Spine Biomechanics and Patient Handling Risk

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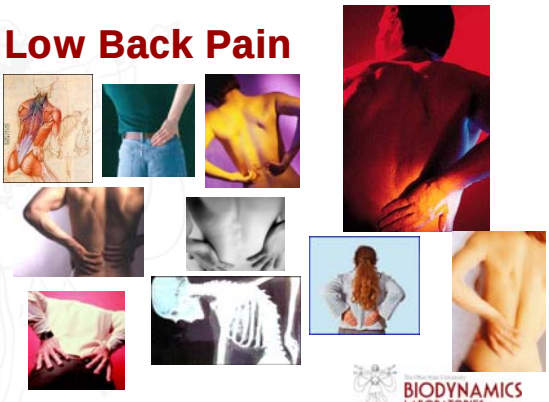
Low Back Pain



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Risk and Patient Handling

- Nursing personnel - top ten occupations for work-related ***musculoskeletal disorders***, with incidence rates of 8.8 per 100 in hospital settings and 13.5 per 100 in nursing home settings (BLS, 2002) but probably under-reported (HHS, 1999).
- Prevalence of ***back injury*** (compiled from over 80 studies) worldwide (Hignett, 1996)
  - point prevalence of approximately 17%
  - an annual prevalence of 40-50%

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Low Back Surgery

- "No operation in any field of surgery leaves in its wake more human wreckage than surgery on the lumbar discs" (DePalma and Rothman,1970)
- Surgical success rates for discectomy = 42.6% (vs. 32.4% non-operative) (Weinstein et. al. 2006)
- Value of ***prevention***

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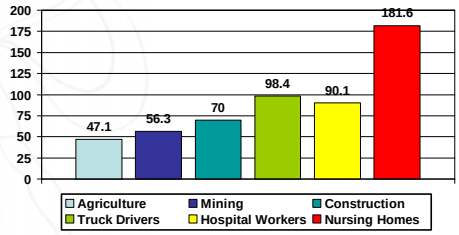
The Most Dangerous Jobs in America

Lost work time to back injuries per 10,000 FTEs



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Source: Bureau of Labor Statistics, *Lost Work Time Back Injuries per 10,000 FTEs*. 2000.

Patient Handling and *Low Back Pain* Risk (Nursing)

- 52 % of nurses complain of LBP (Nelson, 2003)
- 12% of nurses leave the field because of LBP (Stubbs et. al., 1986)
- 20% transfer to a different unit because of LBP (Owen, 1989)
- 38% have LBP severe enough to have lost time (Owen, 2000)
- 38% new LBP cases per year (Yip, 2004)

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Risk of Patient Handling

- Has been a steady decline in rates of most occupational injuries starting in 1992. But work-related MSDs disorders in nursing continue to rise (Fragala & Bailey, 2003).
- The cumulative weight lifted by a nurse in one typical 8-hour shift is equivalent to 1.8 tons (Tuohy-Main, 1997).

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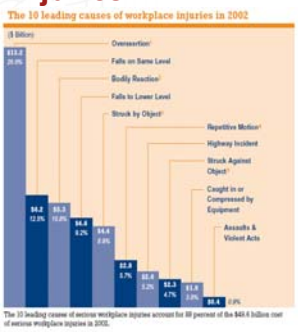
Leading Causes of Workplace Injuries



Liberty Mutual Workplace Safety Index, 2004

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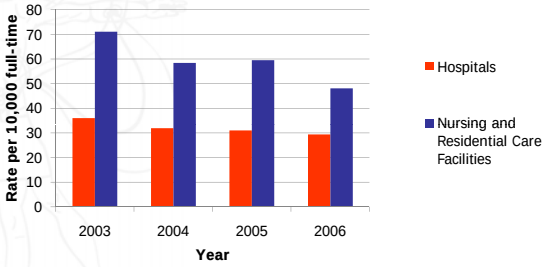
Overexertion During Lifting (BLS, 2007)



- The cumulative weight lifted by a nurse in one typical 8-hour shift is equivalent to 1.8 tons (Tuohy-Main, 1997).

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What do We Know About Low Back Pain Causality?

