Are commonly used manual handling assessment tools effective in the prevention of work-related musculoskeletal symptoms?

Simon Yeung
Associate Professor
Dept of RS

Contents:
- MHO and MS disorders
- Risk Factors for LBD
- MHO assessment methods
- Worker based evaluation
- Cumulative effects of spinal loading

MHO and Musculoskeletal Disorders
- Local Statistics
  - 18.9% (8,375/44,267 in 2005)
- LBD is the commonest and frequently associated with physical demanding tasks such as manual lifting
- Tremendous research in this area
  - e.g. A four-folds increase in studies from 1971-80 vs 1981-90

REVIEW OF PREVALENCE OF LBD

<table>
<thead>
<tr>
<th>Type of Prevalence</th>
<th>Mean</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point prevalence</td>
<td>34.8%</td>
<td>26.9-42.7%</td>
</tr>
<tr>
<td>1-year prevalence</td>
<td>48.9%</td>
<td>43.6-54.1%</td>
</tr>
<tr>
<td>Life time prevalence</td>
<td>62.9%</td>
<td>55.1-70.6%</td>
</tr>
</tbody>
</table>

Based on medline search from 1960-2002
Summary of 65 studies

Does MHO only affect the lower back region?

217 male workers with varied levels of manual lifting experience from Hong Kong
- Nine companies from three major industries: warehouse operations, delivery services, and electric part manufacturing

Yeung SS et al. 2002a
### 12 month Prevalence (%)

<table>
<thead>
<tr>
<th>Body region</th>
<th>12 month Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper back</td>
<td>92.87</td>
</tr>
<tr>
<td>Lower back</td>
<td>58.33</td>
</tr>
<tr>
<td>Hips/Upper legs</td>
<td>32.41</td>
</tr>
<tr>
<td>Knees/Lower legs</td>
<td>21.30</td>
</tr>
<tr>
<td>Ankles/Feet</td>
<td>26.85</td>
</tr>
<tr>
<td>Neck</td>
<td>31.02</td>
</tr>
<tr>
<td>Shoulders</td>
<td>38.89</td>
</tr>
<tr>
<td>Elbows/Forearms</td>
<td>21.30</td>
</tr>
<tr>
<td>Hands/wrists</td>
<td>20.83</td>
</tr>
<tr>
<td>Fingers</td>
<td>12.04</td>
</tr>
</tbody>
</table>

### Nursing Professionals

<table>
<thead>
<tr>
<th>Body region</th>
<th>12 months prevalence</th>
<th>1 month prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck</td>
<td>96%</td>
<td>38%</td>
</tr>
<tr>
<td>Upper back</td>
<td>91%</td>
<td>36%</td>
</tr>
<tr>
<td><strong>Lower Back</strong></td>
<td><strong>98%</strong></td>
<td><strong>59%</strong></td>
</tr>
<tr>
<td>Hips/Upper legs</td>
<td>89%</td>
<td>30%</td>
</tr>
<tr>
<td>Knees/Lower legs</td>
<td>91%</td>
<td>39%</td>
</tr>
<tr>
<td>Feet and ankle</td>
<td>86%</td>
<td>29%</td>
</tr>
<tr>
<td>Shoulder</td>
<td>93%</td>
<td>38%</td>
</tr>
<tr>
<td>Arm</td>
<td>90%</td>
<td>14%</td>
</tr>
<tr>
<td>Hand-wrist</td>
<td>90%</td>
<td>20%</td>
</tr>
<tr>
<td>Fingers</td>
<td>77%</td>
<td>10%</td>
</tr>
</tbody>
</table>

