Changes in Wheelchair Cushions Over Time

Stephen Sprigle, PhD PT
Wheelchair seat cushion degradation study

Study Principals (alphabetically)

- Laura Cohen PhD, PT
- Kim Davis, PT
- Cami Godsey
- Michelle Nemeth, PT
- David Rivard
Wheelchair seat cushion degradation study

• To document the state of wheelchair cushions after everyday use
• To determine changes in state and performance over time
Data sources

- Interview
- Physical Examination
- Dimensioning
- Visual Inspection
Data Sources

- Human pressure mapping
- Rigid model pressure mapping
202 Subjects

- 65:35 Male: female
- Age
  - 46 (20-78)
- Weight
  - 173 (82-334)
- 44% paraplegia
- 35% tetraplegia
- 7% Multiple sclerosis
- 6% Spina Bifida
- 7% Other
Cushion Descriptions

• Avg Age: 32 months
  – ‘New’ → 196 months (16 yrs)
• Hours sat upon per day
  – Mean = 12
  – 1 → 22 hrs
Cushion Descriptions
Repeat visits

- 10 cushions were measured 4 times
- 30 cushions were measured 3 times
- 51 cushions were measured twice

345 visits in total
Tons of variables collected
Self report and Inspection variables

• **User information**
  - Height, weight, age, gender
  - Diagnosis
  - Skin hx
  - Pelvis asymmetry
  - Wheelchair type

• **Equipment usage**
  - Transfer technique and frequency
  - Environmental exposure
  - Stressful activities

• **Cushion information**
  - Model and manufacturer
  - Material construction
  - Age and daily use
  - Condition of cover
  - Condition of cushion components
Stressors and Exposures

- age of cushion
- hours sitting on cushion
- # transfers/day
- exposure to hot/cold temperatures
- exposure to rain/sun weather
- exposure to moisture; shower
- is exposed to sparks from matches, ashes, smoking, machinery, grinding, or welding
- incontinence/week

- High impact activities such as rough transfers
- Full body dropping onto cushion verses sliding smoothly onto the seat
- Transfers from different heights
- Curb jumping
- Vibration from rolling over rough
- Sports
- Cushion is used as a seat in a car, plane, restaurant, movie theater, etc
- Cushion exposed to pets sitting upon and being clawed. Do they shed their fur or have they relieved themselves on the cushion?
Model and Human IPM

- Total Pressure
- Mean Pressure
- Contact Area
- Peak Pressure Index (PPI)
- Total Pressure_IT region
- Dispersion Index (DI)
- Seat Pressure Index
- Asymmetry-Total Pressure
- Asymmetry- PPI
Cushion Inspection

**Cover**
- condition of seams
- condition of fabric
- condition of zipper
- condition of pocket
- condition of attachment

**Cushion**
- condition bladder
- condition valve
- condition of internal seams, sewn or welded structure
- visible tears, breaks, or fractures of any component
- amount of interior component discoloration
cushion's cleanliness

Clean

- 0 = Like New
- 1 = Very Clean
- 2 = Clean

Not clean

- 3 = Moderately Unclean
- 4 = Very Unclean

<table>
<thead>
<tr>
<th></th>
<th>&lt;12 months</th>
<th>12 to 36 months</th>
<th>&gt;36 months</th>
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<tr>
<td>clean</td>
<td>81%</td>
<td>73%</td>
<td>72%</td>
<td>75%</td>
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<td>19%</td>
<td>27%</td>
<td>28%</td>
<td>25%</td>
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</table>

Each category, n>80
Cover inspections

- 247 inspections were done on cushions with a cover,
- 168 of those inspections were on covers with zippers.
- The probability of damage to certain components is shown below

<table>
<thead>
<tr>
<th>Damage Type</th>
<th>Probability</th>
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<tbody>
<tr>
<td>damage to the seams</td>
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<td>damage to fabric</td>
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<td>damage to the pocket</td>
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<td>damage to the attachment</td>
<td>0.032</td>
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<td>damage to the zipper</td>
<td>0.077</td>
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Data allows calculation of the prevalence of different signs of wear

Gives insight into what wears out and how often
153 foam cushion inspections

- 21% foam cushions with visible damage
- 56% foam cushions showing discoloration
- 21% foam showing granulation
- 36% foam showing brittleness
87 inspections of cushions using viscous fluid

- 9% damage to seams or welded components
- 20% showing visible tears or breaks
114 inspections of cushions with air bladders

- 16% air cushions with damage to bladder
- 6% air cushions with damage to valve
- 4% air cushions showing damage to seams or welded components
### Material Comparison

<table>
<thead>
<tr>
<th>Description</th>
<th>% Showing Damage</th>
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<tr>
<td><strong>155 inspections of foam components</strong></td>
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<tr>
<td>Visible Tears, Breaks, or Fractures of any Component</td>
<td>0.21</td>
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<tr>
<td>Interior Component Discoloration</td>
<td>0.56</td>
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<tr>
<td>Foam granulation</td>
<td>0.21</td>
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<td>Foam brittleness</td>
<td>0.36</td>
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<td><strong>87 inspections of cushions using viscous fluid</strong></td>
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<td>damage to seams or welded components</td>
<td>0.09</td>
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<td>showing visible tears or breaks</td>
<td>0.20</td>
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<tr>
<td><strong>114 inspections of air</strong></td>
<td></td>
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<tr>
<td>air cushions with damage to bladder</td>
<td>0.16</td>
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<td>air cushions with damage to valve</td>
<td>0.06</td>
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<tr>
<td>air cushions showing damage to seams or welded components</td>
<td>0.04</td>
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</table>
• Cushion age calculated in hours
  – Age (days) * Daily use (hrs)

