The Science of Seat Cushions

Stephen Sprigle, PhD, PT
Sharon Pratt, PT
Important characteristics of wheelchair cushions

- **Mechanical Properties**
  - Load deflection
  - Recovery
  - Impact Damping
  - Loaded contour depth
  - Frictional properties

- **Load redistribution**
  - Envelopment
  - Off-loading and redirection
  - Interface Pressure Distribution

- **Heat & Water Vapor Dissipation**
Cushion Materials: Material combinations dominate

- **Foam/flexible matrix**: GeoMatt, Supracore, Fundamental
- **Foam & Elastomer/gel**: Southwest Technologies, Action
- **Foam & Viscoelastic Foam**: Maxus, Infinity, Ultimate
- **Foam & Viscous Fluid**: Jay, Cloud, Skil-Care
- **Air**: Roho, Star, BBD
- **Air & Foam**: Varilite, Nexus
Mechanical Properties

- Different materials accommodate body load in different manners
  - foam and air: compression
  - gel and viscous fluid: displacement
  - cover (bladder and/or fabric): tension
Mechanical Properties: Load deflection

- Stiffness is a measure of deflection under a given load
  - Foam: Indentation Force Deflection
  - Elastomers and gel: durometer
  - Viscous Fluid: viscosity & bladder volume
  - Air: Internal air pressure and bladder stiffness
Load Deflection

- The trick is finding the proper stiffness
  - Too stiff → high loads $2^\circ$ to poor deflection
  - Too soft → bottoming-out $2^\circ$ to over-deflection

- Material combinations used to accommodate various needs
Sitting on foam induces compression bending, tension of material
Segmented foam is functionally softer- reduced surface tension
(foam does not like to stretch)
Trick is to find foam that compresses just enough (40-60 IFD is typical for 3”)
Foam gets softer over time (fatigue)- look for tears, compression set
Viscous Fluid

Requires proper base, bladder and volume of fluid
Best viscous fluid cushions are combination cushions
(bladder alone would not be good)
Concept: allow fluid to flow and contain buttocks
Volume of fluid impacts immersion, not viscosity
Viscous Fluid: volume not viscosity matters

<table>
<thead>
<tr>
<th></th>
<th>Beveled Indentor</th>
<th>12 lb Bowling Ball</th>
</tr>
</thead>
<tbody>
<tr>
<td>High viscosity Mineral Oil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 ml x 10 bags</td>
<td>2.3</td>
<td>2.8</td>
</tr>
<tr>
<td>150 ml x 10 bags</td>
<td>1.8</td>
<td>1.7</td>
</tr>
<tr>
<td>WATER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 ml x 10 bags</td>
<td>2.4</td>
<td>3</td>
</tr>
<tr>
<td>150 ml x 10 bags</td>
<td>1.6</td>
<td>1.8</td>
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This mineral oil was 75x more viscous than water
Air: container and volume matters

- Single bladder system
  - Single air pressure
  - Envelopment highly bladder dependent

- Multi-segmented bladders
  - Single air pressure
  - Segment collapse and expansion

All adjustable cushions require assessment
Over-inflation risk
Contoured and Positioning cushions

“Positioning” can mean correction, accommodation, alignment or stability

Contour depth helps determine site specificity and maybe something about transferring and positioning
  – The more complex the features, the more site-specific the fit
  – The more aggressive the support, the greater the potential impact on positioning and transferring

Simple height and depth measurements may be descriptive but do not reflect performance
  – How high is high enough?
  – How deep a contour is enough?
Support Surface v. Overall Thickness

- Thickness of a cushion has clinical relevance
  - And measurement of contour depth must also report thickness
- Supporting material must be distinguished from non-support material
- Certain cushions must be measured in different manners

- Contoured cushion
- Flat Cushion
- Convex Cushion

Support surface thickness measured after placement of plank to level fluid/material

Lateral border

Support surface thickness

Deforming material
Non-deforming material
Contouring impacts stiffness

- Flat cushions must deform to reach the final shape of the buttock-cushion interface
- Contoured cushions are closer to the final buttock-cushion interface shape
In Clinic, How can we use this knowledge?

