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

LaPlante and Kaye (2010)
Paschold and Mayton (2011)
Griffin (1990)
Mansfield (2004)
DiGiovine et al. (2015)

Purpose

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

Methods

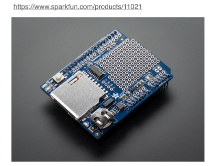
- Instrumented a power wheelchair with accelerometers
  - ISO-2631-1
  - Human Response to Vibration
- Accelerometer locations
  - Chassis
  - Seat Pan
  - Back Pan
- Wheelchair Skills Test
  - 0.88 m/s (2.0 mph)
  - 50th Percentile male Hybrid III ATD

Wheelchair Skills Test and ATD

System Design

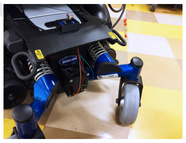
- Arduino based data collection system.
- ± 3 g triaxial accelerometers
- Data collected & stored on SD cards
- Data analysis performed in Matlab

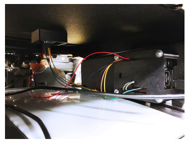
https://www.sparkfun.com/products/11021

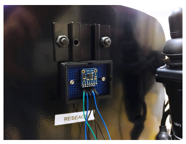


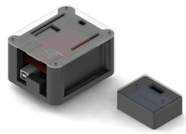
http://www.adafruit.com/product/1141

Mounting Locations and Hardware


Chassis – Transit Bracket

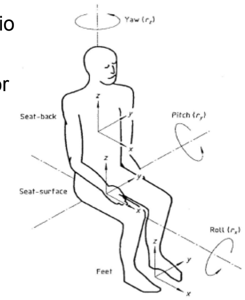

Under Seatpan


Back Support


Data Logger and Accelerometer

Coordinate System

- x – anterior-posterio
- y – medial-lateral
- z – superior-inferior



Data analysis: Vibration measures

- Acceleration – root mean square

$$a_{w\_rms} = \sqrt{\frac{1}{T}\int_0^T a_w^2(t)\,dt}$$

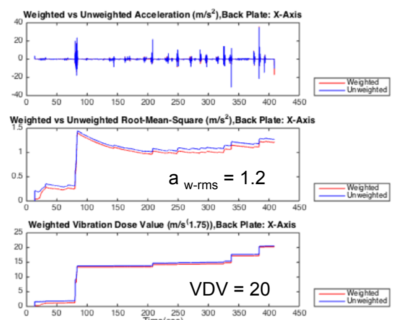
- Vibrational Dose Value

$$VDV = \sqrt[4]{\int_0^T a_w^4(t)\,dt} \qquad VDV_{XYZ} = \sqrt[4]{k_x^4 VDV_x^4 + k_y^4 VDV_y^4 + k_z^4 VDV_z^4}$$

- SEAT % (Seat effective amplitude transmissibility)

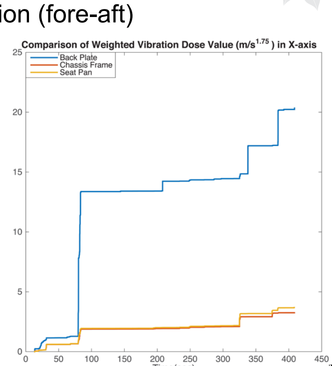
$$SEAT\% = 100 * \frac{VDV_{output}}{VDV_{input}}$$

RMS vs VDV (x-direction)



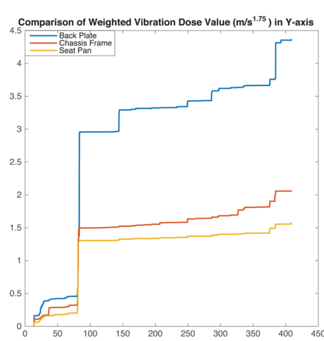
VDV – x-direction (fore-aft)

Back – 20.3
Chassis – 3.3
Seat – 3.7



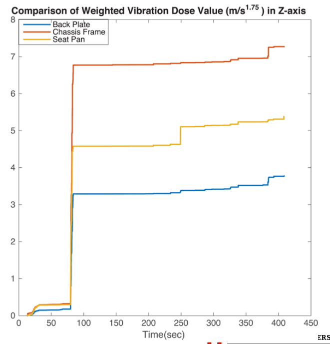
VDV – y-direction (medial-lateral)

Back – 4.4
Chassis – 2.1
Seat – 1.6



VDV – z-direction (superior-inferior)

Back – 3.8
Chassis – 7.3
Seat – 5.4



Results

	Chassis	Seat	Back
VDV resultant (m/s$^{1.75}$)	7.36	5.67	16.28
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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