Dichotomized 2 manners
• 12 months: defined as **4320 hrs of use**
  – 12 hrs/day for 12 months with 30 days/mo
• 36 months: defined as **12960 hrs of use**
  – 12 hrs/day for 36 months with 30 days/mo
Foam cushion damage

Compared to cushions ≤12 mo old, those in use >12 months were

• 7.2 times more likely to show Visible Tears, Breaks, or Fractures of any Component

Compared to cushions ≤ 36 mo old, those in use >36 months were

• 1.6 times more likely to show Visible Tears, Breaks, or Fractures of any Component

This means that significant degradation occurs between 1 and 3 years
That was inspection

Now, look at performance
Model and Human IPM

- Total Pressure
- Mean Pressure
- Contact Area
- Peak Pressure Index (PPI)
- Total Pressure_IT region
- Dispersion Index (DI)
- Seat Pressure Index
- Asymmetry-Total Pressure
- Asymmetry- PPI
IPM and Age: 
the relationship is not simple

Usehrs = age(days) \times \text{daily use (hrs/day)}
Examples illustrate complexity
60 months old
54 months old
12 months old
48 months old
60 months old

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Sometimes, inspection reflects performance
Sometimes, it doesn’t
Model IPM data designed to provide consistency
<table>
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<th></th>
<th>MeanPress</th>
<th>ContactArea</th>
<th>PPI</th>
<th>PPlasymm</th>
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<td>27 months</td>
<td>76.4</td>
<td>0.049</td>
<td>166</td>
<td>0.70</td>
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<td>43 months</td>
<td>73.1</td>
<td>0.052</td>
<td>160</td>
<td>14.1</td>
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Model IPM
A lot of variables, a lot of variance

• In principal components analysis (PCA), one wishes to extract from a set of $p$ variables a reduced set of $m$ components that accounts for most of the variance in the $p$ variables.

• Goal: to reduce a set of $p$ variables to $m$ components prior to further analyses
Principal Component Analysis

Data subset of Repeat Visits only
(232 assessments)

• Model IPM data
• Information about user
• Information about cushion use
Comp_i = \sum_{i=1}^{p} W_i X_i

Where:

- \text{TotPressure, MeanPress, ContactArea, PPI, TotPres_IT, DI, SPI, TotPress-asymm, PPI-asymm}
- 2 “Stressor” components
- 3 “Performance” components
- 3 “Demo” components
- Daily cushion use (hr)
- WC type
- Daily xfers
- SUMFactors
- SUMExposures
- gender
- age
- Weight
- Height
- Asymmetry
- Para
- Tetra
- other
Regression: use to identify predictors of performance

\[ Y = mx + b \]

\[
\text{Cush\_Perf} = \beta_0 + \beta_1(\text{Stress1}) + \beta_2(\text{Stress 2}) + \beta_3(\text{Demo1}) + \beta_4(\text{Demo2}) + \beta_5(\text{Demo3}) + \beta_6(\text{AgeHrs})
\]
Regression model: can the Components predict Performance?

Perf _Component = f (Stressor1, Stressor2, Demo1, Demo2, Demo3, AgeHrs)

<table>
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<tr>
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<th>Sig.</th>
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<tr>
<td>(Constant)</td>
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<tr>
<td>AgeHrs</td>
<td>.108</td>
<td>.048</td>
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R       | R Square
---     | -------
.611    | .373
Users who impart stress on the cushion resulted in cushions with greater IPM component.

Stressful factors included the number of daily transfers, factors resulting from user activities such as curb jumps, sports, high vibration activities, etc., and environmental exposures such as moisture, and high or low temperatures.

Manual wheelchair users appear to induce these stressors more than power wheelchair users.

The overall amount of cushion use was also predictive of higher IPM Performance Measurements.
Summary

• *Take the cover off and look at the cushion*
• Foam components show damage relatively early and often
  – High odds of damage occurring between YR1 and 3
• Overall, the results indicate that *the manner in which the cushion is used* has a greater influence in the IPM Performance Component than the age of the cushion or the individual’s demographic variables.
• In addition, stressful activities and exposures are more associated with users of manual wheelchairs compared to powered wheelchairs.
Acknowledgements

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State of the Science Conference: Wheeled Mobility in Everyday Life

In conjunction with RESNA, July 1-2, 2012

Please Visit:

www.catea.gatech.edu/SOSC.php

For More Information
• cushion shape
  – 0=original shape  1=slight deformation  2=permanent deformation
• cushion's cleanliness
• 0 = Like New  1 = Very Clean  2 = Clean  3 = Moderately Unclean  4 = Very unclean