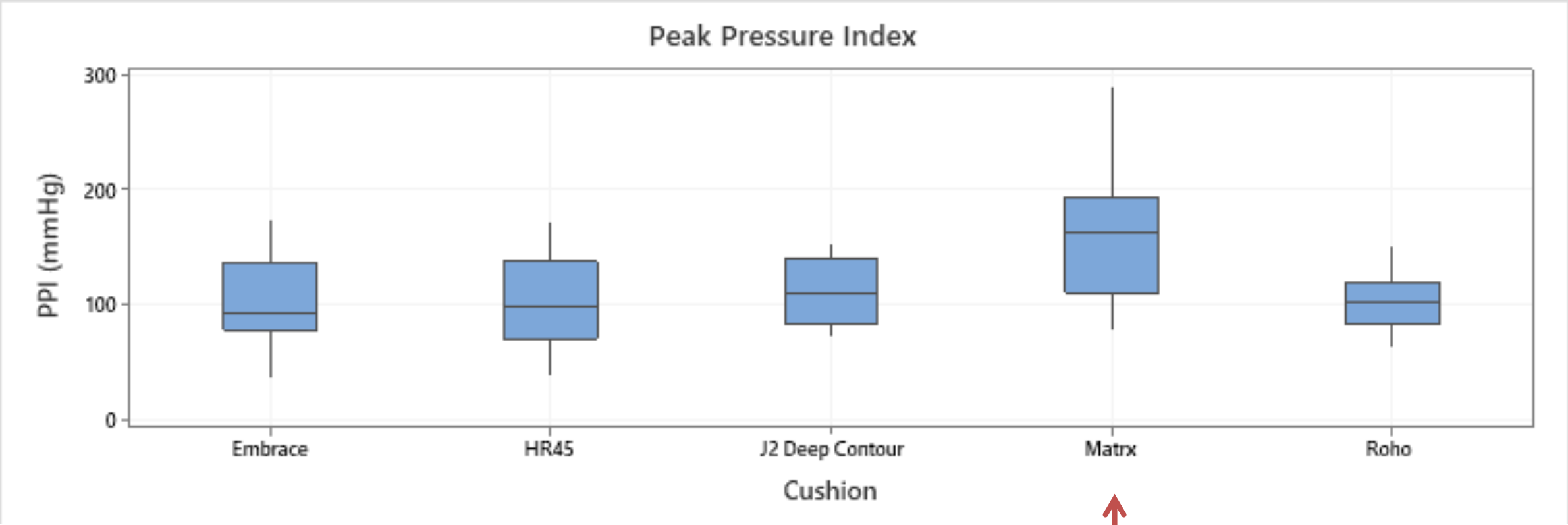

higher gradient = thinner tissue!



