Whole Body Vibration Measurement System for Power Wheelchairs
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Introduction
- More than 3.26 million Americans have a disability that requires wheeled mobility equipment
- Vibration, shock (single event and repeated), and motion have a significant effect on the health and quality of life for individuals who utilize a wheelchair
- Consumer and clinician focus groups
  - Design and manufacture power wheelchairs that minimize vibration, shock and motion
  - Maximize function and minimize the likelihood of pain and injury

Purpose
- Design and implement a methodology for characterizing whole-body vibration when an individual uses a PWC

Methods
- Instrumented a power wheelchair with accelerometers
  - ISO-2631-1
  - Human Response to Vibration
- Accelerometer locations
  - Chassis
  - Seat Pan
  - Back Pan
- Wheelchair Skills Test
  - 0.88 m/s (2.0 mph)
  - 50th Percentile male Hybrid III ATD

Wheelchair Skills Test and ATD

System Design
- Arduino based data collection system.
- ± 3 g triaxial accelerometers
- Data collected & stored on SD cards
- Data analysis performed in Matlab
Mounting Locations and Hardware
- Chassis – Transit Bracket
- Under Seatpan
- Back Support
- Data Logger and Accelerometer

Coordinate System
- \( x \) – anterior-posterior
- \( y \) – medial-lateral
- \( z \) – superior-inferior

Data analysis: Vibration measures
- Acceleration – root mean square
  \[ a_{\text{rms}} = \sqrt{\frac{1}{T} \int_0^T a_w^2(t) \, dt} \]
- Vibrational Dose Value
  \[ VDV = \sqrt{\int_0^T a_w^2(t) \, dt} \quad VDV_{\text{rms}} = \sqrt{V DV_{x}^2 + V DV_{y}^2 + V DV_{z}^2} \]
- SEAT % (Seat effective amplitude transmissibility)
  \[ \text{SEAT} \% = 100 \times \frac{VDV_{\text{rms}}}{VDV_{\text{seat}}} \]

RMS vs VDV (x-direction)
- \( a_{\text{rms}} = 1.2 \)
- \( VDV = 20 \)

VDV – x-direction (fore-aft)
- Back – 20.3
- Chassis – 3.3
- Seat – 3.7

VDV – y-direction (medial-lateral)
- Back – 4.4
- Chassis – 2.1
- Seat – 1.6
Results

<table>
<thead>
<tr>
<th>Back</th>
<th>3.8</th>
</tr>
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<tbody>
<tr>
<td>Chassis</td>
<td>7.3</td>
</tr>
<tr>
<td>Seat</td>
<td>5.4</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>VDV Resultant (m/s^2)</th>
<th>Chassis</th>
<th>Seat</th>
<th>Back</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.36</td>
<td>5.67</td>
<td>16.28</td>
<td></td>
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</tbody>
</table>

| Combined SEAT% | 77 | 277 |

Discussion

- The VDV is largest in the z-direction (vertical) for the chassis and seat pan, while largest in x-direction (forward-reverse) for the back pan.
- Chassis-seat transmissibility – SEAT = 77%
- Chassis-back transmissibility – SEAT = 277%

Conclusions

- VDV and SEAT are appropriate methods for analyzing WBV in power mobility.
- Consistent with consumer reports:
  - They feel like they are often thrown forward when traversing obstacles in real-world environments.

Limitations

- Testing performed with ATD’s which are stiffer than humans => damping related to human body may be different (likely higher).
- Testing performed on wheelchair skills test, not real life exposures.
- Currently no available acceleration data on what users experience on a daily basis.
- Experimental analysis

Future Research and Clinical Implications

- Development of a wireless system.
- Research to develop database of what wheelchair users are exposed to on a typical day/week/month.
- Development of analytical models to better understand and be able to predict vibration behaviors.
Thank you.

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