



Rehabilitation
Engineering &
Applied
Research

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

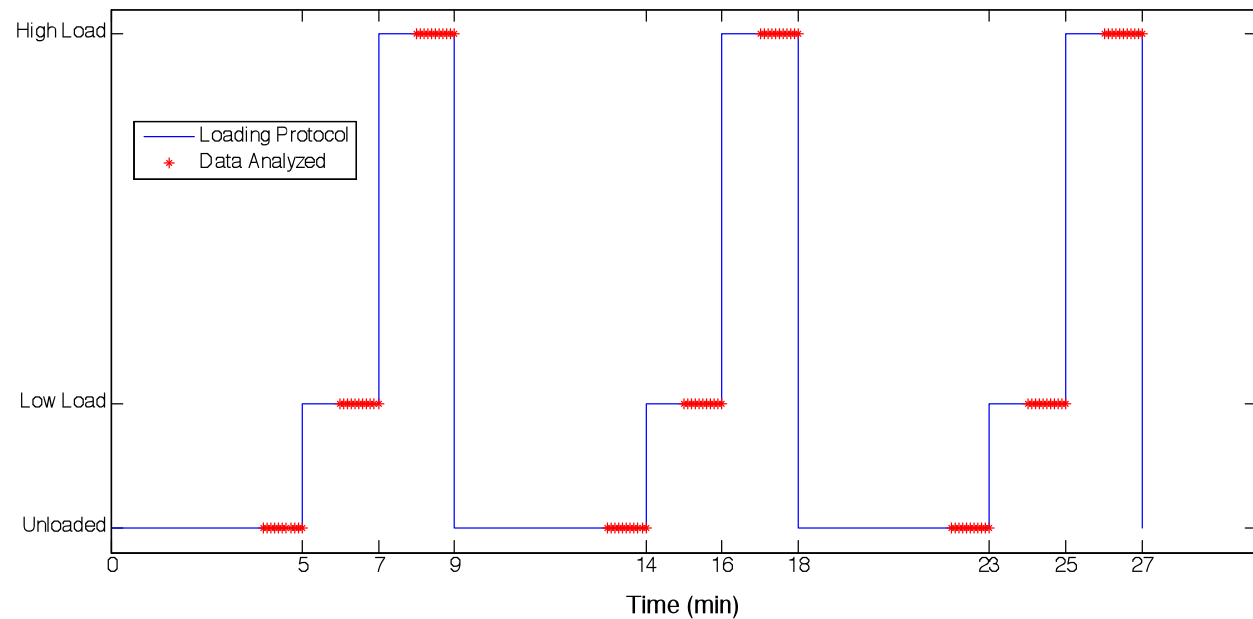
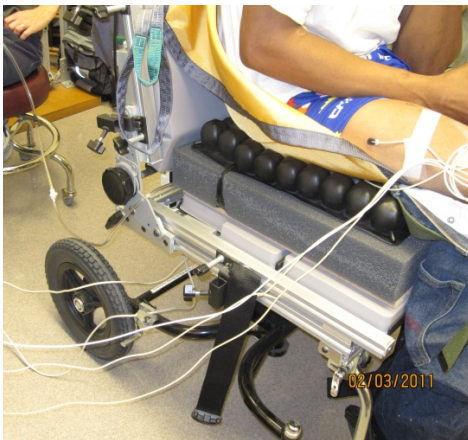
- PU risk assessment tools (e.g., Braden, Norton) identify people who, if treated with standard care, are likely to develop an ulcer.
- So, this informs the clinician to watch more closely, but not about how to individualize interventions.
- Need to understand why different people have different risk (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