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Intervertebral Disc

- The primary source of low back pain is suspected to be the disc (Nachemson, 1976; Videman and Battie, 1996; An, 2004)
- Noxious stimulation of the disc produces symptoms of low back pain
- Annular tears and reduced disc height are associated with low back pain (Videman et. al., 2003)
- Mechanical load can be the stimulus for pain (Marras, 2000)

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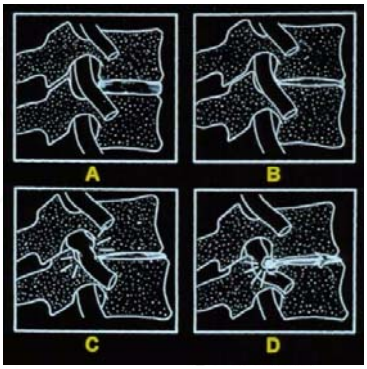
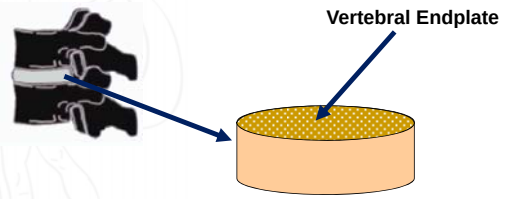
Disc Degeneration

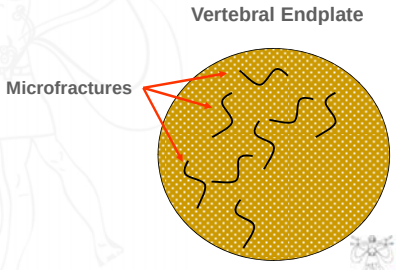


How Cumulative Trauma Develops in the Spine

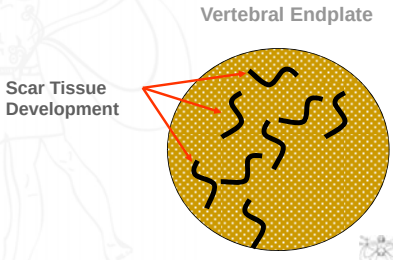


Disc Nutrition Pathways

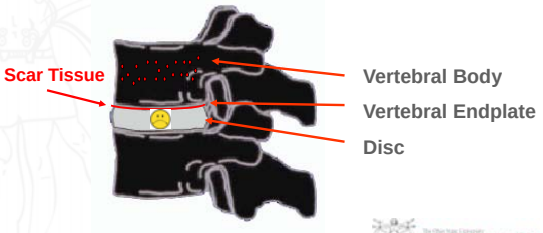
How Cumulative Trauma Develops in the Spine



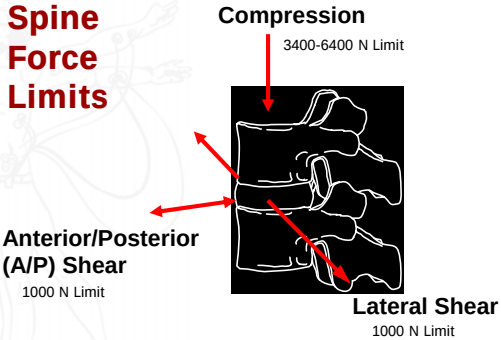
How Cumulative Trauma Develops in the Spine



Disc Degeneration and Cumulative Trauma



Spine Force Limits



Our Early Patient Lifting Studies

ERGONOMICS, 1999, VOL. 42, NO. 7, 904–926

A comprehensive analysis of low-back disorder risk and spinal loading during the transferring and repositioning of patients using different techniques

W. S. MARRAS*, K. G. DAVIS, B. C. KIRKING and P. K. BERTSCHE

Biodynamics Laboratory, The Ohio State University, 1971 Neil Avenue, 210 Baker Systems, Columbus OH 43210, USA

Keywords: Patient handling; Spinal loads; Biomechanics; LBD.

Although patient handlers suffer from low-back injuries at an alarming rate worldwide, there has been limited research quantifying the risk for the specific tasks performed by the patient handlers. The current study used both a comprehensive evaluation system (low-back disorder risk model) and theoretical model (biomechanical spinal loading model) to evaluate risk of LBD of 17 participants (12 experienced and five inexperienced) performing several patient handling tasks. Eight of the participants were female and nine were male. Several patient transfers were evaluated as well as repositioning of the patient in bed;

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Patient Lifting Origins / Destinations

- Bed to/from wheelchair with arms
- Bed to/from wheelchair with one arm removed
- Portable commode chair to/from hospital chair

