THE UTAH LIFTING INDEX: AN EXPLORATION OF LOW BACK PAIN PREDICTIVE MODELS

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ABSTRACT

There is significant evidence that ergonomic risk factors such as posture, force, and repetition are causally related to the development of musculoskeletal disorders and the onset of low back pain (LBP). There are several ergonomic tools currently in use to measure the risk of manual materials handling (MMH), specifically the risk of developing low back pain. Perhaps no ergonomic model has been used for this purpose more than the Revised NIOSH Lifting Equation (RNLE). The RNLE, however, can be complicated to compute when there are multiple lifts with varying parameters. Also, the RNLE is limited in the types of jobs it is intended to analyze (e.g., two-handed, symmetric lifts). This study investigates the ability of several intuitive and science based models to measure LBP risk. Providing safety and health practitioners with simple, but effective, and more usable screening tools will allow industry to analyze more jobs and more efficiently allocate resources to improve jobs that are most likely to result in LBP. The Utah Lifting Index (ULI) was created and tested using a case control study design with an existing database of MMH jobs with known health outcomes. These ULI models show promise for estimating LBP risk associated with MMH jobs and plans are underway to further test them using a prospective cohort study. The current ULI is simpler to use and can be applied to more lifting tasks than the RNLE.

INTRODUCTION AND BACKGROUND

The purpose of this research was to determine if a simplified method for predicting low back pain (LBP) could be devised that would be as effective as the Revised NIOSH Lifting Equation (RNLE) (Waters, 1993), but require less time for data collection and analysis. Such a method could be used by a greater number of analysts to estimate the risk associated with manual material handling (MMH) tasks. A tool that could more easily analyze lifting jobs with high variation would be useful to ergonomists and other health professionals. Several proposed tools based on back compressive force (BCF) were tested using a database of automotive MMH jobs. In addition to increased simplicity, it would be desirable to have a tool that can be applied to lifting tasks that are one-handed or have asymmetrically loaded hands. The authors also wanted to create a tool whose output is not affected by arbitrary grouping of tasks or the order in which tasks are combined. If these additional criteria could be met, a greater number of jobs could be analyzed by a greater number of analysts resulting in improved workplace surveillance.

The Revised NIOSH Lifting Equation (Waters, 1993) is perhaps the best known and most frequently used lifting analysis tool. This study investigates the ability of a new lifting model, the Utah Lifting Index (ULI), to measure risk by predicting employee health outcomes, specifically visits to on-site medical personnel regarding low back pain and self reported low back pain symptoms. Researchers at the University of Utah's Ergonomics and Safety Program conceived the ULI. The rationale behind the ULI was based on previous research conducted by the University of Utah team. The ULI was tested using an existing database of MMH jobs with known health outcomes.

The Revised NIOSH Lifting Equation is intended to evaluate MMH tasks, specifically two-handed lifting tasks (Waters, 1993; Waters, 1994). It produces a recommended weight limit (RWL) at the origin and destination of lift based on the simple product of six measured variables and one constant term. The lesser of the two recommended weights (origin or destination) is used.

The equation is:

$$\text{RWL} = \text{LC} \times \text{HM} \times \text{VM} \times \text{DM} \times \text{AM} \times \text{FM} \times \text{CM} \tag{1}$$

where:

LC = load constant: a constant term equal to 51 lbs.
HM = horizontal multiplier: based on the horizontal distance from the ankles to the load
VM = vertical multiplier: based on the vertical position (height) of the load at the origin and destination
DM = distance multiplier: based on the vertical distance through which the load is moved
AM = asymmetry multiplier: based on the degree of twisting of the torso
FM = frequency multiplier: based on the frequency and duration of lifting
CM = coupling multiplier: based on the grip/interface between the lifted object and the lifter

Each measured multiplier (all of the above except LC) has a range between 0 and 1. Therefore, the maximum possible recommended weight limit (RWL) is 51 pounds and the minimum is zero (indicating that a specific lifting task should not be done). The actual object weight is then compared to this RWL to produce a Lifting Index (LI).

$$\text{LI} = \text{Actual Object Weight} / \text{RWL} \tag{2}$$

NIOSH considers lifts with a lifting index greater than 1.0 to "pose an increased risk for lifting-related low back pain for some fraction of the workforce" and "many workers will be at elevated risk" of work-related injury when performing highly stressful lifting tasks where the lifting index exceeds 3.0. The goal is to design lifting tasks such that the LI is minimized and is preferably less than 1.0 (Waters, 1994).