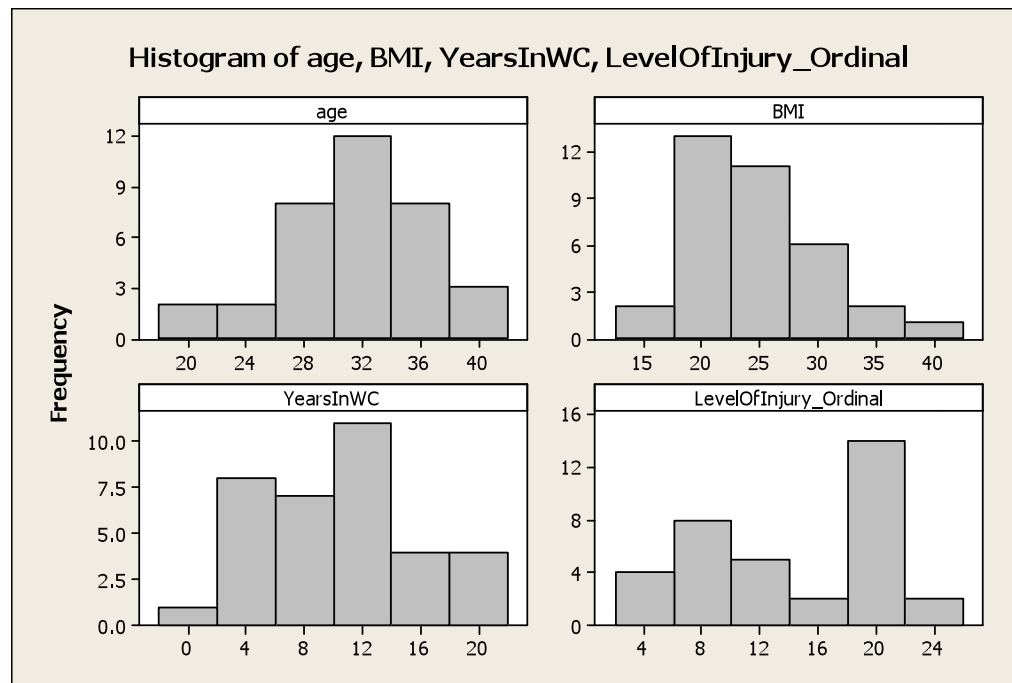
- Pressure under the IT
- Bloodflow
 - Measurement Locations
 - **Active IT (loading/unloading)**
 - Contralateral IT
 - Ipsilateral thigh
 - Variable Types
 - CMBC – concentration of blood cells,
 - Velocity – velocity of blood cells,
 - Flow - which is the overall flux, or $CMBC * Velocity$
- Myotonometer
- 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

Characteristic	Mean (SD)	Median (Range)
Age	31 (5)	32 (20-40)
BMI	24.2 (5.3)	23.1 (15.6-37.9)
Years Using Wheelchair	10 (5)	10 (2-20)



Results: Subject Characteristics

- 19 Black/African American
- 14 White
- 2 Hispanic or Latino

- 29 (83%) visible blanching

Results: Subject Characteristics

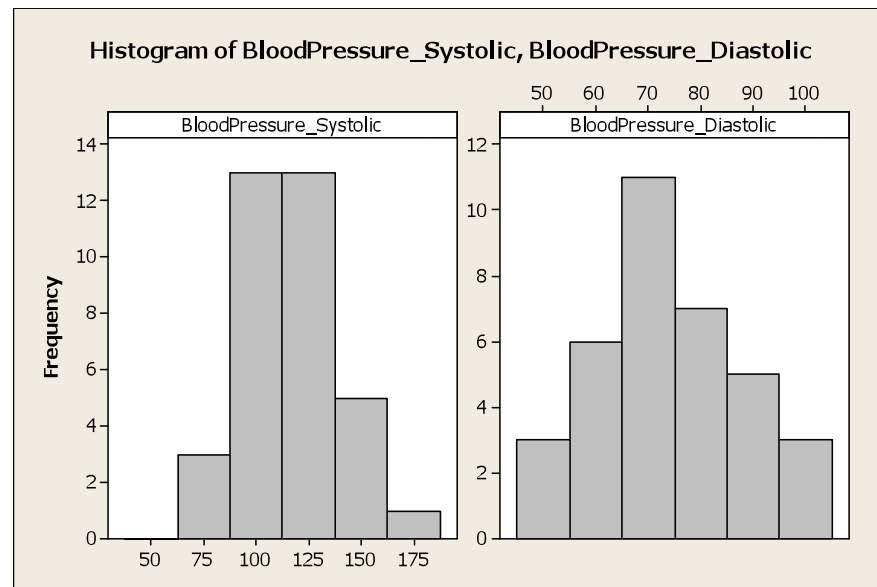
- 16 Cervical Injuries, 16 Thoracic, 3 Lumbar
- 18 (51%) Complete
- 30 (86%) Self-reported spasticity
- 14 (40%) Report some controlled movement below the waist
- 16 (46%) report sensation at the buttocks
- 10 current smokers (29%), 21 (6%) current or previous smokers