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Transfer Techniques

- 1 person hug
- 2 person hook and toss
- 2 person gait belt

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Repositioning Techniques

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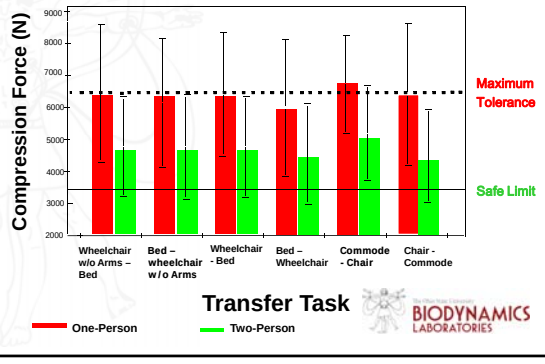
Spine Compression as a Function of *Transfer* Task



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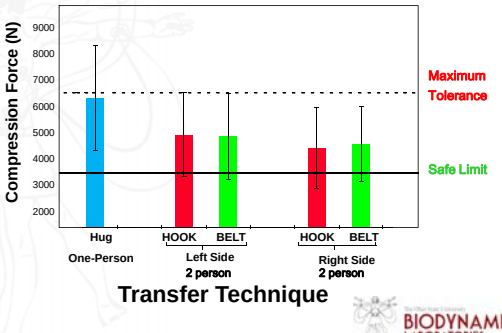
Spine Compression as a Function of *Transfer* Technique



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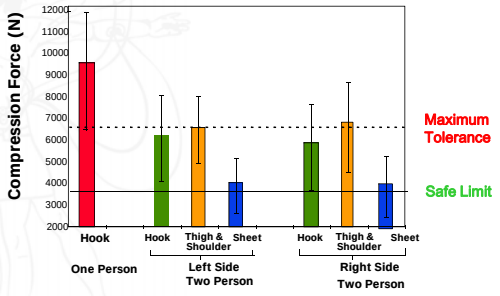
Spine Compression as a Function of *Repositioning* Technique



Biodynamics Laboratory Previous Studies

- Risk associated with one- or two- caregiver patient lifting
  - Conclusion - There is no safe way to lift patient manually!
  - Suggestion - Employ Patient Lifting assistance device
- **Intervention Effectiveness (prospective observation of 100 units)**

Patient Handling Interventions

AMERICAN JOURNAL OF INDUSTRIAL MEDICINE 48:338–347 (2005)

The Effect of Ergonomic Interventions in Healthcare Facilities on Musculoskeletal Disorders

Kaori Fujishiro, PhD,[1] Jean L. Weaver, PT,[2] Catherine A. Heaney, PhD,[3] Christopher A. Hamrick, CPE,[4] and William S. Marras, PhD[5]

Background *The high incidence of musculoskeletal disorders (MSDs) among healthcare workers suggests that the introduction of ergonomic interventions could be beneficial. While laboratory studies have clearly documented the efficacy of ergonomic devices, few studies have examined their effectiveness in the healthcare workplace.*
Methods *This study evaluated a statewide program that provided ergonomic consultation and financial support for purchasing ergonomic devices, which aid in patient handling and lifting. Changes in MSD rates between baseline (1 year pre-intervention) and post-intervention (up to 2 years) periods were examined in 100 work units in 86 healthcare*

Patient Handling Musculoskeletal Disorder Rate Changes (#MSDs/employee-hours worked)*200,000

Type of Intervention	n	Baseline median (Range)	Follow-up median (Range)	Rate Ratio (FU/BL MSD rate)
Reduce Bending	16	9.89 (0.0-42.65)	6.65 (0.0-59.51)	.66
Zero Lift	44	15.38 (0.0-87.59)	9.25 (0.0-28.27)	.54
Reduce Carrying	8	6.47 (0.0-15.80)	0.33 (0.0-6.70)	.15
Multiple Interventions	32	11.98 (0.0-60.34)	7.78 (0.0-25.94)	.56
All	100	12.32 (0.0-87.59)	6.64 (0.0-59.51)	.52

(Fujishiro, et al. 2005)

Patient Handling Change in MSD Rates per Intervention (baseline to follow-up)

Type of Intervention	# Units Decreased or no change	Number of Units Increased	P-value
Reduce Bending	12 (75%)	4 (25%)	0.056
Zero Lift	32 (72.7%)	12 (27.3%)	0.002
Reduce Carrying	7 (87.5%)	1 (12.5%)	0.031
Multiple Interventions	26 (81.3%)	6 (18.7%)	0.001
All	77 (77.0%)	23 (23.0%)	<0.001