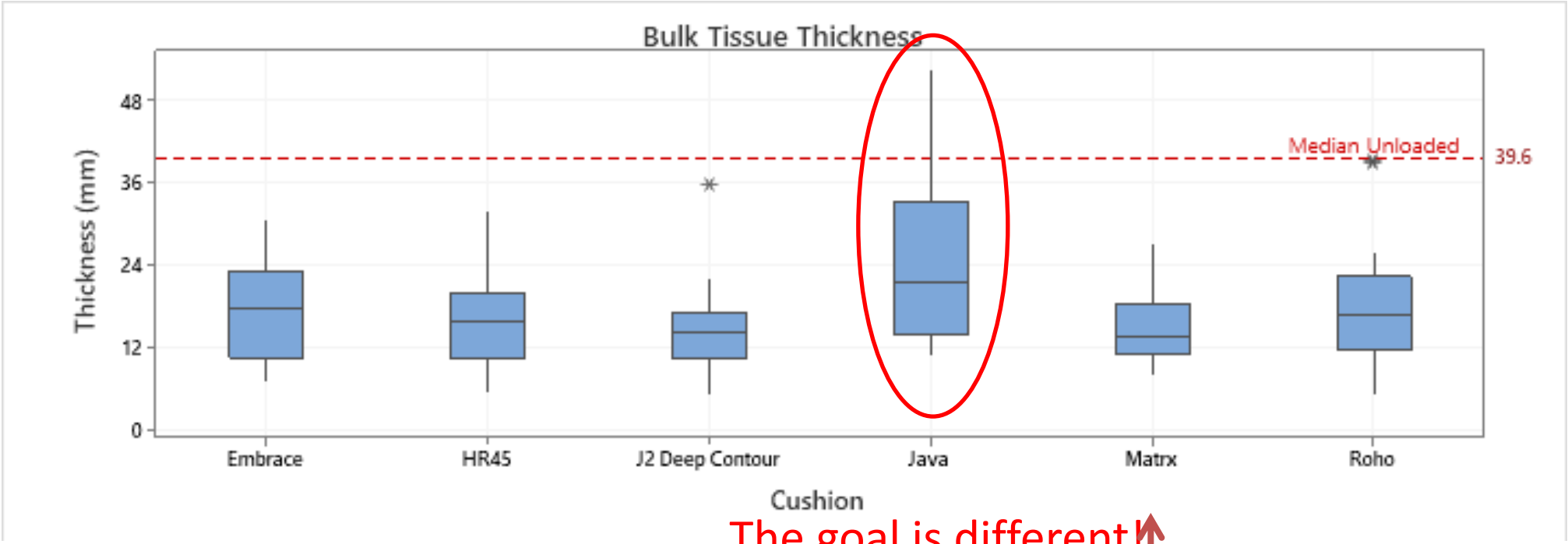



# SEATED TISSUE DEFORMATION ON DIFFERENT CUSHIONS

# Interface Pressure



