Low Back Biomechanics and Patient Handling

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Review Study of Low Back Pain Prevalence

Work-related back pain in nurses
Hignett, S.
- LBP point prevalence = 17%
- LBP annual prevalence = 40-50%
- LBP lifetime prevalence = 35-80%

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

LBP Prevalence/Risk and Patient Handling

Work-relatedness of low back pain in nursing personnel: A systematic review
Yassi, A and Lockhard, K
- Systematic review of literature
- Considered 987 studies; 89 studies met eligibility criteria
- Bradford Hill considerations used (Mix of 21 longitudinal, 36 cross-sectional, 23 biomechanical/ergo, and 9 review studies)
- Conclusion – Patient handling confers the highest risk but other duties confound dose-response assessments. Associations were strong, consistent, temporally possible, plausible, coherent, and analogous to other exposure-outcomes. Risk OR 1.2-5.5 depending on LBP defn.

Establishing Causality: Bradford Hill

1. Strength of Association
2. Temporal Association
3. Consistency of Association
4. Specificity of Association
5. Dose-Response Relationship
6. Biological Plausibility

Low Back Pain Risk Factor Environment

(NRC/IOM, 2001)

Studies with Biomechanical Implications

Expanded OSHA 300 log as metric for bariatric patient-handling staff injuries
Randall, S. B., Pories, W. J., Pearson, A., Drake, D.J.
- Patients with BMI > 35 = < 10% of patients
- Handling patients with BMI > 35 associated with:
  - Turning and Repositioning patient implicated in:
    - 31% of cases
    - 29.8% injuries
    - 27.9% lost time
    - 37.2% restricted time
  - Usually performed using biomechanics and NOT equipment
Biomechanics is More than Strength

Biomechanical Logic
Load – Tolerance Relationship and Risk

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, 2008)
§ Disc problems are very common in those reporting LBP (Cheung et al., 2009)

Disc Degeneration

How Cumulative Trauma Develops in the Spine

Disc Nutrition Pathways
How Cumulative Trauma Develops in the Spine

Vertebral Endplate

Microfractures

Vertebral Endplate

Scarf Tissue Development

Disc Degeneration and Cumulative Trauma

Vertebral Body

Vertebral Endplate

Disc

Scar Tissue

Spine Tolerance Limits

Compression

3400-6400 N Limit (NIOSH, 1981)

Anterior/Posterior (A/P) Shear

1000 N Limit

(McGill, 1994; Yingling, 1999)

Lateral Shear

1000 N Limit (Mikel, 1986)

Biomechanical Modeling of the Low Back

Can we assess specific spine tissue loads?

The Development of a Personalized Biomechanical Model

- Unique to the subject/patient (muscle control, imaging, structure characteristics)
- Driven by muscle activities characteristic of pathology
- Show tissue compromise
- Predict tissue breakdown
- Use to understand biochemical triggering
- Can assist in understanding impact of interventions (surgical vs. conservative)
Spine Loads Results from the Reaction of Internal Forces to External Forces

Internal Force

External Force

Personalized Model Structure

Laboratory Assessment of Push-Pull

Assessment of Spine Forces Based Upon Task

Spine Loads at Different Levels

Specific Tissue Loads with Inclusion of Finite Element Analysis
Our Early Patient Lifting Studies

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

W. K. Mielke, K. D. Davis, A. R. King and F. K. Bertone
Biodynamics Laboratory, The Ohio State University, 1671 Neil Avenue, 216 Baker Science, Columbus, OH 43210, USA

Keywords: Patient lifting; Spinal Loads; Biomechanics, LBD

Although patient handling often involves lifting and/or moving patients, few studies have been reported quantifying the risk for the injuries that occur during the actual procedures performed by the patient handlers. The current study used both a comprehensive computerized biomechanical analysis and a validated experimental testing methodology to investigate patient lifting in four different scenarios: (1) bed-to wheelchair transfer with arms, (2) bed-to-from wheelchair with one arm removed, (3) portable commode chair to/from hospital chair, and (4) straight transfer from bed to wheelchair. The load to the LBD was determined using the FEA technique and for the experimental study, 12 participants performed the transfers. From these data, the lifting methods were evaluated, and optimal lifting methods were developed to reduce the risk of injury.

Transfer Techniques

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

Repositioning Techniques

- Bed to/from wheelchair with arms
- Bed to/from wheelchair with one arm removed
- Portable commode chair to/from hospital chair
Spine Compression as a Function of Transfer Task

<table>
<thead>
<tr>
<th>Transfer Task</th>
<th>Compression Force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bed</td>
<td>2000</td>
</tr>
<tr>
<td>Wheelchair w/o Arms</td>
<td>3000</td>
</tr>
<tr>
<td>Wheelchair</td>
<td>4000</td>
</tr>
<tr>
<td>Commode</td>
<td>5000</td>
</tr>
<tr>
<td>Chair</td>
<td>6000</td>
</tr>
<tr>
<td>Commode - Chair</td>
<td>7000</td>
</tr>
<tr>
<td>Wheelchair - Bed</td>
<td>8000</td>
</tr>
<tr>
<td>Chair - Commode</td>
<td>9000</td>
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Spine Compression as a Function of Transfer Technique

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</tr>
<tr>
<td>Bed - Wheelchair w/o Arms</td>
<td>4000</td>
</tr>
<tr>
<td>Chair - Commode</td>
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</tr>
<tr>
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<td>8000</td>
</tr>
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Spine Compression as a Function of Repositioning Technique