(Fujishiro, et al. 2005)

Our Previous Studies

- Risk associated with one- or two- caregiver patient lifting
  - Conclusion - There is no safe way to lift patient manually!
  - Suggestion - Employ Patient Lifting assistance device
- **Intervention Effectiveness (prospective observation of 100 units)**
  - Conclusion – Often observe significant reduction in risk
  - Not all interventions created equally!
  - 27% of zero lift interventions had increased reporting

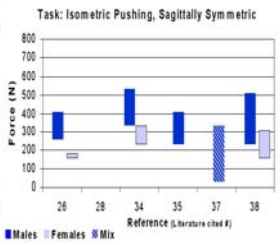
Lifting Transformed into Pushing and Pulling

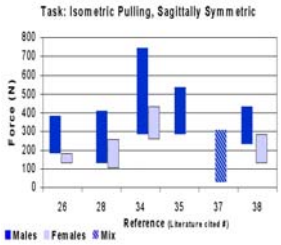
Research Question

- Does changing patient handling from a lifting activity to a pushing activity eliminate the risk to the caregiver?
- Is there a difference in pushing ceiling mounted vs. floor based patient lifting devices?

What do we Know about Low Back Pain Risk During Pushing and Pulling?

Strength Based Push-Pull Recommendations





References:
26. NRC-IOM, 2001
28. Snook, 1978
34. Hoozemans, 2001
35. Snook and Ciriello, 1991
37. Kumar et al., 1995
38. Kumar, 1995

Risk of Low Back Pain when Pushing and Pulling

Odds Ratios

- LBP – pushing/pulling OR = 2.6 (van der Beek, et al. (1993)
- Push/Pull & high intensity LBP OR = 2.15 (Hoozemans et al., 2002)
- Pulling & LBP OR =1.5 for objects over 56 lbs. (Harkness et al., 2003)

% of Claims

- As much as 20% of LBD injury claims associated with pushing and pulling (NIOSH, 1981)
- 27% of Ohio BWC LBP claims associated with pushing/pulling (Hamrick, 2005)

Spine Biomechanical Loading During Pushing and Pulling

- **<u>Pulling</u> L5/S1** compression = 2353N
  shear = 654 N (Gagnon, 1988)
- **<u>Pushing</u> 22 Kg load at different heights - L5/S1 compression (using 2 muscle model):**
  2993N @ 58 cm height
  1398N @ 99 cm
  921N @ 141 cm (Gagnon, 1992)
- **Refuse collection pushing and pulling (static model) L5/S1**
  <u>pushing</u> comp = 2000 N
  shear = 160 N (de Looze et. al., 1995)
  <u>pulling</u> comp = 2600 N
  shear = 300 N

Spine Biomechanical Loading (continued)

- **L4/L5 load using Watbak model:**
  pushing 65 Kg comp = 822 N
  shear = 202 N
  pulling 65 Kg comp = 1445 N
  shear = 95 N (Schibye, et. al., 2001)
- **L5/S1 comp =** 5000 N for pushing carts over 225 Kg (Resnick and Chaffin, 1995)
- **These spinal loads do NOT explain LBP risk observations**
- **What is mechanism of LBP?**

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OSU EMG – Assisted Biodynamic Model

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Spine Loading Model Development

- **Sagittal Plane**
  - Marras and Reilly, 1988; Reilly and Marras, 1989; Marras and Sommerich, 1991a; 1991b; Marras and Mirka, 1993; Granata and Marras, 1993, 1995; Davis et al., 1998; Marras et al., 1999, 2001; Marras and Granata, 1997
- **Asymmetric Lifting**
  - Marras et al., 1999, 2001
  - Fathallah et al., 1998;
  - Granata and Marras, 1993,
  - Marras and Sommerich, 1991,
- **Lateral Flexion**
  - Marras and Granata, 1997
- **Axial Twist**
  - Marras and Granata, 1995
- **Gender Adjustment**
  - Marras et al., 2001;
  - Jorgensen et al, 2001
- **Push – Pull Adjustments**
  - Theado et al., 2007 (flexion adjustments, standing anthro)
  - Knapik et al., 2007 (entire lumbar spine)