### Personal Care Assistant in Nursing home

<table>
<thead>
<tr>
<th>Body region</th>
<th>12 months Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck</td>
<td>65.8%</td>
</tr>
<tr>
<td>Upper back</td>
<td>85.5%</td>
</tr>
<tr>
<td><strong>Lower Back</strong></td>
<td><strong>94.7%</strong></td>
</tr>
<tr>
<td>Hips/Upper legs</td>
<td>81.6%</td>
</tr>
<tr>
<td>Knees/Lower legs</td>
<td>71.1%</td>
</tr>
<tr>
<td>Foot and ankle</td>
<td>76.3%</td>
</tr>
<tr>
<td>Shoulder</td>
<td>92.1%</td>
</tr>
<tr>
<td>Arm</td>
<td>73.7%</td>
</tr>
<tr>
<td>Hand-wrist</td>
<td>63.2%</td>
</tr>
<tr>
<td>Fingers</td>
<td>44.7%</td>
</tr>
</tbody>
</table>

Source: Yeung SS et al. 2004
Personal Care Assistant in Nursing Home

<table>
<thead>
<tr>
<th>Low back pain</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>12 month prevalence</td>
<td>94.7%</td>
</tr>
<tr>
<td>Symptoms duration with past 12 month:</td>
<td></td>
</tr>
<tr>
<td>- 1-7 days</td>
<td>15.8%</td>
</tr>
<tr>
<td>- 8-30 days</td>
<td>18.4%</td>
</tr>
<tr>
<td>- &gt;30 days</td>
<td>23.7%</td>
</tr>
<tr>
<td>- Everyday</td>
<td>36.8%</td>
</tr>
<tr>
<td>Affecting work</td>
<td>26.3%</td>
</tr>
<tr>
<td>Pain in the past 7 days</td>
<td>50.0%</td>
</tr>
</tbody>
</table>

MHO and Musculoskeletal Disorders

- We should not only focus on lower back
- Kinematics changes with multiple joints involvement
- Definition of LBP

RISK FACTORS ASSOCIATED WITH LBD

REVIEW OF RISK FACTORS

- Medline database from 1960-2002
- 94 studies extracted

<table>
<thead>
<tr>
<th>Physical</th>
<th>Non-physical</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ve</td>
<td>no</td>
</tr>
<tr>
<td>Lifting</td>
<td>34  4</td>
</tr>
<tr>
<td>Push/pull</td>
<td>3 Stress/anxiety</td>
</tr>
<tr>
<td>Carrying</td>
<td>2 Education</td>
</tr>
<tr>
<td>Twist/bend</td>
<td>22  2 Job dissatisfaction</td>
</tr>
<tr>
<td>Vibration</td>
<td>13 High work demand</td>
</tr>
<tr>
<td>Work injuries</td>
<td>12  1</td>
</tr>
</tbody>
</table>
RISK FACTORS ASSOCIATED WITH LBD

Work related biomechanical
Non-physical
Individual attributes

<table>
<thead>
<tr>
<th>Study design</th>
<th>CS</th>
<th>N=60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prospective</td>
<td>N=30</td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>N=3</td>
<td></td>
</tr>
<tr>
<td>Risk factors assessed</td>
<td>Physical</td>
<td>N=45</td>
</tr>
<tr>
<td></td>
<td>Non-physical</td>
<td>N=16</td>
</tr>
<tr>
<td></td>
<td>Both</td>
<td>N=32</td>
</tr>
<tr>
<td>Evaluation methods</td>
<td>Questionnaire</td>
<td>N=79</td>
</tr>
<tr>
<td></td>
<td>Interview</td>
<td>N=16</td>
</tr>
<tr>
<td></td>
<td>Observation</td>
<td>N=8</td>
</tr>
<tr>
<td></td>
<td>Direct measure</td>
<td>N=15</td>
</tr>
<tr>
<td>Outcome measures</td>
<td>Self-reported</td>
<td>N=78</td>
</tr>
<tr>
<td></td>
<td>Medical Exam</td>
<td>N=9</td>
</tr>
<tr>
<td></td>
<td>Work injuries</td>
<td>N=12</td>
</tr>
</tbody>
</table>

METHOD OF ASSESSMENT

Self-reported evaluation
Direct measurement
Systematic observation
Questionnaires, interviews, diaries
Biomechanical
Psychophysical
Physiological
Checklist
Mathematical and/or Computer Modeling

