Georgia Tech College of Architecture

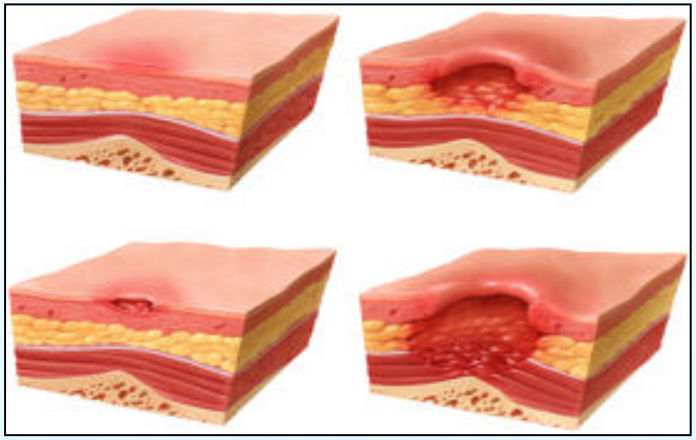
catea Center for Assistive Technology and Environmental Access

DYNAMIC RESPONSE OF WHEELCHAIR CUSHIONS

Rehabilitation Engineering Research Center
on Wheeled Mobility
Georgia Institute of Technology

Bummo Chung

Motivation



http://www.acpinternist.org/archives/2007/07/special.htm

http://www.erc.montana.edu/biofilmbook/MODULE_07/Mod07_S02_Blue.htm

- Pressure Ulcers (decubitis ulcers or bed sores)
  - Caused by pressure on skin, soft tissue, muscle, and bone that exceeds capillary-filling pressure for an extended period of time
- Individuals who are
  - Unable to sense the pressure
  - Unable to change their body position to relieve the pressure
- Annual treatment cost
  - 5 to 8.5 billion dollars in U.S.

Objectives

- Wheelchair seating (ISO 16840-2)
  Part 2: Determination of physical and mechanical characteristics of devices intended to manage tissue integrity – Seat cushions
  - **Impact Damping Test (IDT)**
    - Ability to reduce impact loading on tissues
    - Help maintain postural stability

- No body of work that investigates the impact damping characteristics of wheelchair cushions using the ISO IDT

- **OBJECTIVEs**
  - Perform ISO IDTs
    - Impact damping characteristics of three different types of cushions
  - Identify critical issues of the ISO IDTs

Instruments

- **Tested Wheelchair cushions**
  A. 3” elastic foam (EF)
    - Reference foam
  B. 3” viscoelastic foam (VEF)
  C. 3” laminar cushion (LC)
    - viscous fluid bladder on top of an elastic foam

- **Preconditioning**
  - Cushions were kept in the test environments more than 12 hours
    - Temperature
      - 24.1 °C
    - Relative humidity
      - 50 %
  - Preload 830N were
    - Loaded for 3 minutes and unloaded for 2 minutes
    - Re-loaded for 3 minutes and unloaded for 5 minutes