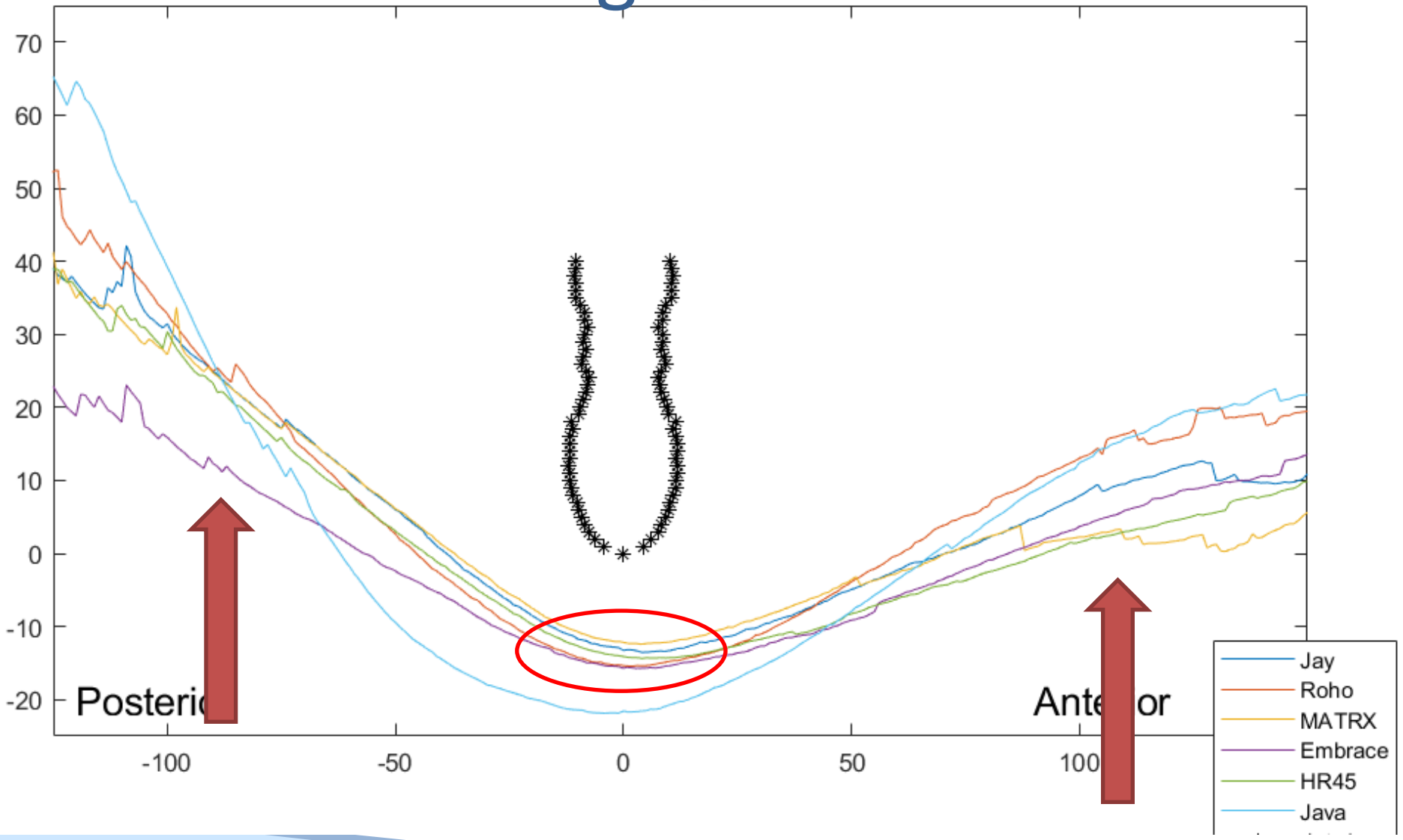
# Tissue Thickness Under the Ischium



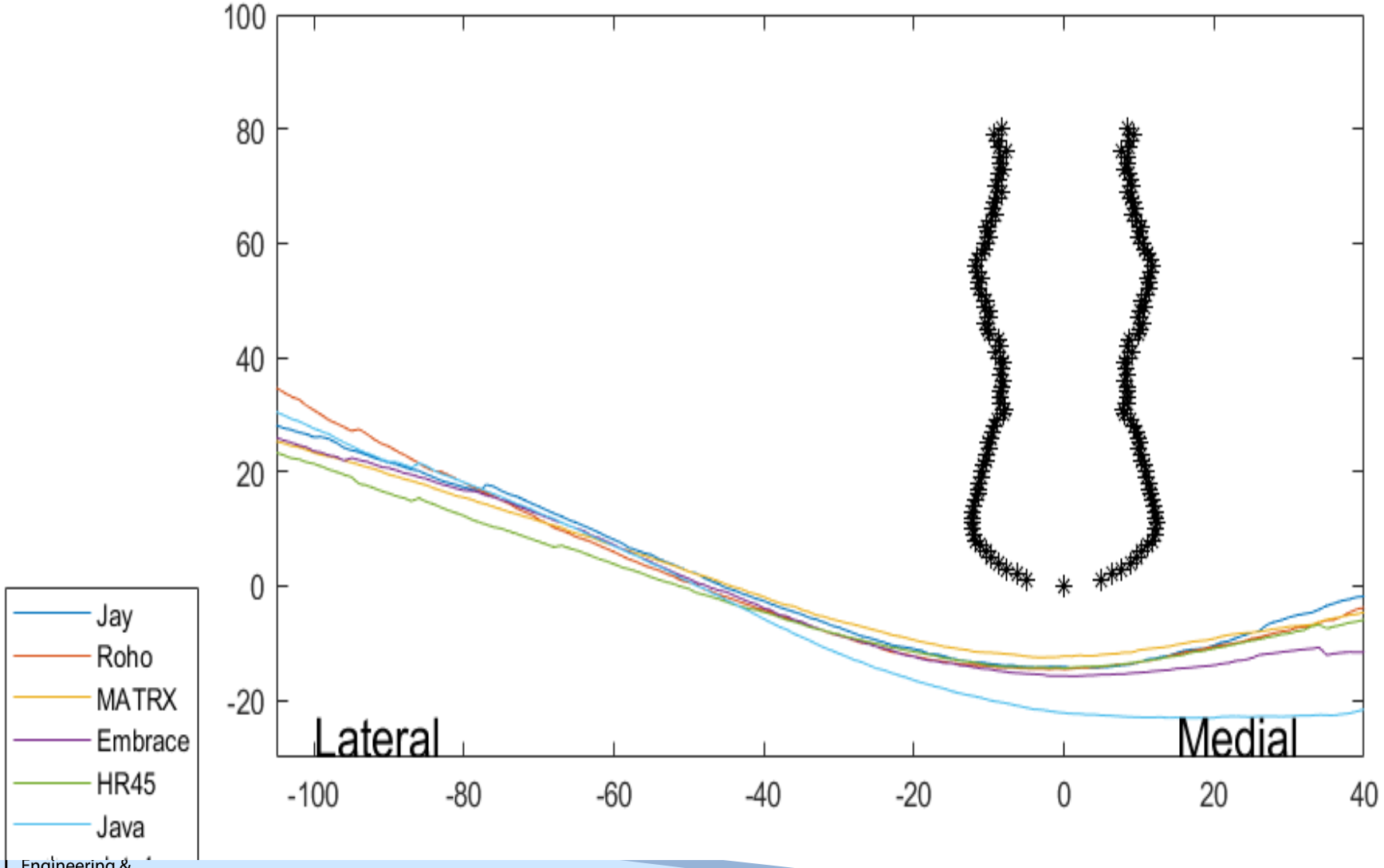

The goal is different!