- What style of product do we choose?

- How much maintenance and adjustment is required for it to function consistently over time?
In Clinic, How can we use this knowledge?

- Foam might be the perfect solution…
  - What's the life expectancy of this foam?
  - What happens if the clients shape changes?
  - What happens if the foam breaks down and changes the shape relationship?

- Consider how long it’s required to last

- What changes are predicted to occur with the client
Maybe Fluid is the choice…

- Do I have the right amount of viscous fluid?
- When tried – is the client “in it, or on top of it?"
- When using air, can the client do the required maintenance consistently?
Load redistribution

- The ability of a cushion to manage loads on the buttock tissues impacts tissue health and comfort
- Techniques used include:
  - Envelopment
  - Redirection of forces (including off-loading)
Envelopment

- Capability of a support surface in deforming around and encompassing the contour of the human body.
- An enveloping cushion should have the ability to encompass and equalize pressure about irregularities in contour due to buttock shape, objects in pockets, clothing, etc.
Envelopment & Off-loading: how we measure it

Parity: how equal are the 3 most inferior values; 0 means parity

Magnitude: sum of 3 most inferior values
Redirection of forces & off-loading

- Choosing where to apply loads on the body is commonly used in prosthetics and orthotics.
- Several cushion designs use this approach to reduce ischial loading:
  - Isch-Dish; Ride Designs
  - Contoured systems
  - Any system with ‘reliefs’ in a region.
## Envelopment measures

Values closer to 0 reflect best envelopment

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<th>Envelopment</th>
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<tr>
<td>Reference flat HR45</td>
<td>0.44</td>
</tr>
<tr>
<td>Air &amp; foam</td>
<td>0.07</td>
</tr>
<tr>
<td>Cellular matrix</td>
<td>0.06</td>
</tr>
<tr>
<td>convoluted foam</td>
<td>0.20</td>
</tr>
<tr>
<td>viscoelastic foam</td>
<td>0.20</td>
</tr>
<tr>
<td>segmented air</td>
<td>0.08</td>
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Characterizing Load Distributing Performance

- One value is not enough
  - Magnitude
  - Envelopment
  - Immersion
Characterizing Adjustability

- Measuring the ability to adjust to different types and sizes of people
  - 2 weights
  - 2 models
  - Comparison to flat foam

<table>
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<th>56 Kg</th>
<th>84 Kg</th>
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<tbody>
<tr>
<td>Peaked model</td>
<td></td>
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In Clinic, How do we use this knowledge?

- Immersion
- Envelopment
- Magnitude
Immersion

- How far does the client sink in?
- Tools we have to determine this…
  - Visual inspection of how much the pelvis, thighs and trochanters are immersed into the cushion
  - Pressure Mapping
    - Surface contact area
How much does the pelvis sink in?

- Palpation and visual inspection
- Remember the ischials in a bony person need to be able to immerse approx 2” without bottoming out

Approx. 2”
Envelopment

- How intimate is the shape formed with the clients shape?

- What tools have we to determine this?
  - Hands and eyes – Difficult......
  - Pressure Mapping
    - Color distribution and gradient
How much does this matter when ..... 

...Anything that interferes with the conformation is placed over top of the conforming material?