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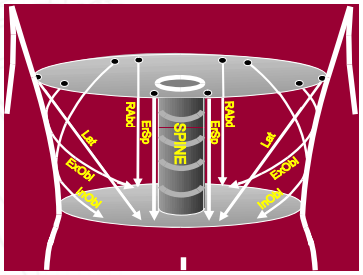
OSU Biodynamic Model

Model Structure



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EMG-Assisted Model Input

- Trunk motion - LMM goniometer
- Body motion – goniometers, position sensors
- Anthropometry based muscle vectors and segment proportions
- 10 muscles' EMG - surface electrodes
  - Right & left erector spinae
  - Right & left latissimus dorsi
  - Right & left external oblique
  - Right & left internal oblique
  - Right & left rectus abdominus
- Assess muscle gain via calibration on force plate

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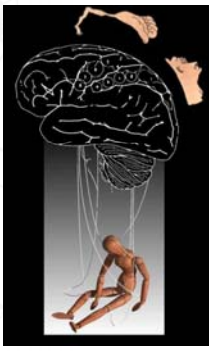
The Control System



Courtesy of
A. Schwartz, 2006

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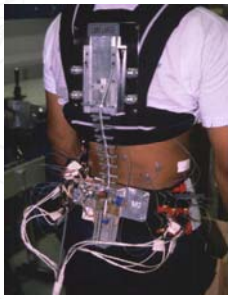
Instrumentation



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Whole Body Motion Tracking

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Laboratory Assessment of Push-Pull

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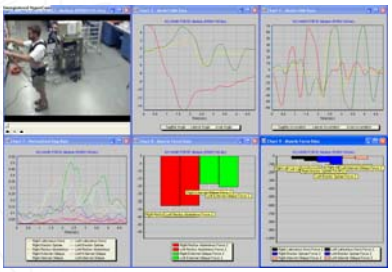
Laboratory Assessment of Push-Pull



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Whole Body Modeling

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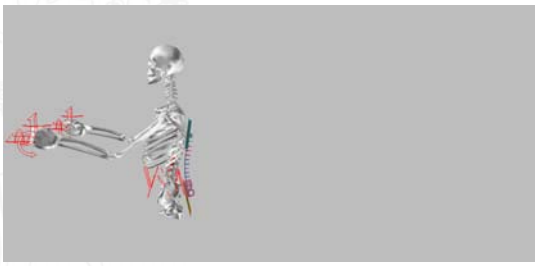
Assessment of Spine Forces Based Upon Task



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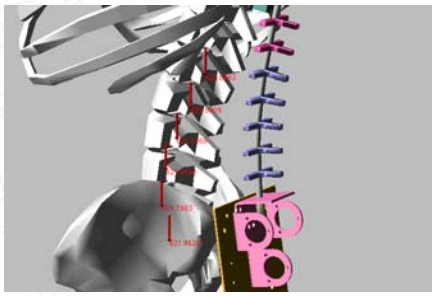
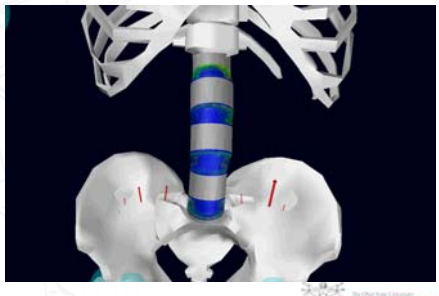
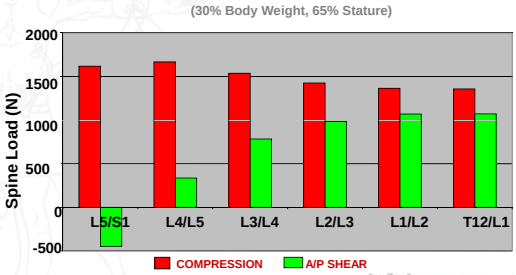
Spine Loads at Different Levels



Disc Wear at Different Levels (FEM Hybrid Model)



Loads at Different Lumbar Levels During Pushing



(Knapik & Marras, 2008)

Relevance to Patient Handling

- Are we eliminating risk of LBP or simply changing the mechanism of risk with patient lift devices?
- Is there a difference in risk as a function of the patient lift device design?
  - Ceiling lift
  - Floor based lift

Patient Pushing using Lift Assist Devices

Approach

- Use OSU Personalized Biodynamic Model to realistically assess spine loads when pushing patient with ceiling lifts vs. floor-based lifts

Task

- Push a patient lifting device through a course that contains many of the typical challenges within a health care facility