# Tissue Thickness Under the Proximal Thigh

# Sagittal

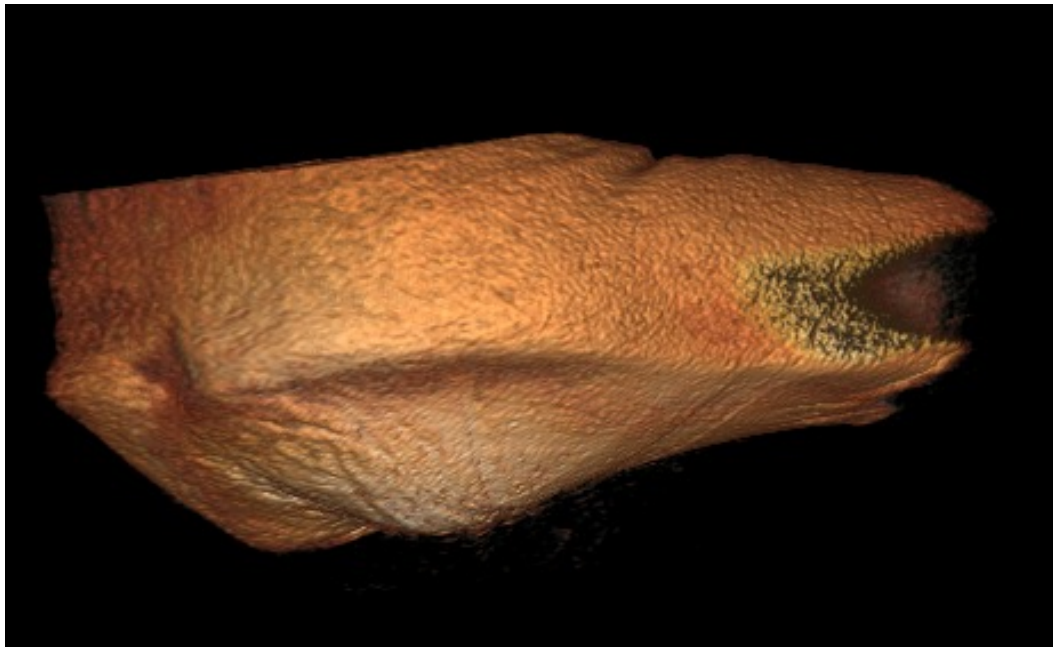

70
60
50
40
30
20
10
0
-10
-20
-100
-50
0
50
100
Posteri
Ante or
Jay
Roho
MATRX
Embrace
HR45
Java

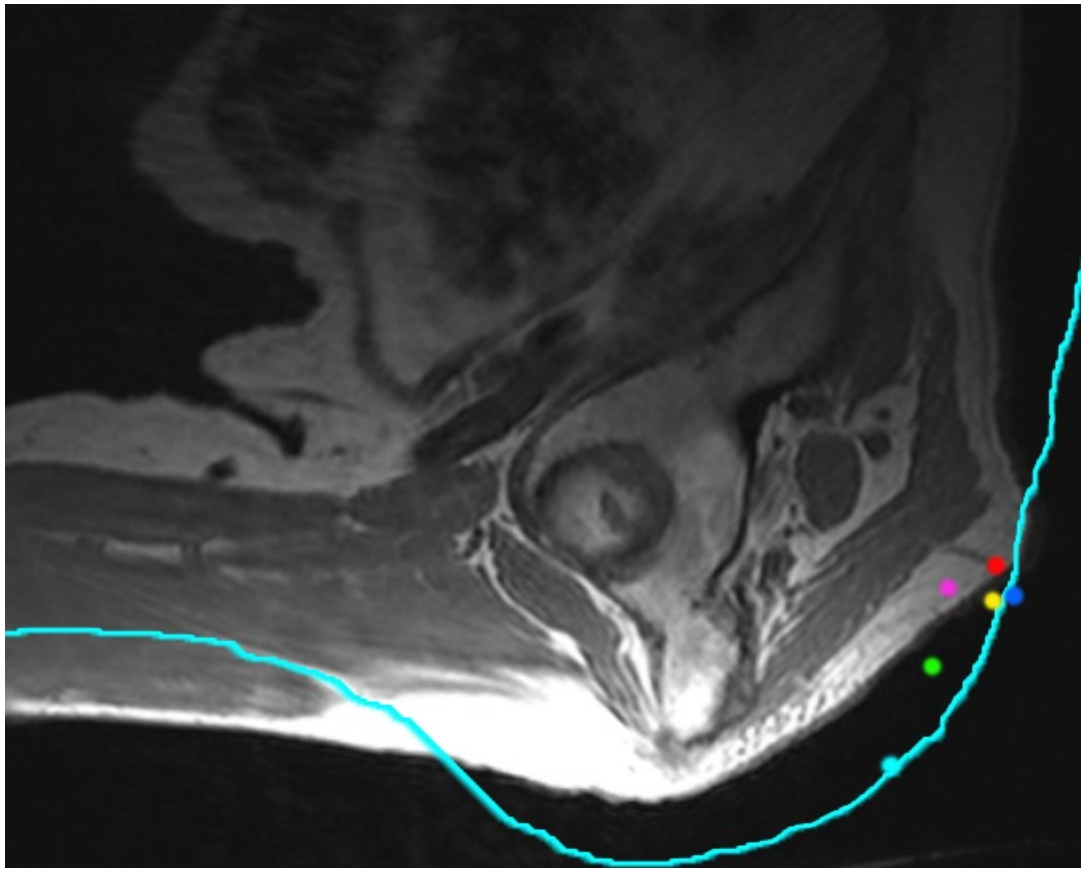
# Coronal


100
80
60
40
20
0
-20
-100
-80
-60
-40
-20
0
20
40
Lateral
Medial
Jay
Roho
MATRX
Embrace
HR45
Java

