Blood Flow to the Butt

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Background

• Pressure ulcers (PUs) are a leading secondary complication of spinal cord injury (SCI)

• Defining causes of pressure ulcers
  – the magnitude of pressure, addressed by selection of appropriate horizontal support surfaces and wheelchair cushions
  – duration of loading, addressed by the establishment of turning and pressure relief schedules.

• Limited evidence available to inform these preventative practices
Background

- PU risk assessment tools (e.g., Braden, Norton) identify people who, if treated with standard care, are likely to develop an ulcer.
- So, this informs the clinician to watch more closely, but not about how to individualize interventions.
- Need to understand why different people have different risk (i.e., how their buttocks respond to loading)
- Occlusion of blood flow is one of the contributing factors to pressure ulcer prevention. So understanding occlusion of blood flow under loading while seated can help inform about individual risk.
Specific Aim

To determine the relationship between individualized risk factors and the response of buttock tissue to loading in persons with SCI.
Protocol

• Custom cushion with bladder for loading and unloading the IT of a seated participant
Methods: Inclusion/Exclusion Criteria

- Men
- Ages 18-40
- SCI
- > 2 years post injury
- Use a wheelchair regularly
- No open sores
Protocol: Measurements

- Pressure under the IT
- Bloodflow
  - Measurement Locations
    - Active IT (loading/unloading)
    - Contralateral IT
    - Ipsilateral thigh
  - Variable Types
    - CMBC – concentration of blood cells,
    - Velocity – velocity of blood cells,
    - Flow - which is the overall flux, or CMBC * Velocity
- Myotonometer
- Skin color / visible blanching
- Blood pressure (typically after the protocol, though not 100% of the time)
- Blood labs (typically before the protocol, but not 100% of the time. A few subjects were on different days)
- Standard demographics and history info.
Methods: Individual Characteristics

- SCI injury level
  - cervical vs. non-cervical
- blood pressure
  - hypertension, hypotension, normal
- BMI
- smoking status
  - current
  - history
- Lymphopenia
Results: Subject Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean (SD)</th>
<th>Median (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>31 (5)</td>
<td>32 (20-40)</td>
</tr>
<tr>
<td>BMI</td>
<td>24.2 (5.3)</td>
<td>23.1 (15.6-37.9)</td>
</tr>
<tr>
<td>Years Using Wheelchair</td>
<td>10 (5)</td>
<td>10 (2-20)</td>
</tr>
</tbody>
</table>

![Histogram of age, BMI, YearsInWC, LevelOfInjury_Ordinal](image)

Rehabilitation Engineering & Applied Research
Results: Subject Characteristics

- 19 Black/African American
- 14 White
- 2 Hispanic or Latino
- 29 (83%) visible blanching
Results: Subject Characteristics

- 16 Cervical Injuries, 16 Thoracic, 3 Lumbar
- 18 (51%) Complete
- 30 (86%) Self-reported spasticity
- 14 (40%) Report some controlled movement below the waist
- 16 (46%) report sensation at the buttocks
- 10 current smokers (29%), 21 (6%) current or previous smokers
Results: Subject Characteristics

- 19 Had previous pressure ulcers
  - 19 sacral / coccyx
  - 5 IT
  - 3 recurrent (1 sacral, 2 IT)
Results: Blood Pressure

• Hypertension (systolic above 140)
  – \( n = 6 \)

• Hypotension (systolic below 110)
  – \( n = 10 \)
Results: Example Bloodflow Data