When multiple tasks are involved, a composite lifting index (CLI) is computed for the overall job. The CLI is computed by taking the largest (worst) individual lifting index (LI) and adding to it incrementally based on the lifting indices of the other tasks modified by the relative frequencies of the tasks. The procedure for computing the CLI can be somewhat complicated and therefore may not be applied (or applied incorrectly) by the typical safety and health practitioner.

The Revised NIOSH Lifting Equation was designed to assess the physical stress associated with two-handed manual lifting tasks. Its application assumes the following conditions:

1. Other manual handling activities are minimal and do not require significant energy expenditures. For example, pushing, pulling, carrying, walking, and climbing activities do not account for more than about 10% of the total work activity.
2. Unpredicted conditions, such as unexpectedly heavy loads, slips, or falls are not present.
3. One-handed lifting, lifting while seated or kneeling, or lifting in constrained workspaces does not occur.
4. An adequate worker/floor coupling (coefficient of friction) is present.
5. The RNLE assumes that lifting and lowering have the same risk.

Most of these assumptions are reasonable for a survey tool. However, the number of jobs that can be analyzed by a tool that excludes one-handed lifts or asymmetric loads will be much smaller than an analysis tool that can evaluate one-handed or asymmetric loads. In a previous study of automotive assembly jobs (Sesek, 2003b), only 57% of the jobs had lifting tasks that were capable of analysis using the RNLE (e.g., had only two-handed, symmetric lifts). The inability to analyze jobs with one-handed tasks is viewed as a major drawback of the RNLE. Lavender et al., (1999) and Sesek et al., (2003a) have investigated the potential for using the RNLE in measuring one-handed lifts. Their intention was to include many manufacturing jobs that did not meet the original limitations of the RNLE.

MATERIALS AND METHODS

Data were analyzed from a database consisting of 667 manufacturing jobs collected from the automotive industry in a prior study. The database included historical injury data for the analyzed jobs as well as symptom interviews and basic medical exams for approximately 1100 subjects. Ergonomic data were quite extensive, with jobs analyzed at the task and sub-task level. Since there was no personal information linking subjects to the jobs studied, approval for accessing the database was granted by both the automotive company and its union representation. Institutional review board (IRB) approval was obtained for the study. All participants signed informed consent documents before participating in the original study.

Ergonomic data for the database were collected at six different automotive plants with a mix of operations ranging from component manufacturing to vehicle assembly. Jobs that were not primarily related to manufacturing, such as administrative jobs or jobs that did not have well defined tasks or relatively short cycle times, such as trouble-shooters and maintenance personnel, were not analyzed.

The parent automotive company maintains occupational injury data. The company uses the injury database to perform occupational medical surveillance of its manufacturing facilities and to identify areas or departments where injuries are prevalent. Outcome data used in this study were both historical and cross-sectional. Historical data included low back pain related first-time office visits (FTOVs) to facility medical for a one-year period retrospectively form the date of the data collection. Cross-sectional data included a symptom survey administered by occupational health nurses to workers at the time that the jobs were video-taped and analyzed.

This was a case-control study in which case jobs were defined as those jobs with at least one of two low back pain criteria: 1) at least one FTOV to facility medical relating to low back pain for any worker on that job during the previous 12 months, or 2) at least one symptom survey report of current low back pain related to the job. Control jobs were those jobs with neither low back pain related FTOVs during the previous year nor current low back pain symptoms.