Care Givers

- Subjects (10)
  - 5 males, 5 females
  - Age = 24.2 (4.66) years
  - Height = 175.11 (11.98) cm
  - Weight = 70.66 (16.11) Kg

Patient Lift Devices

Ceiling lift

Likorall 243 ES
(230 Kg capacity)

Floor based lift

Liko Viking L
(250 Kg capacity)

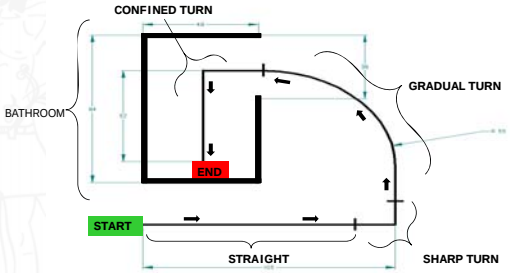
Experimental Conditions

- Lift system
  - Ceiling based
  - Floor based – large wheel vs. small wheel
    - Large wheels (5 inch diameter rear; 4 inch diameter front)
    - Small wheels (3 inch diameter rear; 2 inch diameter front)
- Floor Surface
  - Hard Floor
  - Carpet

Patient

- **Patient weight**
  - 125 lb (56.8 Kg)
  - 160 lb (72.7 Kg)
  - 360 lb (163 Kg)

Course Path and Required Control



NOTE: All dimensions are in inches

Course Path and Required Control

Experimental Conditions

- **Lift system**
  - Ceiling based
  - Floor based
    - large wheel vs. small wheel
      - Large wheels (5 inch diameter rear; 4 inch diameter front)
      - Small wheels (3 inch diameter rear; 2 inch diameter front)
    - Floor surface
      - Hard floor
      - Carpet (short pile)
- **Patient weight**
  - 125 lb (56.8 Kg)
  - 160 lb (72.7 Kg)
  - 360 lb (163 Kg)
- **Course control required**
  - Straight
  - Sharp (90 deg) turn
  - Gradual turn
  - Sharp turn in confined space (bathroom)

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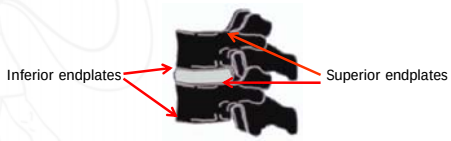
Spine Loads Determined by Model

- Vertebral endplate compression, disc lateral shear, and disc A/P shear at the superior and inferior vertebrae levels from T12 to S1



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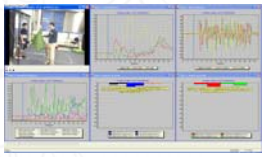
Ceiling Lift Trial and Analysis



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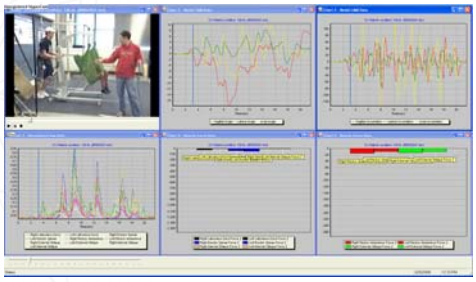
Floor Based Lift used on Carpet



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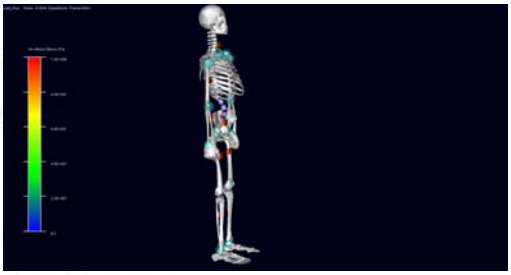

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Results:

Spine Load Magnitudes

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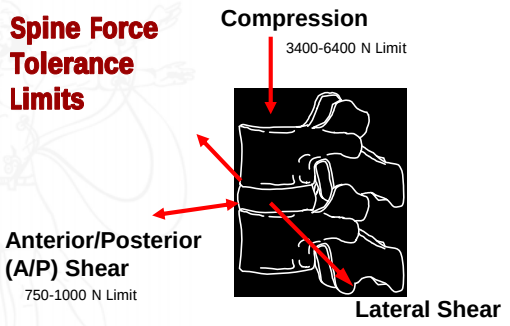
Spine Force Tolerance Limits