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<thead>
<tr>
<th>Repositioning Technique</th>
<th>Compression Force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hook</td>
<td>2000</td>
</tr>
<tr>
<td>Hook &amp; Thigh &amp; Shoulder Sheet</td>
<td>3000</td>
</tr>
<tr>
<td>Hook &amp; Thigh &amp; Shoulder Sheet</td>
<td>4000</td>
</tr>
<tr>
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Biodynamics Laboratory Previous Studies

- Risk associated with one- or two- caregiver patient lifting
  - Conclusion – There is no safe way to lift patient manually!
    - The magnitude of spine loading is so great any benefits of using proper body mechanics is negligible
  - Suggestion – Must employ patient lifting assistance device
- Intervention Effectiveness (prospective observation of 100 units)

Patient Handling Interventions

The Effect of Ergonomic Interventions in Healthcare Facilities on Musculoskeletal Disorders

| Type of Intervention | Baseline 
|----------------------|---------|
|                      | median  
|                      | (Range)  |
| Reduce Bending       | 16      |
| Zero Lift            | 44      |
| Reduce Carrying      | 8       |
| Multiple Interventions | 32  |
| All                  | 100     |

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Patient Handling Musculoskeletal Disorder Rate Changes

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

(Fujishiro, et al. 2005)
### Patient Handling Change in MSD Rates per Intervention (baseline to follow-up)

<table>
<thead>
<tr>
<th>Type of Intervention</th>
<th># Units Decreased or no change</th>
<th>Number of Units Increased</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce Bending</td>
<td>12 (75%)</td>
<td>4 (25%)</td>
<td>0.056</td>
</tr>
<tr>
<td>Zero Lift</td>
<td>32 (72.7%)</td>
<td>12 (27.3%)</td>
<td>0.002</td>
</tr>
<tr>
<td>Reduce Carrying</td>
<td>7 (87.5%)</td>
<td>1 (12.3%)</td>
<td>0.031</td>
</tr>
<tr>
<td>Multiple Interventions</td>
<td>26 (81.3%)</td>
<td>6 (18.7%)</td>
<td>0.001</td>
</tr>
<tr>
<td>All</td>
<td>77 (77.0%)</td>
<td>23 (23.0%)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

(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!
  - 23% of zero lift interventions had increased reporting

### Lifting Transformed into Pushing and Pulling

- Pushing and Pulling
- Pushing/Maneuvering Patients
- Patient Lift Devices

- Pushing/Maneuvering Patients

- 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

Patients

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

Course Path and Required Control

- Straight
- Sharp Turn
- Gradual Turn
- Bathroom
- Confinement Turn
- Start
- End

Ceiling Lift Trial and Analysis

Floor Based Lift used on Carpet

NOTE: All dimensions are in inches
Floor Based Lift used on Carpet

Results:
Spine Load Magnitudes

Compression as a Function of Vertebral Level

Lateral Shear as a Function of Vertebral Level

A/P Shear as a Function of Vertebral Level

Significant Effects

<table>
<thead>
<tr>
<th></th>
<th>Lateral Shear</th>
<th>Compression</th>
<th>A/P Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Handling System (System)</td>
<td>0.003*</td>
<td>0.015*</td>
<td>0.060</td>
</tr>
<tr>
<td>Patient Weight (Weight)</td>
<td>0.124</td>
<td>0.069</td>
<td>0.057</td>
</tr>
<tr>
<td>Required Control over System (Control)</td>
<td>0.006*</td>
<td>0.105</td>
<td>0.005*</td>
</tr>
<tr>
<td>System*Weight</td>
<td>0.015*</td>
<td>0.189</td>
<td>0.133</td>
</tr>
<tr>
<td>System*Control</td>
<td>0.106</td>
<td>0.002*</td>
<td>0.001*</td>
</tr>
<tr>
<td>Weight*Control</td>
<td>0.496</td>
<td>0.695</td>
<td>0.497</td>
</tr>
<tr>
<td>System<em>Weight</em>Control</td>
<td>0.154</td>
<td>0.081</td>
<td>0.070</td>
</tr>
</tbody>
</table>
**L3 A/P Shear a Function of Required Control**

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* Significant (p<0.005)

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

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* Significant (p<0.001)

**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.

**Non-Physical Factors Affecting Spine Loading:**

**Individual & Psychosocial Factors**

**The Influence of Psychosocial Stress, Gender, and Personality on Mechanical Loading of the Lumbar Spine** (Marras et al., 2000)

**Study Procedure**

1. **Un-Stressed Session** - Perform Lift Tasks
2. **Experiment Interruption / Experimenters Called Out of Room**
3. **Stressed Session** - Perform Same Lift Tasks
Variability of Biomechanical Responses to Psychosocial Stress (Marras et al. 2000)

![Graph showing variability of biomechanical responses to psychosocial stress.](image)

Differences in Spinal Loads Between Personality Traits in Response to Psychosocial Stress (Marras et al., 2000)

![Graph showing differences in spinal loads between extraverts and introverts.](image)

Differences in Spinal Loads Between Personality Traits in Response to Psychosocial Stress (Marras et al., 2000)

![Graph showing differences in spinal loads between sensors and intuitors.](image)

Musculoskeletal Control and Tissue Load

![Diagram illustrating musculoskeletal control and tissue load.](image)

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!

Thank You!

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