Checklist Approach

- Code of Practices & Guidelines
  - MHO Guidelines (Labour Dept, HK, 1998)
  - MHO Guidelines (HSE, UK 1992)
  - MMH Code of Practices (Victoria, Australia 1988)
- Lack sufficient practical guidance (Industry Commission, 1995)

Mathematical and/or computer modeling approach

- NLE (Revised NIOSH lifting equation, Waters et al., 1993)
- LMM and OSU Model (Marras et al., 1992, 1993)
- Psychophysical Approach - Snook et al., 1978
- The University 3D Static Strength Prediction Program (3DSSPP)
- Physiological model (University of Michigan EEPP)

NIOSH lifting equation

- A mathematical equation for the calculation of recommended weight limit (RWL) and lifting index (LI)
- Only for two-handed manual lifting activities
- Input data: 7 lifting variables
  - Weight of load
  - Horizontal distance
  - Twisting angle
  - Origin of lift
  - Height of lift
  - Frequency and duration
- LI = L/RWL
NIOSH lifting equation (1991)

- Limitation
- In 1985, NIOSH convened an ad hoc committee of experts to update information on physiological, biomechanical, psychophysical, and epidemiological aspects manual lifting

Criteria used to develop the equation

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Design criterion</th>
<th>Cut-off value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomechanical</td>
<td>Max disc compression force</td>
<td>3.4 kN</td>
</tr>
<tr>
<td>Physiological</td>
<td>Max energy expenditure</td>
<td>2.2-4.7 kcal/min</td>
</tr>
<tr>
<td>Psychophysical</td>
<td>Max acceptable weight</td>
<td>75% of female and about 99% of male workers</td>
</tr>
</tbody>
</table>

Rationale

- Principal product: Recommended Weight Limit (RWL)
- For a specific set of tasks conditions as the weight of the load that nearly all healthy workers could perform over a substantial period of time (up to 8 hrs) without an increased risk of developing lifting related LBP
- “Healthy workers” are those who are free of adverse health conditions that would increase their risk of musculoskeletal injury
- Load constant: 23 kg

LIFTING INDEX (LI)

LI = L / RWL

- RWL is compared with the actual weight W of the object being lifted
- Comparison is made at the origin and destination of a lift
- Larger of the two values is considered the “stress level” of a lift
- LI < 1.0 .... protective of most workers
- LI > 3.0 .... poses significant risk to most workers
- 1.0 < LI < 3.0 .... many jobs fall in this region
- Jobs need to be either redesigned to minimize LI, otherwise need increased job screening, more careful training, and medical monitoring

Evaluation of the Revised NIOSH Lifting Equation

- Waters et al, 1999 conducted a cross-sectional epidemiologic study to determine the correlation between the prevalence of low back pain and exposure to manual lifting stressors using the LI
- Evaluated 55 jobs from 4 industrial sites with the NIOSH lifting equation

<table>
<thead>
<tr>
<th>LI</th>
<th>Odds of Low Back Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>LI &lt; 1.0</td>
<td>Peak odds ratio</td>
</tr>
<tr>
<td>LI &gt; 3.0</td>
<td>in the 2&lt; LI &lt; 3 category (OR =2.45)</td>
</tr>
<tr>
<td>LI &gt; 3.0</td>
<td>However, OR (=1.45) was lower for jobs with LI &gt; 3</td>
</tr>
</tbody>
</table>
OSU Regression Model

- Developed in 1993 by Marras and co-workers
- Literature review suggests trunk motions experienced by workers may be an overlooked causal factor
- Data reported by Bigos et al (1991) suggested risk of LBD is associated with dynamic lifting, but it has never been shown in in vivo studies

OSU Dynamic Trunk Motion Analysis

- Trunk motion variables were measured by a tri-axial electrogoniometer called Lumbar Motion Monitor (LMM)
- Allow capture of trunk angle position, velocity, and acceleration characteristics in each of the cardinal planes
- Together with other task variables:
- Logistic regression models were developed