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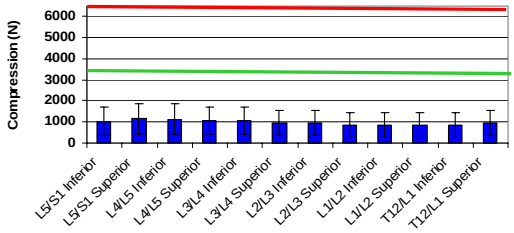
Compression as a Function of Vertebral Level



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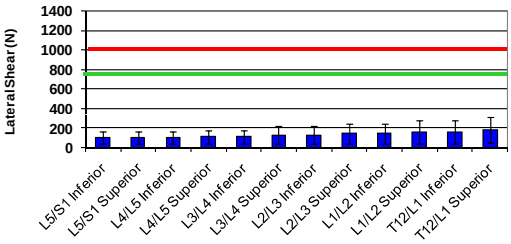
Lateral Shear as a Function of Vertebral Level



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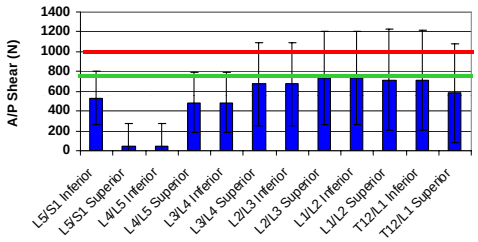
A/P Shear as a Function of Vertebral Level



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Significant Effects

	Lateral Shear	Compression	A/P Shear
Patient Handling System (System)	0.003*	0.015*	0.060
Patient Weight (Weight)	0.124	0.069	0.057
Required Control over System (Control)	0.006*	0.105	0.005*
System*Weight	0.015*	0.189	0.133
System*Control	0.106	0.002*	0.001*
Weight*Control	0.496	0.695	0.497
System*Weight*Control	0.154	0.081	0.070

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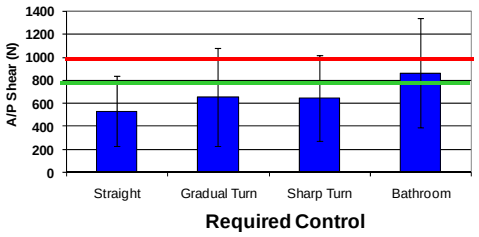
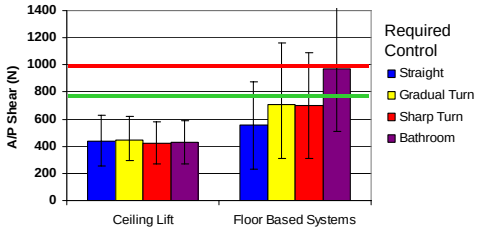
L3 A/P Shear a Function of Required Control



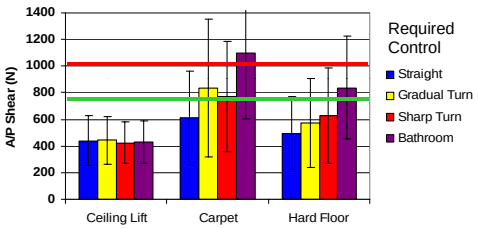
* Significant (p<0.005)

L3 A/P Shear as a Function of System and Required Control

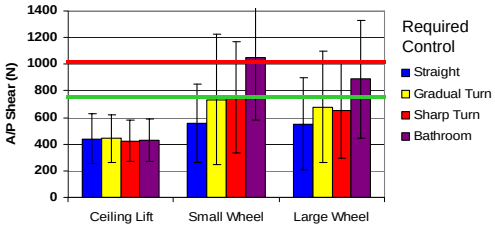


* Significant (p<0.001)

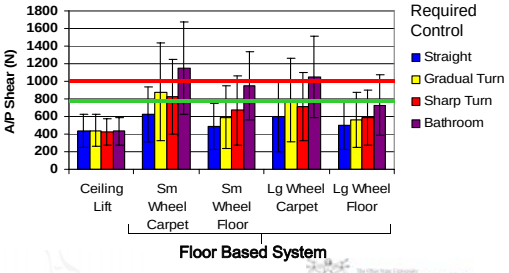
L3 A/P Shear as a Function of Lift System, Floor, and Required Control



L3 A/P Shear as a Function of System Wheel Type and Required Control



L3 A/P Shear as a Function of Floor Based Systems and Required Control



* Significant (p<0.001)