A

B

C

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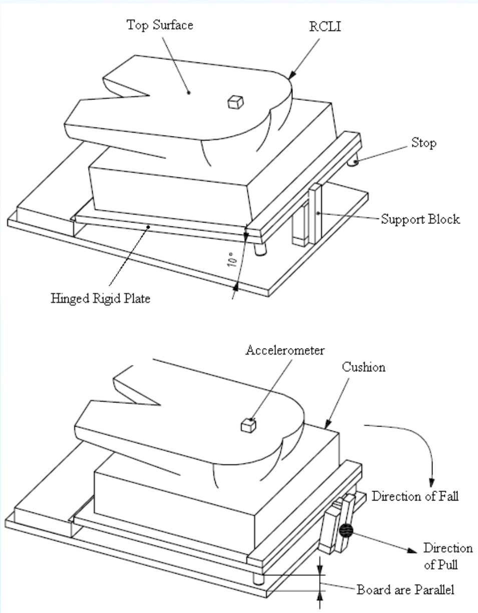
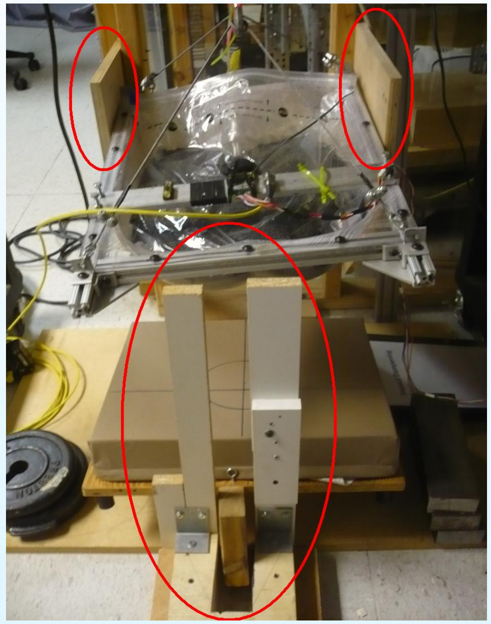
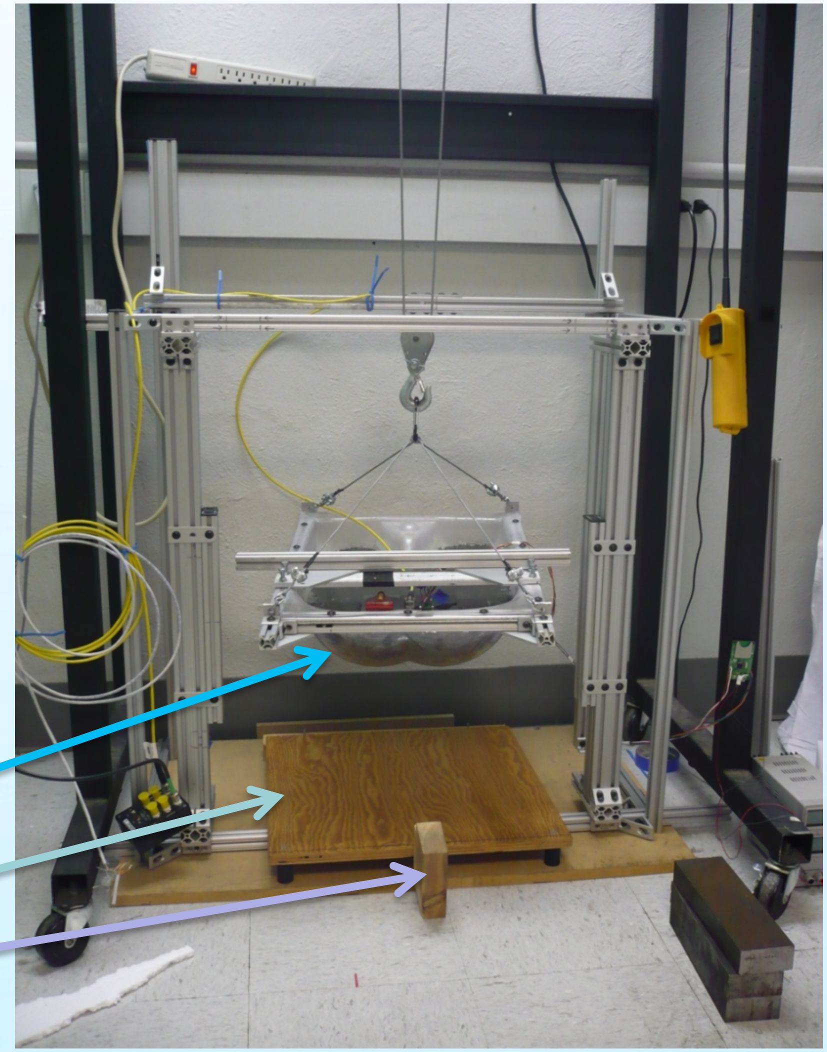
Instruments