Evaluation of OSU Regression Model

- Cross-sectional study of 403 industrial jobs from 48 manufacturing companies
- Jobs were divided into three groups, high, medium and low risk of LBD, based on examination of the injury and medical records (independent variables)
- Dependent variables consisted of workplace, individual and trunk motion characteristics

Logistic regression analysis was used to determine the association of the low risk jobs to high risk jobs with workplace, individual and trunk motion characteristics

- Maximum moment (OR 5.17 between high and low risk; OR 4.04 between low and medium risk) and velocity (OR 3.33 between high and low risk) are the two most powerful variables for discriminating between risk groups

PSYCHOPHYSICAL APPROACH

- Snook and Ciriello database
- Provide weight limits for lifting
- Base on workers’ perception (integration of stress and strain)
- Maximum acceptable weight of lift for specified combinations of lifting variables (frequency, height of lift….etc.)

Evaluation of NIOSH Guide/Equation & Psychophysical Measures

- Marras et al, 1999 assessed the NIOSH Guide (1981), Revised NIOSH Lifting Equation (1991) and psychophysical measures for their ability to correctly identify high, medium and low risk of LBD jobs (Independent variables)
- Defined workplace characteristics (Dependent variables) in 353 industrial jobs representing over 21 million person-hours exposure
Evaluation of NIOSH Guide/Equation & Psychophysical Measures

- Only factors of average weight of object lifted and average horizontal distance produced a statistically significant OR.

- Both 1981 and 1991 NIOSH measures had odds ratios for high risk versus low risk of LBD:
  - OR 3.1 and 3.5 (average moment arm)
  - OR 4.3 and 4.6 (maximum horizontal moments)

The NIOSH Guide 1981:
- Good specificity (91%) but low sensitivity (10%)

The NIOSH Guide 1991:
- Better sensitivity (73%) but did not identify medium and low risk
- NIOSH guide (1981) underestimating the risk
- Revised NIOSH lifting equation (1991) overestimating risk

Assessment of lifting tasks

- Weight of load
- Horizontal distance
- Twisting angle
- Height of lift
- Frequency
- Duration

3D static strength prediction program (3DSSPP):
- A user-friendly biomechanical analysis software
- Required input of joint angles to define body posture
- Anthropometric measures for body characteristics
- Magnitude and direction of externally applied forces
- Software for the analysis of:
  - Moments
  - Anterior-posterior and lateral shearing force; and
  - Compressive force at L5/S1
  - Estimation of muscle strength requirements
CURRENT PROBLEM OF LBD

- LBD statistics had not declined to a satisfactory level
- Point prevalence 31.5 vs 39.3% in nursing profession between 1975-1990 and 1990-2000
- Similar statistics in UK, 12 month prevalence 36.4 vs 49.1% between 1987-8 and 1997-8.

MHO Evaluation

- Work Demands
- Workers’ Qualification

MHO and LBD

- LBD-multi-factorial
- Evaluation: self-reported, checklist, and direct measurement
- Outcome measure: self-reported
- LBD statistics had not declined to a satisfactory level

WORK DEMANDS

- Physical Task Demands
- Mental Task Demands
- Physical Environment Demands
- Socio-organizational environment

WORKER-BASED EVALUATION

Existing worker-based evaluation is predominately checklist-based model.

Worker-based evaluation capitalised workers knowledge and expertise in the evaluation of their own workplace.

Workers commit more easily to the work environment that they help create.

**LIFTING**

- Weight of Load
- Horizontal Distance
- Twisting angle
- Height of Lift
- Frequency
- Duration

**Bio-mechanical**

**Posture**

**Effort**

**Physiological**

**Evaluation Procedures**

- Weight of Load: light, mod, heavy
- Horizontal Distance: close, mod, far
- Twisting angle: small, mod, large
- Vertical distance: short, mod, long
- Vertical location: floor, waist

**Linguistic-numerical mapping for weight of load**

A given numerical value for a lifting task parameters translates to different linguistic interpretation with a given certainty factor.