# Meet our Subject

- 47 yo M
- T6 SCI
- 4.5 Years in a W/C
- 66”
- 128 lb
- History of Sacral PrI





Blue = Unloaded

Red = HR45

Yellow = Jay2
Deep Contour

Dark Blue = Matrx Vi

Magenta = Roho

Green = Java

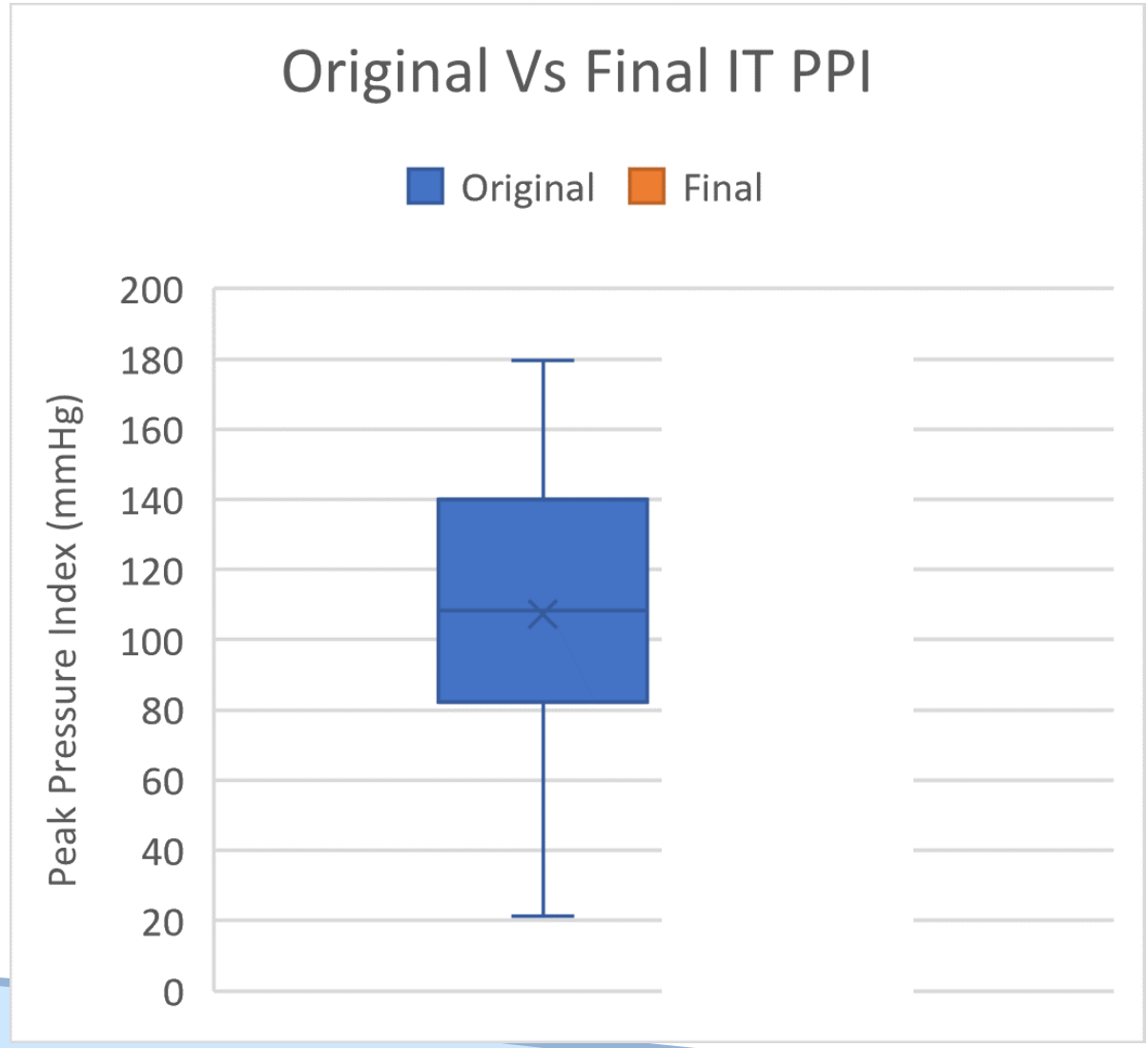
# Across **High Performing** Pressure Redistribution Cushions

- Similar Interface Pressure
- Similar Ischial Deformation (even if pressure is different)
- Only a slight difference at the proximal thigh for one surface