• Schematic diagram of the test rig



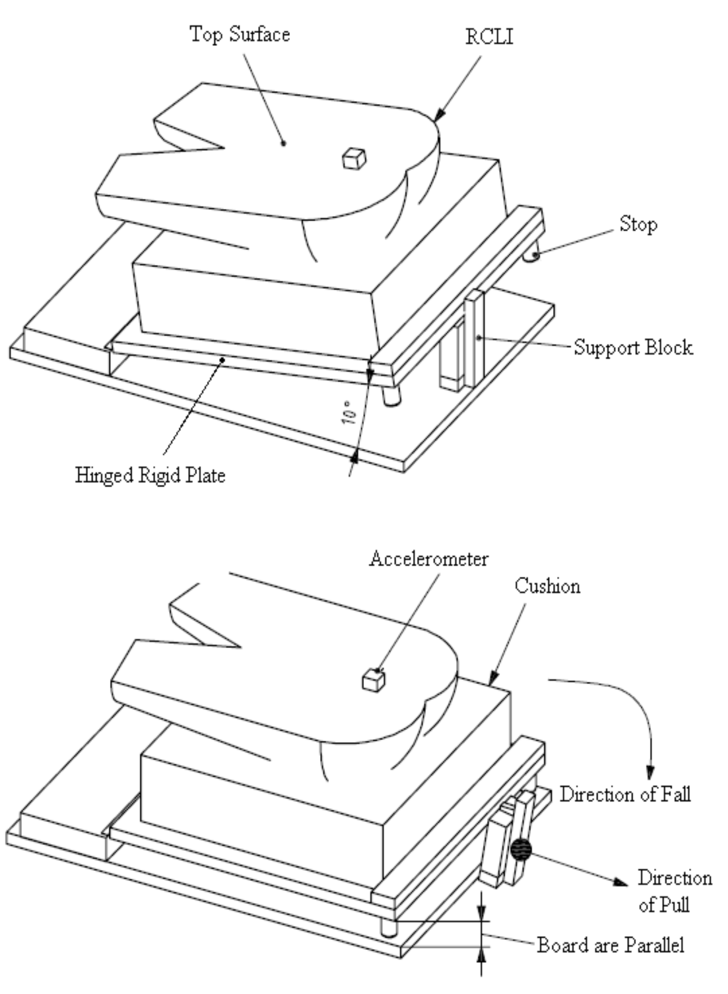
•Impact Damping Test Setup



Updated Impact Damping Test Setup

- **Components**
  - Rigid Cushion Loading Indenter (RCLI)
  - Hinged Rigid Plate
  - Support Block
  - Stops (older IDT setup)

Experimental Protocols



- **Impact Damping Test**
  1. Set hinged rigid plate at a 10° angle by placing the support block
  2. Place the cushion
  3. Place the RCLI (500 N)
     - Its ischial tuberosities were positioned at the location approximately 140 mm forward from the rear edge of the cushion
  4. Release of the support block
  5. Repeat steps 1 through 4 three times for each cushion

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Data Analysis

- ## Matlab script 1

ISO metrics

- Mean number of rebounds greater than 10% of the peak impact acceleration
- Mean of the peak rebound acceleration, a_a
- Mean of the second highest rebound acceleration, a_2
- Mean of ratio of a_2 to a_a

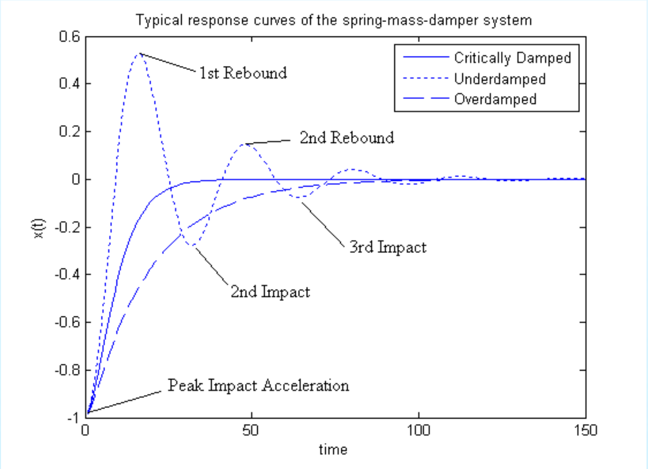
Suggested metrics

- Initial impact
- 2^{nd} impact
- 3^{rd} impact
- Impact ratio of 3^{rd} to 2nd

- ## Matlab script 2
  - Curve fit analysis
    - Filtered data is fit to the solution of an underdamped case of a simple harmonic oscillation using a least sqaure curve fit.

$$x(t) = x(0) \cdot e^{-\xi \cdot \omega_n \cdot t} \left(\frac{\xi}{\sqrt{1-\xi^2}} \sin\left(\omega_n \sqrt{1-\xi^2} \cdot t\right) + \cos\left(\omega_n \sqrt{1-\xi^2} \cdot t\right) \right)$$

where ζ is a damping ratio, ω_n is a natural frequency, and x(0) is a peak impact acceleration



Typical response of the simple damped harmonic solution

Results

Results of the ISO IDT (n=19, 2 tester over 2 days)

	# Reb	1st Reb (m/s^2)	2nd Reb (m/s^2)	Reb Ratio
EF	1.00 ± 0.00	4.88 ± 0.29	1.41 ± 0.49	0.29 ± 0.10
VEF	1.16 ± 0.37	13.82 ± 2.92	3.19 ± 0.50	0.25 ± 0.13
LC	2.00 ± 0.33	7.30 ± 0.59	3.49 ± 0.44	0.48 ± 0.06

- EF and VEF dampen impacts quicker than LC
  -> **superior ability to help maintain postural stability**