Results: Subject Characteristics

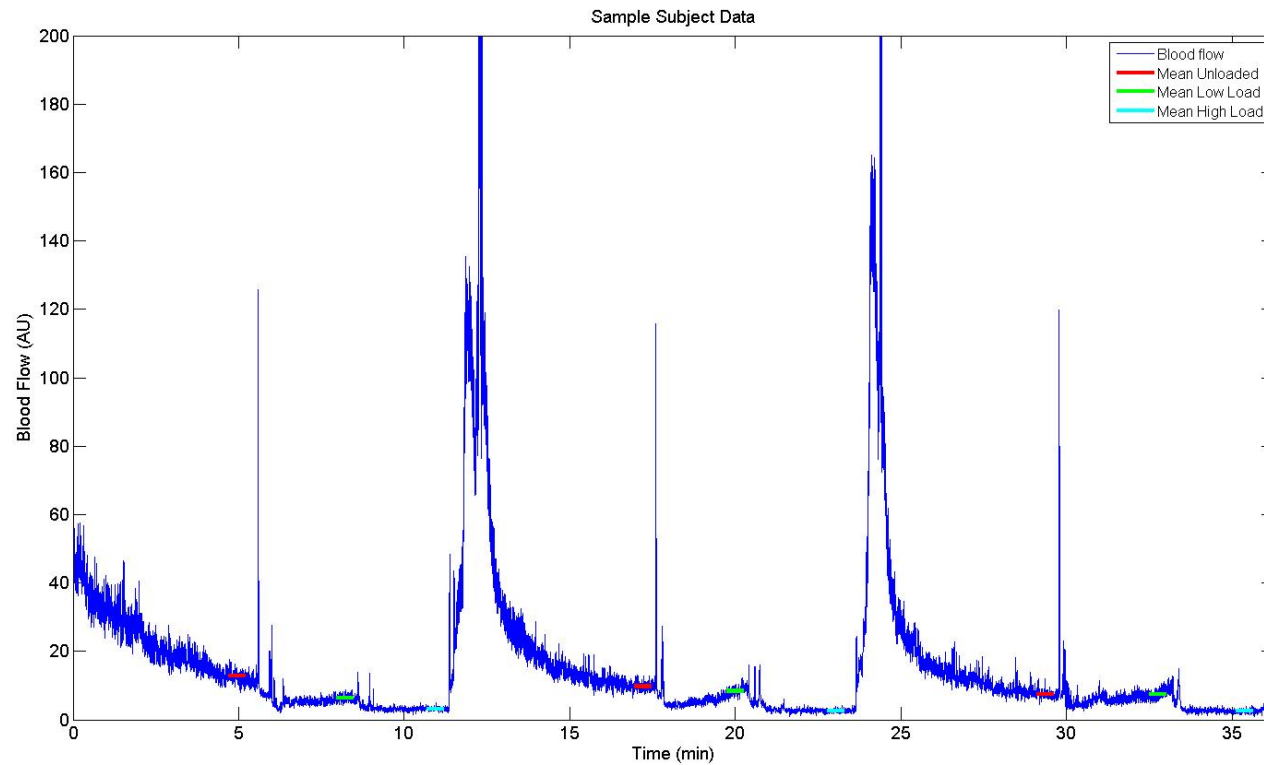
- 19 Had previous pressure ulcers
 - 19 sacral / coccyx
 - 5 IT
 - 3 recurrent (1 sacral, 2 IT)

Results: Blood Pressure

- Hypertension (systolic above 140)
 - $n = 6$
- Hypotension (systolic below 110)
 - $n = 10$