![Sample Subject Data](image)
Results: Blood Flow

High Load / Unloaded

Flow (flux)  Velocity  CMBC
Results: Blood Flow

Flow (flux)  Velocity  CMBC

Low Load / Unloaded

High Load / Unloaded

Flow (flux)
Velocity
CMBC

meanFlow_1_Low/Un
meanVel_1_Low/Un
meanCMBC_1_Low/Un

meanFlow_1_hi/un
meanVel_1_hi/un
meanCMBC_1_hi/un
## Results: Blood Flow

<table>
<thead>
<tr>
<th></th>
<th>Load Load</th>
<th>High Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Blood Flow</td>
<td>1.00</td>
<td>0.27*</td>
</tr>
<tr>
<td>Mean Velocity</td>
<td>1.37*</td>
<td>2.12*</td>
</tr>
<tr>
<td>Mean CMBC</td>
<td>0.80*</td>
<td>0.13*</td>
</tr>
</tbody>
</table>

* Indicates significant difference from unloaded
## Results: Individual Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Low Load</th>
<th>High Load</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bloodflow</strong></td>
<td>BP (hi BP – hi flow)</td>
<td>Sensation (sensation – low flow)</td>
</tr>
<tr>
<td></td>
<td>PU Hx (Yes – low flow)</td>
<td>Movement (move – low flow)</td>
</tr>
<tr>
<td></td>
<td>Lymphopenia (yes – low flow)</td>
<td>Smoking (yes – low flow)</td>
</tr>
<tr>
<td></td>
<td>BMI (slight relationship, hi BMI – hi flow)</td>
<td>Complete (yes – hi flow)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lymphopenia (yes – low flow)</td>
</tr>
<tr>
<td><strong>Velocity</strong></td>
<td>Ever smoked (yes – hi vel)</td>
<td>BP</td>
</tr>
<tr>
<td></td>
<td>LOI (cervical – hi vel)</td>
<td>Movement (move – low vel)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Skin Color (light skin- hi vel)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LOI (cervical – hi vel)</td>
</tr>
<tr>
<td><strong>CMBC</strong></td>
<td>BP</td>
<td>Complete (yes – hi CMBC)</td>
</tr>
<tr>
<td></td>
<td>PU Hx (Yes – low CMBC)</td>
<td>LOI (cervical – low CMBC)</td>
</tr>
<tr>
<td></td>
<td>LOI (cervical – low CMBC)</td>
<td>Lymphopenia (yes – low flow)</td>
</tr>
</tbody>
</table>
## Results: Individual Characteristics

### Low Load
- **Some expected results:**
  - Lymphopenia associated with decreased flow
  - PU history associated with decreased flow
  - Folks with Hypertension had more flow than folks with normal blood flow and hypotension
- **Other results:**
  - Increased BMI had a slight relationship with increased flow

### High Load
- **Some expected results:**
  - Lymphopenia associated with decreased flow
  - History of smoking associated with decreased flow
- **Surprising results**
  - Presence of sensation below the waist associated with decreased flow
  - Ability to move below the waist was associated with decreased flow
  - Complete injury associated with increased flow
Next Steps

• Look at tissue stiffness versus blood flow response
• Create models to understand the amount of effect that individual characteristics have on flow
• Determine how this relates to a change in intervention.
Conclusions
Helpful Blood Flow References

**Blood flow response to sitting**


**An example of a study using blood flow response following loading to inform individualized risk**

Helpful Blood Flow References

**Blood flow responses in other positions (SCI)**
Results: Blood Flow
Am I at Steady State?
Results: Blood Flow

Am I at Steady State?

![Graphs showing blood flow data](image)
Results: Blood Flow
Am I at Steady State?

<table>
<thead>
<tr>
<th>Loading Condition</th>
<th>95% Confidence Interval</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Load</td>
<td>(-0.00043, 0.00594)</td>
<td>0.089</td>
</tr>
<tr>
<td>Low Load</td>
<td>(-0.00861, 0.00436)</td>
<td>0.517</td>
</tr>
<tr>
<td>Unloaded</td>
<td>(-0.02161, -0.00355)</td>
<td>0.007</td>
</tr>
</tbody>
</table>

Unloaded: Corresponds with 0.6 PU over 60 seconds. Mean flow is 10.3 PU, so this is a change of 5-6%.

Not Really!