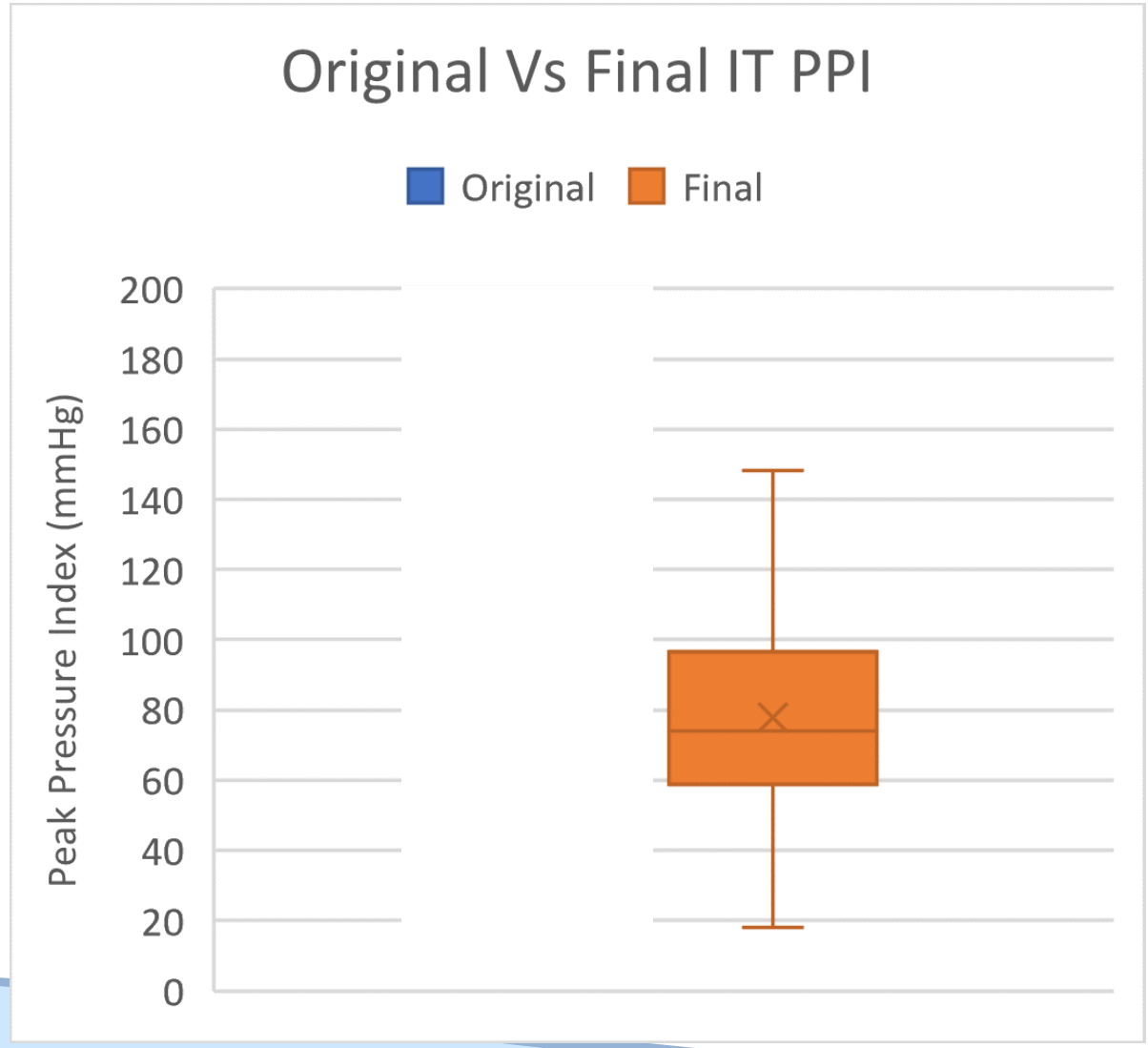
# Let’s Talk about Cushion Evals

- N=133 subjects
- Shepherd Center Seating Clinic
- Inclusion Criteria:
  - ≥18 years
  - cushion evaluation
  - Use a wheelchair as primary means of mobility
  - IPM data available