Results: Example Bloodflow Data



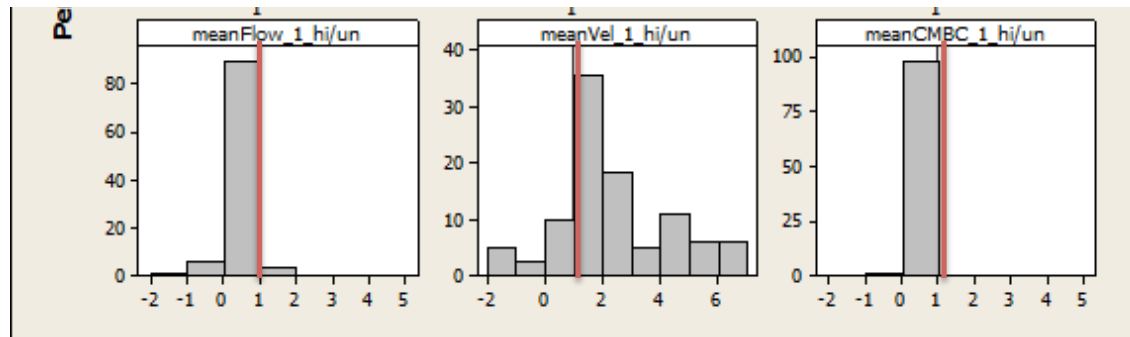
Results: Blood Flow

Flow (flux)

Velocity

CMBC

High Load /
Unloaded



Results: Blood Flow

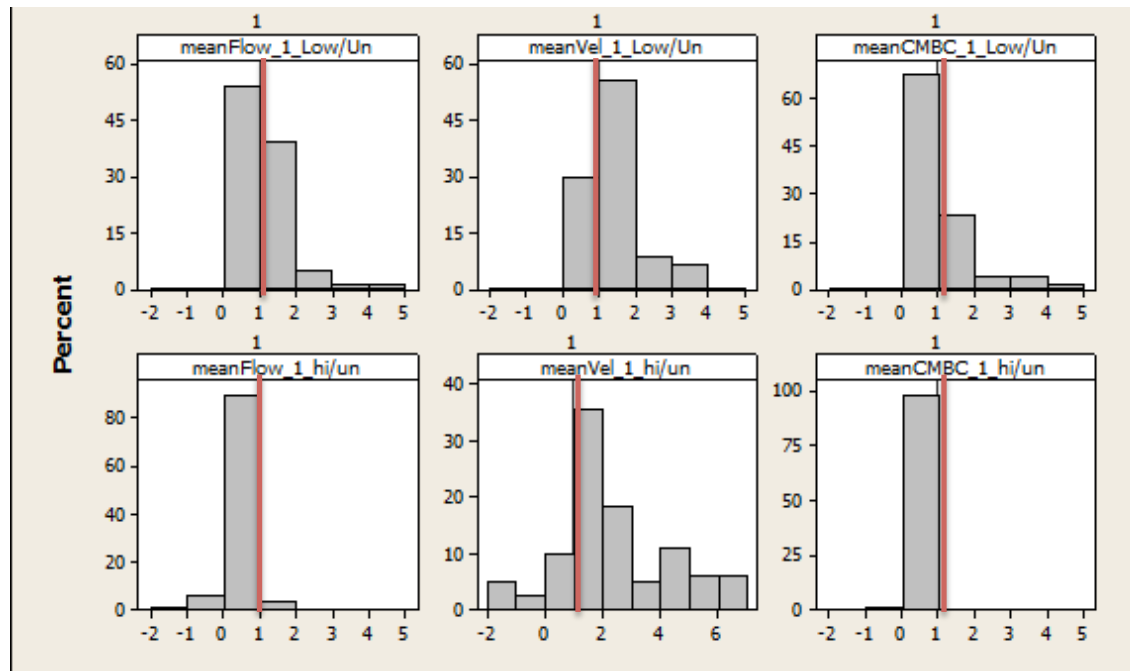
Flow (flux)

Velocity

CMBC

Low Load /
Unloaded

High Load /
Unloaded



Results: Blood Flow

	Load Load	High Load
Mean Blood Flow	1.00	0.27*
Mean Velocity	1.37*	2.12*
Mean CMBC	0.80*	0.13*

* Indicates significant difference from unloaded

Results: Individual Characteristics

	Low Load	High Load
Bloodflow	BP (hi BP – hi flow) PU Hx (Yes – low flow) Lymphopenia (yes – low flow) BMI (slight relationship, hi BMI – hi flow)	Sensation (sensation– low flow) Movement (move – low flow) Smoking (yes – low flow) Complete (yes – hi flow) Lymphopenia (yes – low flow)
Velocity	Ever smoked (yes – hi vel) LOI (cervical – hi vel)	BP Movement (move – low vel) Skin Color (light skin- hi vel) LOI (cervical – hi vel)
CMBC	BP PU Hx (Yes – low CMBC) LOI (cervical – low CMBC) Lymphopenia (yes – low flow)	Complete (yes – hi CMBC) LOI (cervical – low CMBC)