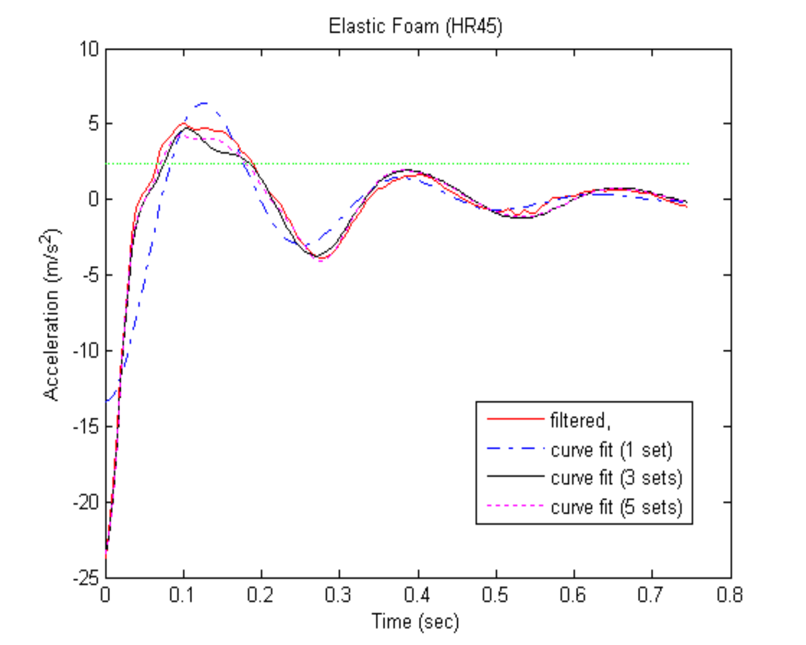
- EF has the smallest mean number of rebounds greater than 10% of the peak impact acceleration
  -> **superior ability to reduce impact loading**

Impact side results of the ISO IDT (n=19, 2 tester over 2 days)

	Initial Impact (m/s^2)	2nd Imp (m/s^2)	3rd Imp (m/s^2)	Imp Ratio
EF	-24.03 ± 0.90	-3.53 ± 0.48	-0.92 ± 0.46	0.26 ± 0.13
VEF	-37.96 ± 2.00	-7.69 ± 1.32	-1.16 ± 0.28	0.15 ± 0.04
LC	-25.11 ± 2.94	-5.77 ± 0.71	-2.10 ± 0.42	0.37 ± 0.07

- EF and LC has the lower initial impact compared to VEF
  -> **superior ability to reduce the impact load**

- VEF has the lowest impact ratio of 3rd to 2nd
  -> **superior ability to help maintain postural stability**



Result of the frequency analysis

- Curve fit analysis results show that when three or more sets of frequency, amplitude, and damping ratio were used in a fit, the data and curve fit matched well.

- This shows that the oscillation resulted from the IDT is ***not a simple damped harmonic oscillation***

Discussions

- **3 Critical Issues**
  1. Impact magnitude in the analysis
     - Impact loading on tissues is a stated purpose
  2. Impact instead of rebound accelerations
     - Nonlinear responses
       - Material
       - Contact area
  3. Oscillation from impact is not a simple second order damped harmonic
     - Three to five natural frequencies are embedded in the damped harmonic oscillation
       - Simple ratios of accelerations do not represent the damping properties of cushions

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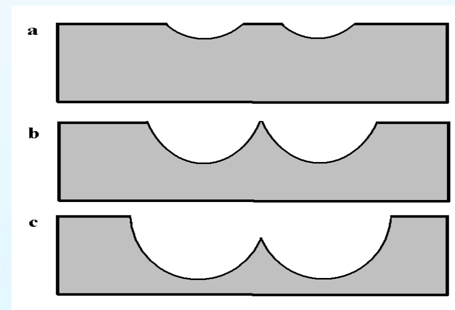
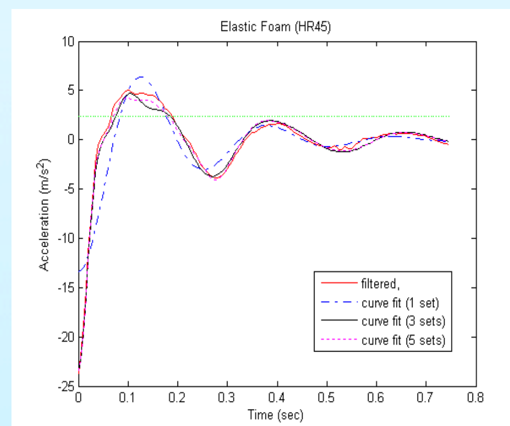
Initial Impact Results



Expected contact area during the rebound; a) at the rebound, b) a midpoint between the rebound and the impact, c) at the impact



Typical response of the ISO IDT results

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Conclusions

- **The ISO IDTs of three cushions were performed**
  - 3” elastic foam and 3” viscoelastic foam
    - *superior ability to help maintain postural stability*
  - 3” elastic foam
    - *best ability to reduce the impact loading*
- **The current study suggests that the ISO IDT should incorporate**
  1. ***Initial impact*** value in the analysis
  2. Use the ***impact side information*** instead of the rebound side information
     - 3” elastic foam and 3” laminar cushion
       - *Superior ability to reduce the impact load*
     - 3” viscoelastic foam
       - *Superior ability to help maintain postural stability*
  3. Employ ***more complex nonlinear analysis*** to better characterize the damping properties of wheelchair cushions

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Questions

Thank you…