Discussion

- Ceiling lifts impose lowest (and safest) load on the spine
  - No risky conditions were identified for this condition
- Floor-based lifts ***can*** impose significant biomechanical risk to spine but *depends upon conditions of use*
- Risk occurs primarily to the upper lumbar vertebrae (L3 and above)
  - Previous studies have not studied those levels
  - May help explain the 27% of LBP associated with pushing and pulling
- These results may explain why interventions are not always effective

Discussion

- A/P shear is mechanism of risk when pushing patients
- Floor based risk increases with increased required control
  - Controlling lift in confined space (bathroom) poses greatest risk
  - Turning (gradual or sharp turn) poses next greatest risk
  - Pushing without turning has minimal risk (but greater than ceiling lift)
  - No increased risk with ceiling lift as a function of control
- Operating floor based lifts on carpet or with small wheels greatly magnifies risk
  - Small wheels and carpet together create hazardous conditions when control is required.

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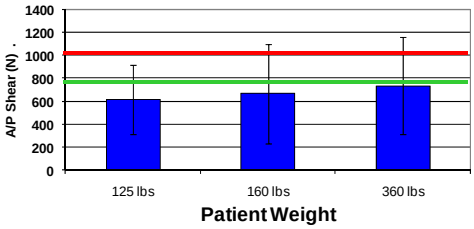
L3 A/P Shear as a Function of Patient Weight



*Not statistically significant

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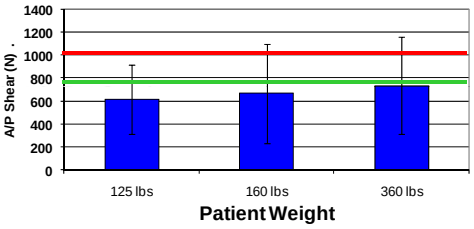
L3 A/P Shear as a Function of Patient Weight



*Not statistically significant

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Obesity Trends Among U.S. Adults between 1985 and 2007

Definitions:

- Obesity: Having a very high amount of body fat in relation to lean body mass, or Body Mass Index (BMI) of 30 or higher.
- Body Mass Index (BMI): A measure of an adult's weight in relation to his or her height, specifically the adult's weight in kilograms divided by the square of his or her height in meters.

(**CDC , 2008** U.S. Obesity Trends 1985-2007)

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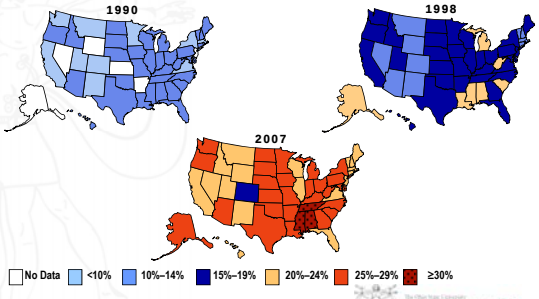
Obesity Trends* Among U.S. Adults
BRFSS, 1990, 1998, 2007
(*BMI ≥30, or about 30 lbs. overweight for 5'4" person)



CDC (2008) U.S. Obesity Trends 1985-2007

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Things I wish I could have included in this study

- Other types/designs of lifts
  - We could use these techniques to optimize lifts
  - Adjust handle heights
- Greater range of patient weights
- Subject cooperation/resistance
- More care givers
- Experienced care givers
- Different push techniques?

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Conclusions

- There is no safe way to lift a patient manually (loads are too great for body mechanics to make a difference)
- There is surveillance evidence that interventions can help control risk
- Lifting devices can help but the degree of control required greatly influences risk
- Use ceiling lifts if at all possible
- When using floor mounted lifts –
  - Use extreme caution when turning and controlling patient within the bathroom (this is where the risk occurs)
  - Use extreme caution when using these systems on carpet
  - Don't use small wheels with floor based systems!

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Acknowledgments / Thanks

- Mr. Greg Knapik
- Kim Vanlen and Cliff Hoschouer
- Liko Inc. (access to lifting equipment)
- Mr. Joe Joliff (expert advice)

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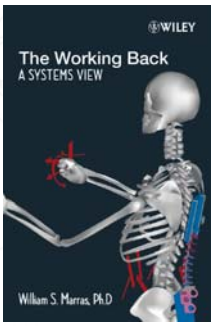

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Thank You!

http://biodynamics.osu.edu

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