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

- Jan YK, Jones MA, Rabadi MH, Foreman RD, Thiessen A. Effect of wheelchair tilt-in-space and recline angles on skin perfusion over the ischial tuberosity in people with spinal cord injury. Arch Phys Med Rehabil. 2010 Nov;91(11):1758-64.
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An example of a study using blood flow response following loading to inform individualized risk

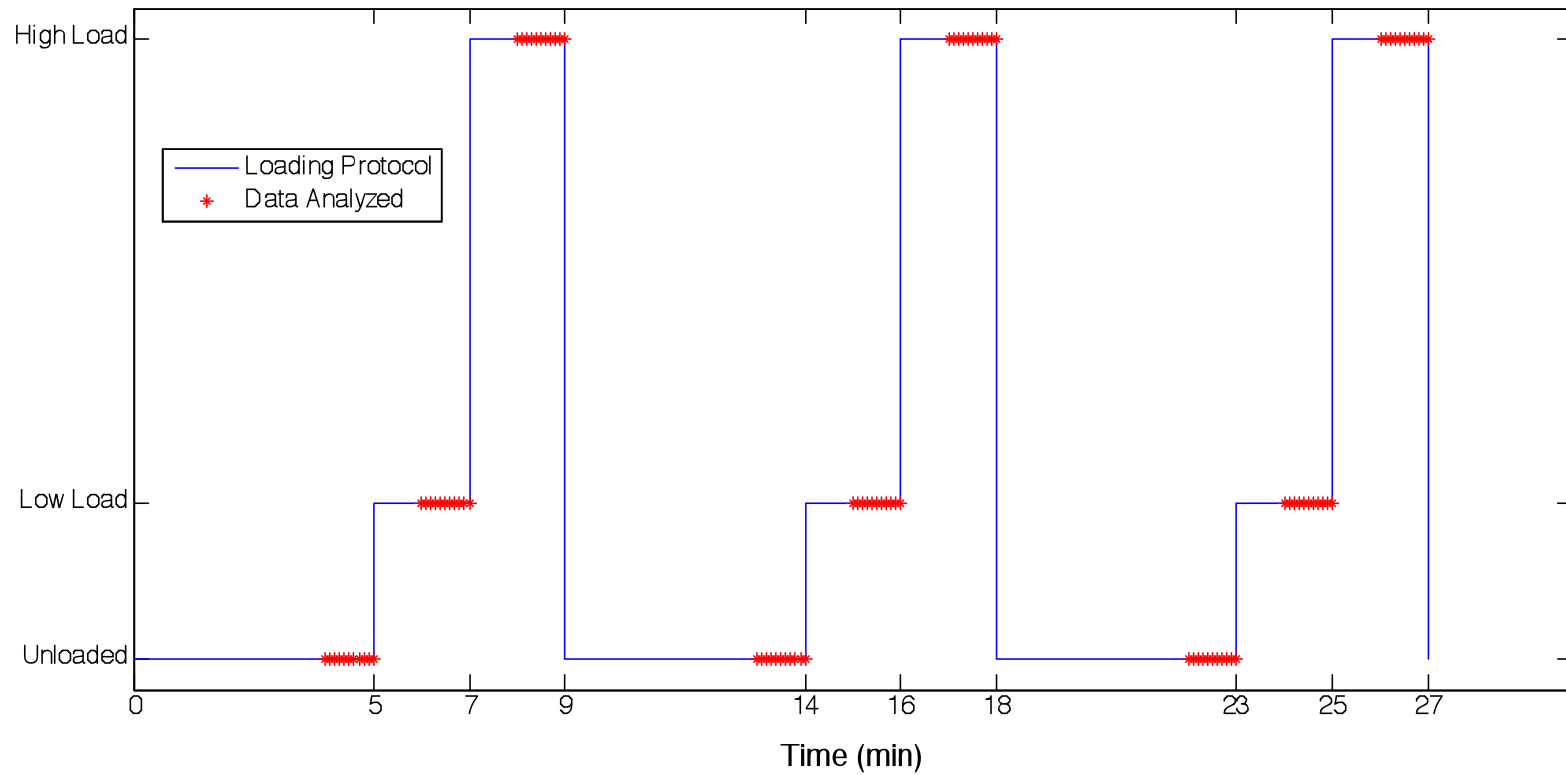
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Helpful Blood Flow References