- Effort significantly associated with lifting variables; objective indices reported in the published literature for evaluating lifting stresses, and MS symptoms;
- Weight of load is the most important variable influencing effort;
- Relative importance of other variables were not in total agreement with NIOSH LE.
A Field Study

- Cross-sectional study (Tam & Yeung 2006)
  - on 38 staff of NEATS Dept.
- Four categories of risk factors
  - personal, physical, psychosocial & exposure factors
- Five LBP definitions with progressing severity

LBP definitions

- LBP ≥ 1 day
- LBP > 7 days
- LBP > 4/10 pain
- LBP need treatment (from health care provider)
- LBP need sick leave (>1 day)

LBP cases that required treatment from health care providers

<table>
<thead>
<tr>
<th>Variables</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.05</td>
<td>0.75</td>
</tr>
<tr>
<td>RPE**</td>
<td>2.45</td>
<td>1.07</td>
</tr>
<tr>
<td>Job satisfaction*</td>
<td>1.45</td>
<td>1.07</td>
</tr>
<tr>
<td>Fatigue after work*</td>
<td>2.00</td>
<td>0.93</td>
</tr>
<tr>
<td>Self-perceived work load*</td>
<td>2.57</td>
<td>0.98</td>
</tr>
<tr>
<td>Flexor peak torque at 60°/s*</td>
<td>1.04</td>
<td>0.99</td>
</tr>
<tr>
<td>Flexor peak torque at 120°/s*</td>
<td>1.05</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Risk and protective characteristics of work-related factors and the prevalence of MS symptoms

- 97 female registered nurses
- Two surveys were used to document the workload exposure of the nurses.
- One survey consisted of 148 items aimed to measure the acting workload variables from the environment; the other survey included 33 items which were aimed to measure the nurses’ experienced workload.
- MS outcomes were documented with a modified version of the Nordic MS Symptom Survey.

Measurements of risk factors

- Risk Factors
  - Personal Factors
    - Demographic, health, lifestyle
    - Self-reported Questionnaire
  - Physical Factors
    - Max strength, lifting capacity, cardiovascular fitness
    - Objective physical measurements
  - Psychosocial Factors
    - Job satisfaction, work stress, peer support & etc.
    - Self-reported Questionnaire
  - Exposure Factors
  - Driver/non-driver, Full-time/part-time
Factor analyses revealed three factors that accounted for 56% of the total variance.

- Factor 1 represented the psychological effects of work characteristics, effort, perceived risk and performance.
- Factor 2 consisted of non-physical variables of the work characteristics
- Factor 3 loaded on the both acting and experienced workload.

Logistic regression analyses indicated that Factor 3 was significantly associated with the musculoskeletal symptoms of lower and upper back, hands/wrists, and knees/lower legs (odds ratios > 1.0)

- Factor 2 was significantly associated with the musculoskeletal symptoms of the upper back and knees/lower legs (odds ratios < 1.0).

Comprehensive understanding of the relationship between the risk and protective elements of acting and experienced workload at the workplace

How about effects of cumulative spinal loading?

![Time-varying load-tolerance model (Marras 1998)](image)
Meta-analysis

- Association between cumulative spinal loading and lower back disorders (LBD)
- 13 articles were identified as relevant
- Six of these studies evaluated the association of cumulative spinal loading with lower back disorders

Quality of the studies are in general poor

The meta-odds ratio for the fixed effect model was 1.66 (95% CI=1.46-1.89)

Waters T, et al., 2006a, 2006b

Summary

- MHO and MS disorders
- Multiple factorial risks for LBD
- MHO assessment methods
- Worker based evaluation
- Cumulative effects of spinal loading

Yeung SS et al. (2002a) Prevalence of musculoskeletal symptoms in single and multiple body and effects of perceived risk of lifting injury among manual handling workers. Spine 27(19) 2166-2172
Yeung SS et al. 2003b: A Participatory approach to the study of lifting demands & musculoskeletal symptoms among Hong Kong workers. Ergonomics 46(6): 574-597

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