NIOSH Lifting Equation

General description and development of the method

The NIOSH Lifting Equation is a method to assess risk of low-back disorders in jobs with repeated lifting. It consists of two primary products, the recommended weight limit (RWL) and the lifting index (LI). The RWL is defined for a specific set of task conditions as the weight of the load that nearly all healthy workers could perform over a substantial period of time (e.g. up to 8 hours) without an increased risk of developing lifting-related low back pain. It is calculated as a product of the weight that is considered safe for an ‘ideal’ lift (i.e. load constant equal to 23 kg) and six weighted task variables, which include the: (1) horizontal distance of the load from the worker (H); (2) vertical height of the lift (V); (3) vertical displacement during the lift (D); (4) angle of asymmetry (A); (5) frequency (F) and duration of lifting; and, (6) quality of the hand-to-object coupling (C).

\[
\text{RWL} = H \times V \times D \times A \times F \times C.
\]

Lifting index (LI) is the ratio of the actual load weight and the recommended weight limit.

\[
\text{LI} = \frac{L}{\text{RWL}}
\]

LI values >1 indicate increased risk.


LI is limited to jobs with similar lifting tasks. For jobs with multiple tasks, procedures have been proposed to compute the composite lifting index (CLI) (Tolbert 2007, Waters 2006, Waters 1994) or the sequential lifting index (SLI) (Waters 2007) for the overall job.

The National Institute for Occupational Safety and Health (NIOSH) developed the Work Practices Guide for Manual Lifting in 1981 to assist safety and health practitioners in evaluating lifting and lowering jobs in the sagittal plane. Because the 1981 equation could only be applied to a limited number of lifting jobs, it was revised in 1991. The objective is to prevent or reduce the occurrence of lifting and lowering overexertion injuries and low back pain among workers (Garg 1995).

Exposure descriptors

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Description of exposure</th>
<th>magnitude/amplitude</th>
<th>duration</th>
<th>frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>posture</td>
<td>Defined by the horizontal and vertical position of the load in relation to the trunk.</td>
<td>X .</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>movements</td>
<td></td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>(external) force</td>
<td>Load handled</td>
<td>X .</td>
<td>X .</td>
<td>X .</td>
</tr>
<tr>
<td>vibration</td>
<td></td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>contact forces</td>
<td></td>
<td>.</td>
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</tbody>
</table>

Resource demands and usability


**Equipment needed**

A tape measure is required to take distance measures.
A weigh scale or force gauge is required to measure the weight of the object(s) being lifted/lowered.
A protractor or goniometer can be used to measure angle of asymmetry or this can be estimated. ([http://www.whsc.on.ca/pdfs/MSD%20Prevention%20Toolbox-%20Part%20C.pdf](http://www.whsc.on.ca/pdfs/MSD%20Prevention%20Toolbox-%20Part%20C.pdf))

**Process of coding and analysis**

Prior to data collection, the analyst must decide (1) if the job should be analyzed as a single-task or multi-task manual lifting job and (2) if significant control is required at the destination of the lift.

| Recommended Weight Limit (RWL) = LC \times HM \times VM \times DM \times AM \times FM \times CM |

\[ LC = \text{Load Constant} = 23 \text{ kg} \]
- The weight of the object being lifted/lowered
- Height of the hands at both the start and end of the lift/lower. \( V \)
- The vertical travel distance of the hands from the start to the end of the lift. \( D \)
- The horizontal distance of hands on the load from the mid-point between the ankles at the start and end of lift. \( H \)
- Angular location of the load relative to a line ‘sticking out’ from the worker’s navel, if the worker was standing in a neutral posture. \( A \)
- Frequency of lifts (average number of lifts per minute and total duration of lifting). \( F \)
- How well the load can be grasped (based on presence and type of handles). \( C \)

Lifting Index (LI) = Actual Load Weight / Recommended Weight Limit

**Output type/level (risk assessment)**

Recommend weight limit, lifting index

**Criteria to help the evaluator to make decision**

RWL is the weight that can be lifted/lowered under the task specific conditions, by 90 per cent of healthy workers (male and female) without increased risk of lifting-related low back pain.

The lifting index (LI) can be used to assess the relative risk of different lifting tasks. When the LI is greater than 1.0, there is an increased risk of lifting-related low back pain and changes should be considered. NIOSH also suggests that when the LI is greater than or equal to 3.0, the risk of lifting-related low back injury is very high and that almost all workers would be at an increased risk.

When the LI is greater than or equal to 3.0, changes to the design of the lifting/lowering task are strongly recommended. ([http://www.whsc.on.ca/pdfs/MSD%20Prevention%20Toolbox-%20Part%20C.pdf](http://www.whsc.on.ca/pdfs/MSD%20Prevention%20Toolbox-%20Part%20C.pdf))

**Fields of the working life where the method has been used**

- physiotherapists (Yeung 2002)
- construction workers (van der Beek 2005)
- industry workers (Wang 1998)
- warehouse workers (Marklin 1999)
- commercial fishing (Kucera 2008)
- bartenders, waitresses and cooks in neighborhood pubs (Jones 2005)
- industry workers and office workers (Waters et al. 1999)
- child care (preschool) workers (Grant 1995)

**Validity**

**Face validity / Contents validity**

Does the method seem to be valid for the aimed purpose?