Blood flow responses in other positions (SCI)

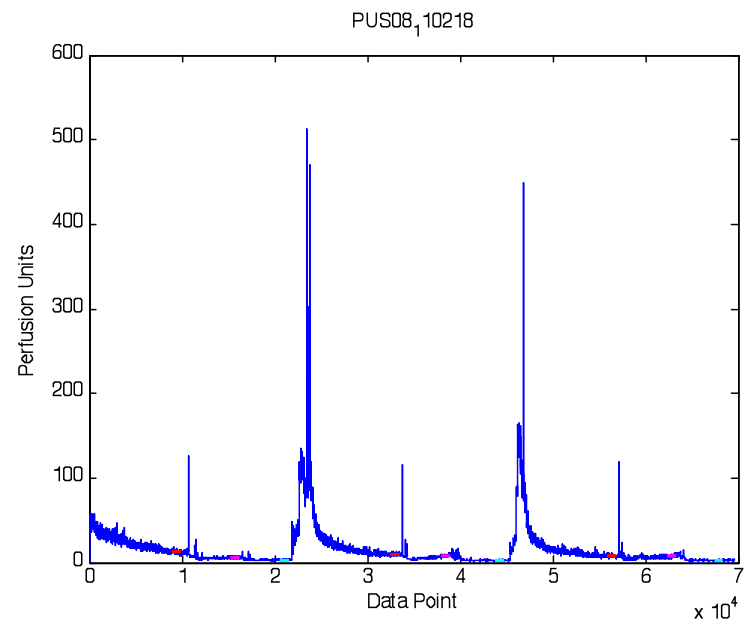
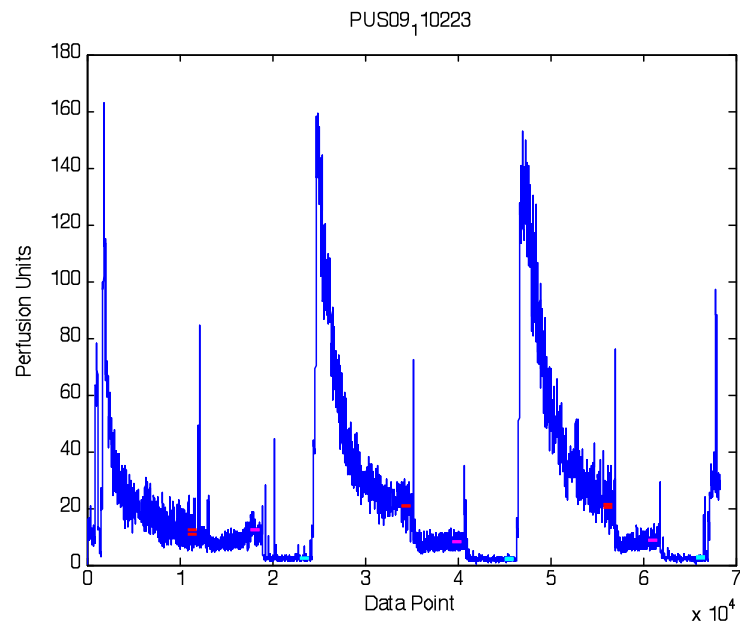
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- Li Z, Leung JY, Tam EW, Mak AF. Wavelet analysis of skin blood oscillations in persons with spinal cord injury and able-bodied subjects. Arch Phys Med Rehabil. 2006 Sep;87(9):1207-12; quiz 87.
- Rithalia SV. Evaluation of alternating pressure air mattresses: one laboratory-based strategy. Journal of tissue viability. 2004 Apr;14(2):51-8.
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Results: Blood Flow Am I at Steady State?



Results: Blood Flow

Am I at Steady State?



Results: Blood Flow

Am I at Steady State?

Loading Condition	95% Confidence Interval	P-value
High Load	(-0.00043, 0.00594)	0.089
Low Load	(-0.00861, 0.00436)	0.517
Unloaded	(-0.02161, -0.00355)	0.007

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!