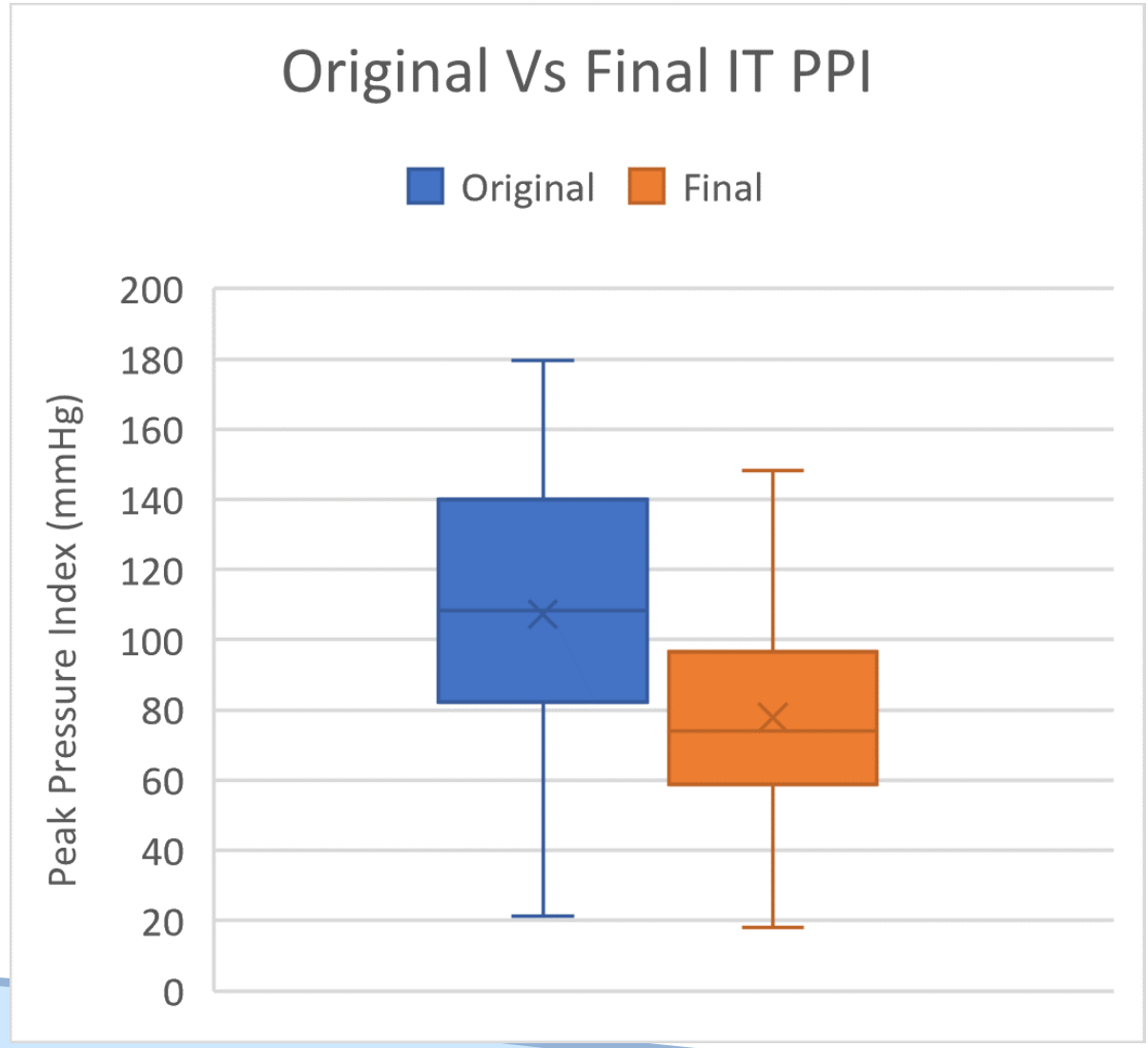
# How do people sit when they show up?



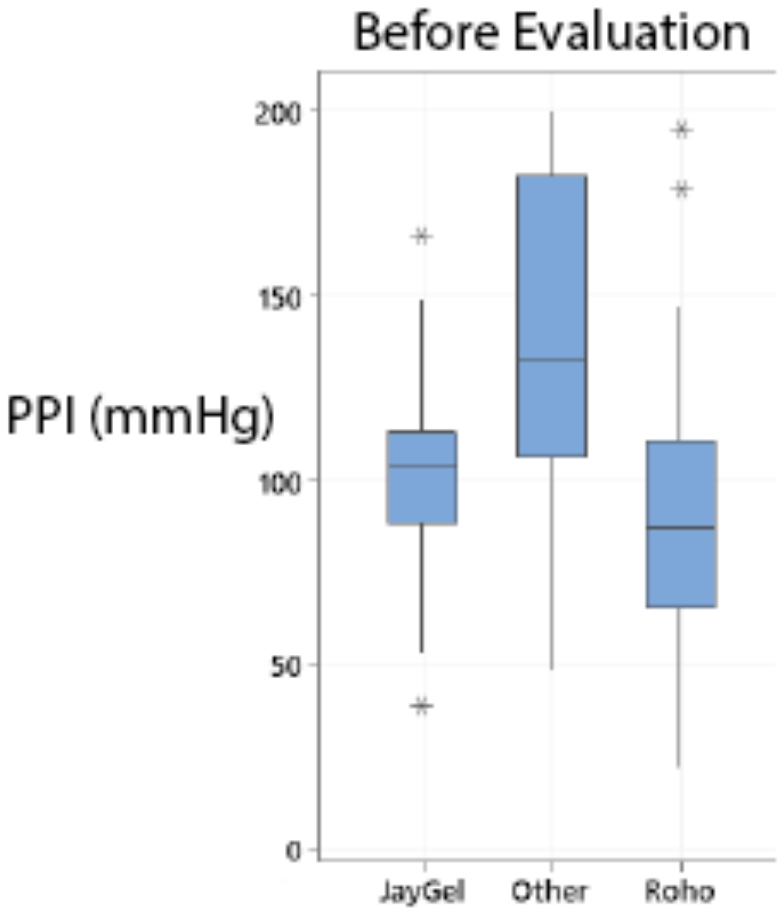
# How do we send them home?