- Chuck pads
- Slings
- Diapers
- The list goes on......!!!!!
Magnitude

- How well has the cushion distributed the pressure
- The goal is usually to decrease the pressures on the IT’s and spread to areas that can take load
- Tools to determine this…
  - Pressure Mapping
  - Where are the risk sites and how high is the pressure there?
Redirection of forces

- Choosing where to apply loads on the body
- Generally we try to
  - load the areas tolerant of load
    e.g. the posterior thigh, feet and thorax
  - redirect load from areas less tolerant,
    e.g. the ischials, sacrum

The BIG Questions –

- Can the client tolerate load for long periods of time on these areas?
- Does the client **consistently** get put into this shape that has been created for them
- If they need to move – can they?
Shear and friction

- **Shear**
  - Actually, *shear strain*- movement of tissues in relation to bony structures; tissue deformation

- **Friction**:
  - contact force that impedes sliding
  - clinically, often refers to damaging forces caused by sliding
  - frictional forces are proportional to normal forces

- Friction is a type of shear force, but not all shear forces are friction

- ALL forces on tissue (normal, friction, shear) induce shear strain in tissue
  - Any interaction causing tissue deformation will induce strain
Shear strain in tissues
Friction and Shear

Anytime a backrest is used, friction must exist to keep a person seated.

Frictional forces due to semi-recumbent position.
Horizontal Stiffness
Sliding Resistance
Horizontal Stiffness Data

Height shows force required to slide

Stress relaxation illustrated by some products

[Graph showing stiffness data for Honeycomb Cushion, Air Cushion, and Foam Cushion over time]
Horizontal Stiffness

High Horizontal Stiffness

Low Horizontal Stiffness
Cushion impact on Posture & Reach
Sprigle, et. al, 2002

- SCI subjects
- Forward & lateral reach; uni- and bilateral
- 3 cushions
  - Roho HP
  - Jay 2
  - Varilite evolution
- No differences in reach or posture across subjects
- Subjects did reach and sit better on a particular cushion
How does this impact tissue integrity & function

- Friction is ever present
  - Required to keep one in the cushion
  - Too much can hinder transfer and adversely impact tissue

- Some cushions are harder to slide upon
  - May help with positioning but hinder transfers

- “Functional Stability” reflects design and strategy
Resilience & recovery

- Ability to return to original dimensions after a deforming force is removed
  - Recovery relates to a slower process
  - Resilience reflects a more rapid response

- Ability to absorb energy
  - Impact and vibration
Resilience during lean

Resilient material-
↑ compression leads
To ↑ reactive forces
(like a spring)

Stress relaxation
allows nonresilient
materials to relax
when deformed
Recovery - during & after a lean

Resilient material:
- Resets itself after deformation

Non resilient material:
- Responds to loads and does not reset automatically
Impact Dampening
A measure of resilience & ability to absorb accelerations during everyday mobility
Impact Dampening

- Accelerations seen by the body
  - Vibration exposure
  - Force (F=mA)
Impact Dampening Test
45 ILD Foam

Impact Dampening G's vs Time

Dampening of initial impact
Initial impact

Time (s)
Impact Dampening

Low Impact Transmission

Higher Impact Transmission
Accelerations in everyday mobility

- Accelerations influenced by
  - Speed
  - Surface
  - Wheelchair design and configuration

- Everyday wheelchair usage
  - Most travel <1 mile

- Over everyday barriers, cushion does not have a significant influence on accelerations
  - DiGiovanne, et. al, 2003

- Impact dampening may be important for a select number of users

- Cushion is only one of several influences
Temperature, Humidity, Friction
3 Friends
Friction and Moisture

- As moisture increases, friction increases
  - ↑ softness → ↑ contact between surfaces
- Excessive moisture weakens skin’s ability to withstand load
Segueing from moisture to temperature

- Linked via perspiration
  - ↑ skin temp induces perspiration
  - Obviously other sources of moisture
Temperature and it’s impact on tissue viability

- ↑ tissue temperature ↑ metabolic demand
  - Added demand coupled with reduced nutrient delivery leaves tissues vulnerable

- Evidence suggests that reduced temperature has protective influence
  - Kokate (1995)
  - Patel (1999)

- Kokate: “At a given pressure, … lower temperatures exert a significant protective influence with respect to the development of pressure ulcers”
Temperature and pressure

