Study of 3D buttocks tissue deformation to inform pressure ulcer risk and cushion test method development.

Sharon Sonenblum, PhD
Stephen Sprigle, PhD, PT
Questions

• Anatomical Variations
  – What variations are visible in this subset of participants?

• Tissue Under Load
  – What tissue is most loaded when seated?

• Strain
  – Which tissues experience the most strain?
  – Which subjects experience the most strain?
<table>
<thead>
<tr>
<th>Subject ID</th>
<th>Gender</th>
<th>Age</th>
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<th>Diagnosis</th>
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Approach: FONAR “Stand-up” MRI
Approach: Sitting surfaces

• “Unloaded”

• Flat foam (HR45)
Anatomical Variation of Buttocks Structures While Seated

- Gluteus
  - Quantity
  - Shape
  - Position
Anatomical Variation of Buttocks Structures While Seated

- Gluteus
  - Quantity
  - Shape
  - Position
- Adipose Tissue
  - Subcutaneous
  - Visceral and intermuscular
Typical Assumption: People are Sitting on Muscle


Are the Gluts the Tissue Under Greatest Load During Sitting?

![Diagram showing the Gluts under greatest load during sitting.](image)
Are the Gluts the Tissue Under Greatest Load During Sitting?

Percent of Ischial Tuberosity (30 mm ROI) with Gluteus Underneath

Subject

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<td><img src="image2.png" alt="Image of Anterior View" /></td>
<td><img src="image3.png" alt="Image of Inferior View" /></td>
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Example of the Gluteus Maximum While Seated: (G) T12 SCI Male

Inferior View

Medial View
If not the gluts, what is loaded?

- Gluteus
  - Quantity
  - Shape
  - Position
- Adipose Tissue
  - Subcutaneous
  - Visceral and intermuscular
- Connective Tissue
Strain: The Inner Adipose Surface

(B) AB Male, 52 yo  (F) T12 SCI Male, 43 yo  (G) T12 SCI Male, 56 yo
Strain: Unloaded vs Loaded Buttocks

Sagittal View

(B) AB Male, 52 yo

(F) T12 SCI Male, 43 yo

(G) T12 SCI Male, 56 yo
Key Points & Questions

• Multiplanar
• Shear strain of the gluts isn’t always the priority – have to measure other structures.
• Challenges to measuring shear
  – How do we define an “unloaded” reference?
  – How do we model when structures vary across people?
  – How do we model and measure different structures?
  – How do we account for the varying material properties?
Shape compliance as a measure of cushion performance
Shape Compliance

• the ability of a cushion to support the buttocks with minimal buttocks deformation.
• can be considered a metric of cushion performance,

• Approach
  – Different compliant buttock models
  – Different loads on cushion
Measuring shape compliance with a compliant buttock model

- Elastomeric shell
  - Engineered to fall within tissue stiffness range
  - *Parametric design* capable of being scaled larger or smaller
  - Reflects hip width anthropometry of persons using 41 cm wide cushions
  - Axisymmetric
- Rigid substructure
  - Medial and Lateral protuberances to match bony skeleton
  - *Parametric design* capable of being scaled larger or smaller
  - Reflects bi-ischial spacing and bi-trochanteric breadth
- Stress- one side
  - measured via pressure sensors imbedded in protuberances
- Strain- one side
  - Measured using 7 ultrasound transducers
Elliptical model

Trigonometric model

View A
Pressure - STS TD10 sensors are used
Ultrasound - 5MHz unfocused transducers are used except the lateral prominence which has a 5MHz transducer focused at 1 inch
Dataset

- Benchmarking of 3” HR45 foam
  - 4 manufacturers
  - 5 samples from each
- Cushion cohort
  - 2”HR70 foam
  - Roho
  - Jay 3
  - Vicair
  - Matrx
- 2 buttock models
  - Elliptical and trigonometric
- 3 loads
  - 61 kg, 53 kg, 44 kg
Use of stress and strain to model tissue strain

• Pressure metrics
  – Magnitude of pressures @ medial and lateral protuberances
  – Relationship between medial and lateral pressures

• Deformation metrics
  – Elastomer strain at each location
  – Sum of absolute strain across model surface
  – Strain uniformity

• Comparison to HR45 foam cohort metrics
**Pressure metric:**
Magnitude
Equality of medial and lateral pressures

### Elliptical model pressures @ Medial & Lateral Protuberances (mmHg)

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<th>lateral</th>
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### Trig model pressures @ Medial & Lateral Protuberances (mmHg)

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Strain varies across buttock model
- elastic materials have peak strains under medial protuberance
- elastomer bulges at lateral protuberance

\[ \text{Strain} = \frac{\text{Deflection}}{\text{Unloaded}} - \text{thickness} \]

Absolute Strain across Elliptical model

Absolute Strain across Trig model
Total Strain across buttock model

Uniformity of strain is also important
Relating human deformation to buttock model deflection
Jay cushion
Remaining objectives

• Determine a useful selection of stress and strain metrics

• Optimize protocol
  – Buttock model profiles
  – Loads

• Attract stakeholder interest
Acknowledging the Team and the Funding source

• Imaging collaborators
  – Dr John Winder & Dr John Cathcart
  – University of Ulster

• Cushion test methods
  – Nagmesh Kumar & James Martin
  – Georgia Tech

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