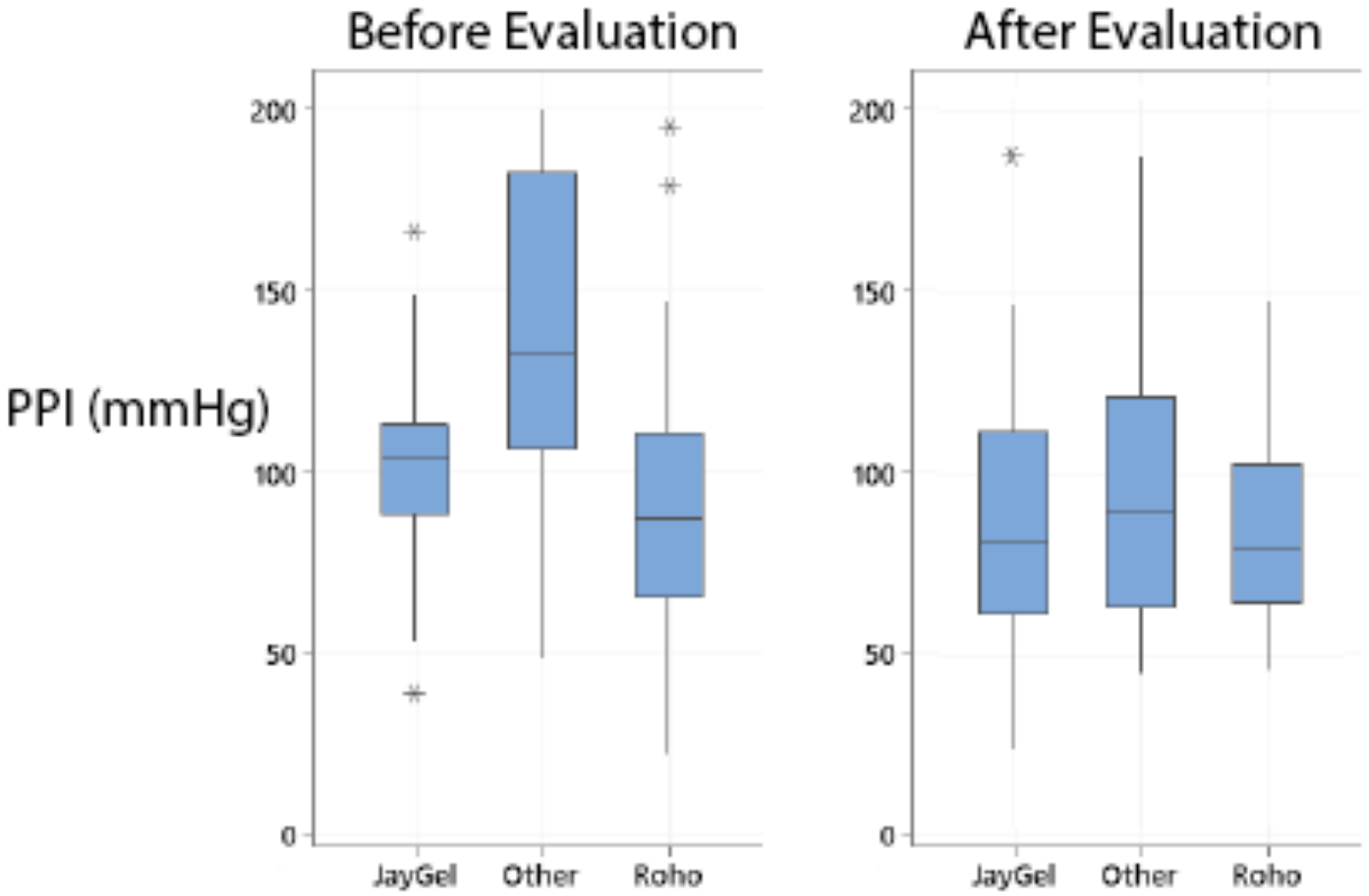
# How’d we do??


Original Vs Final IT PPI
Original
Final
Peak Pressure Index (mmHg)
200
180
160
140
120
100
80
60
40
20
0

# How do people sit when they show up?



# And when they went home?



# Summary

- Biomechanical risk
  - Your hands!
  - Immersion
  - Stiffness
  - Compressible hip tissue
  - Coccyx Morphology
  - Interface pressure mapping - gradient
- Differences across cushions
  - Amount of tissue under the ischium is similar for most ***high performing*** immersion/envelopment cushions
  - The use of the cushion (fit, seating system, etc.) impacts cushion performance
  - Matching the cushion to the person still matters

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- UC Denver
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