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The contents of the method is such that a relevant assessment can be expected</td>
<td>x</td>
</tr>
<tr>
<td>Comments: Considers only lifting with two hands; properties of the load like unstability not included</td>
<td></td>
</tr>
<tr>
<td>2. Items to be observed have a sound basis</td>
<td>x</td>
</tr>
<tr>
<td>Comments: Based on the scientific literature</td>
<td></td>
</tr>
<tr>
<td>3. Sound operationalization of the items to be observed</td>
<td>x</td>
</tr>
<tr>
<td>4. Sound process to collect data</td>
<td>x</td>
</tr>
<tr>
<td>5. Sound process to get the output of the collected data</td>
<td>x</td>
</tr>
<tr>
<td>Comments: Multiplicative model probably better than an additive one</td>
<td></td>
</tr>
<tr>
<td>6. Output can help in decision making</td>
<td>x</td>
</tr>
<tr>
<td>Comments: The index score does not directly advise which factor at work should be changed</td>
<td></td>
</tr>
</tbody>
</table>

**Concurrent validity**

How well does the method correspond with more valid method/s?

1) **Comparison of revised (1) NIOSH lifting equation, (2) Arbouw method, (3) rapid appraisal of the NIOSH lifting equation (practitioners’ method), and (4) systematic observations** (van der Beek 2005)

Results: Tab 4 - 6, p. 217-218

"Arbouw and practitioners’ method resulted in a similar ranking order of tasks (transport > construction > dismantlement). In contrast, the observational method gave transport the lowest ranking."

Comments: The other methods are simplifications of NIOSH lifting equation, not more valid ones

2) **Cross-validation based on the previously published data** (Hidalgo 1995) (compare with (Waters 1993)).

- Psychophysiological criteria well agrees but the biomechanical and physiological not totally.
3) NIOSH lifting equation, RULA, Shoaf pulling model and 3D Static Strength prediction program (Jones 2005)
- Comparative data of NIOSH lifting equation, Shoaf pulling model and 3D Static Strength prediction not shown side by side

4) Comparison of five methods to assess risk among autoworkers NIOSH LI, Static Strength Prediction Program, the Lumbar Motion Monitor model, and two variations of the United Auto Workers (UAW)–General Motors Ergonomic Risk Factor Checklist. (Lavender 1999)
- NIOSH LI estimated the jobs be of higher risk relative to other methods.
Comments: Not known, which of the methods is more valid

5) NIOSH Lifting Equation, Static Strength Prediction Program, LLM Borg Scale (Marklin 1999)
- Case studies. Results see Tab 1. All methods show reduction of load after interventions.
Comments: Not known, which of the methods is more valid

6) Comparison of NIOSH, ACGIH TLV, Snook, 3DSSPP and WA L&I lifting assessment instruments (Russell 2007)
The NIOSH, ACGIH TLV and Snook methods were similar (High) in their results with respect to the pattern of exposure associated with lifting two different weights over various height levels - up to shoulder level. The WA L&I and 3DSSPP predicted substantially lower exposures than the three first mentioned. The ACGIH TLV had a relatively higher exposure rating for the two levels above shoulder level, i.e. it weighted lifts above the shoulder more than the other methods. Still, I found these lifts, from high positions with such high weights very uncommon, therefore I checked the “High” box above.
Furthermore, ACGIH TLV and Snook were easier to implement in the field than NIOSH, but not as conductive to experimentation with different inputs.

7) NIOSH and Psychophysically Determined 4-h maximum acceptable weight of lifting (Lee 2005)
- Lab. study, young men made their psychophysiological estimation for maximal weights to be handled for 4 hours. The estimates were much higher than those of NIOSH equation
Comment: The validity of the estimations was not tested e.g. by work simulation.
Comments: It is not known which one of the compared methods is more valid than the NIOSH method
"Predictive validity"
How well has the risk-estimation of the method been shown to be associated with or predicting musculoskeletal disorders (MSDs)?

1) Severity of back pain correlated with LI. (Wang 1998)
   - Linear trend, Tab 3, fig 4

2) LBP during the past 12 mths associated with LI. (Waters 1999)
   - Tab 3-5. "As the lifting index increased from 1.0 to 3.0, the odds of low back pain increased"  

3) Comparison of NIOSH LI with incidence of low-back pain in 353 industrial jobs. (Marras 1999)
   - The revised LI correctly identified 73% of the high-risk jobs but did not identify low- and medium-risk jobs well. Results Tab 5 and Fig 2.

4) Predictive validity of LI (Sesek 2003)
   "When using a lifting index of 1.0 as the cut point, good sensitivity (.76) was achieved, but specificity (.40) was poor. These results are similar to previous research where a sensitivity of .73 and a specificity of .55 were found (Marras et al., 1999). When a lifting index of 3.0 was used as the cut point, sensitivity dropped to .22 and specificity increased to .93"

Intra-observer repeatability (within observers)
- No formal studies

Inter-observer repeatability (between observers)
Participants of one day training course were tested for accuracy eight weeks later (Waters 1998)
- 27 observers, simulated lifting in lab. Frequency not included.
- The "expert" served as a reference
- Variance generally small. Difficulties in location of the reference for horizontal distance; coupling factor, and asymmetry angle (effect on index see tab 2-3)

NOTE: No clear figures given to assess inter-observer repeatability

Conclusions

Strengths of the method
Well documented and tested in several laboratory studies. Sound background based on scientific studies. Outcome related to the risk of the health of back. Calculators available in internet.

Limitations in the use of the method
Plenty of practical limitations (Dempsey 2002). Still the method can be modified without loss of predictive validity (Sesek 2003)
Requirement of several technical measures and calculations means increased requirements for skills and time to make the estimation.
To whom can this method be recommended?

For reseachers to assess individual lifting situations in detail

NOTE: The original method has been adopted to more practical methods (ACGIH TLV, Washington method) for the use of OSH practioners

References


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