- Lachenbruch (2005)
  - 2nd analysis of published data
  - 8°C decrease in skin temperature is equivalent to a 29% reduction in interface pressure
  - Rightly advocates attention to skin temperature
Heat: Insulators & Conductors

- Foam is an insulator
- Water is a good heat conductor
Low Thermal Mass

High Thermal Mass
Temperature & Humidity changes over 1 hour

Temperature changes @ 1 hour
-5
-4
-3
-2
-1
0
1
2
3
4
5
foam
(n=12)
visco foam
(n=2)
gel
(n=6)
water
(n=3)
Roho
(n=1)

Relative Humidity Change @ 1 hr
0
5
10
15
20
25
30
foam
(n=12)
visco foam
(n=2)
gel (n=6)
water
(n=3)
Roho
(n=1)

Foam & visco foam: warmer & drier
Gel & water: cooler & moister

(Stewart, 1980)
Heating up and cooling down

- Sequence of images taken
  - Before sitting (T0)
  - After 15 of sitting (T15)
  - 5 & 15 minutes after transfer (T20 & T35)

Cushions that take a longer time to warm up, take a long time to cool down

Ferrarin & Ludwig, 2000
Logging Temp over 24 Hrs

Male #1 Summer Cushion Temperature 07/27/02

0
5
10
15
20
25
30
35
40

7/28/06 0:00
7/28/06 2:24
7/28/06 4:48
7/28/06 7:12
7/28/06 9:36
7/28/06 12:00
7/28/06 14:24
7/28/06 16:48
7/28/06 19:12
7/28/06 21:36
7/29/06 0:00

Time

Prep for Work
Work
Evening at Home
Retire
In bed
Afternoon out of Chair
Evening at Home
Retire

Male #1 Summer Cushion Temperature 07/27/02

Ambient
Buttock Interface
Heat and Water Vapor Test
Heat & Moisture Vapor Test
The effect of contouring

Effect of Contouring

No difference in temperature

Contoured cushion offers lower humidity
What does all this mean to you?

- Put patients/clients into postures in which they can do stuff
  - Movement unweights tissue so dissipates heat & alters normal and shear loading
    - Body handles dynamic loading better than static

- Support surfaces that cause sweating need to be re-evaluated
  - Shear, friction and temperature implications

- Pressure reliefs have at least 2 purposes:
  - Alleviate pressure and dissipate heat
Heat and Water Thoughts..

- Is the cushion material an insulator or conductor of heat?
- What are the variables? – clothing – climate etc
- Is the cushion moisture resistant with and without the cover?
- Is there moisture trapped around the skin surface?
- Incontinent covers – pads – diapers?
Heat...

- The slide tracking a 24 hour period reflects a key relationship between weight shifting and heat build up/dissipation.
- The more weight shifting that a person does, the greater the heat dissipation.
- So, when a client is experiencing and reporting a lot of sweating discomfort, the clinical responsibility is to educate and be aware of the impact of the selected materials.
Heat...

- The better the cushion is for envelopment, Immersion and magnitude, the bigger the challenge it can be for heat and moisture issues.

- Add incontinence to this
  - There is a greater need for increased frequency of weight shifting
Clinical Summary…

Immediately applicable take home messages
Load deflection
  • Stiffness

Heat & Water Vapor Dissipation

Load redistribution
  • Envelopment
  • Immersion
  • Magnitude
Which Cushion to Choose?

- Think about level of stability needed
  - What happens when I move?
- Level of risk for skin issues
- Depth of immersion capabilities
  - Contact area provided?
- Envelopment
  - Even pretty colors….
- Magnitude
  - No red - ?? – remember – color means nothing
- How easy it is to customize?
Which one to choose?

- Can the client carry out all functional activities on the selected product

- IS IT COMFORTABLE? …For the client!!
Questions..
Thank You for Your Attention