ULI modeling data have been computed for the sub-set of tasks involving manual materials handling, specifically lifting, lowering, and carrying. There were 251 jobs with lifting, lowering, or carrying that were included in this analysis. Odds ratios, as well as sensitivities, specificities, positive predictive values, and negative predictive values were computed for several ULI cutpoints to evaluate tool performance.

NIOSH (Waters, 1981) reported that most young, healthy workers can tolerate a back compressive force (BCF) of 770 pounds and that BCFs in excess of 1430 pounds were not tolerable to most workers. The ULI relies on a reference BCF of 770 pounds. The total number of lifts for each task is recorded and used to compute the ULI. Like the RNLE, the maximum single task is used to compute the "baseline level of risk" associated with manual handling. The BCF of this task is divided by 770 to produce the principal component of the lifting index. All lifts are used to estimate the cumulative risk of repeated lifting. The ULI allows for risk estimation of jobs with one-handed lifts or unevenly loaded hands and is not affected by arbitrary grouping of tasks. The ULI is increased incrementally for every lift that a worker performs beyond the maximum single task. Other research indicates that the risk of a negative health outcome associated with a job is at least as great as the risk presented by the maximum single task within that job (Drinkaus, 2005a; Drinkaus, 2005b). The ULI concept is still being explored and other methods of adding incrementally to the risk of the baseline risk are still being explored.

The only data required for the ULI are the horizontal distance of the load from the L5/S1 (or hip) to the hands, the amount of torso flexion, and the total number of lifts performed in this posture per shift or per day. More precise estimates of BCF can be made by including the individual subject's height and weight in the computation of BCF or by using more sophisticated BCF modeling tools such as the University of Michigan's 3-D Static Strength Model (3DSSM). Because this is a survey tool, such advanced methods for BCF estimation may not be warranted. Current computation is straightforward and can be easily computed using paper and pencil or a simple computer spreadsheet program. The current ULI as evaluated here relies on the simple user-friendly computation form developed at the University of Utah.

Two methods of computing the ULI were explored for this research. These methods use the Equations 3 and 4 below, where BCFLI is the BCF/770 and $BCFLI_{max}$ is the maximum single task BCFLI for the job.

$$ULI = BCFLI_{\max} + \sum_{i=1}^{j} BCFLI_{i} / 1000 \tag{3}$$

$$ULI = BCFLI_{\max} + \sum_{i=1}^{j} (BCFLI_i)^2 / 1000 \qquad (4)$$

The baseline risk for a given job is represented by the "worst" individual task ($BCFLI_{max}$) and an additional factor is added to account for the cumulative aspects of repeated lifting (summation of all BCFLIs). A factor of 1000 was chosen as a relatively easy scaling factor to account for the cumulative aspects related to multiple lifting without unduly inflating the cumulative risk component of the ULI. Squaring the BCFLI (Equation 4) was intended to downplay the contribution of relatively "easy" lifts (LIs less than 1) and increase the contribution to the risk metric of more stressful lifts (LIs greater than 1). Alternate methods are being investigated with the goal to keep combination methods as simple as possible.

RESULTS

The maximum individual task BCF ($BCFLI_{max}$) alone appears to be associated with higher incidence of low back pain with an odds ratio (OR) of 2.5 (1.2-5.5, 95% CI) for a cut point of 1.0. Likewise, total BCF ($\sum$BCFLI/1000) alone also appears to be associated with higher incidence of low back pain, OR 2.8 (1.5-5.1, 95% CI) for a 0.5 cut point. When these components were combined ($ULI = BCFLI_{max} + \sum BCFLI/1000$), the predictive ability improved further, OR 3.2 (1.9-5.4, 95% CI) for a ULI cutpoint of 1.0. When comparing ULIs above 2.0 to those below 1.0, the OR was 4.1 (1.3-12.6, 95% CI). These data are summarized in Table 1 below.

Table 1. Results for $ULI = BCFLI_{max} + \sum BCFLI/1000$

LI	Odds Ratio
1	3.2 (1.9-5.4, 95%CI)
1.5	3.4 (1.7-6.9, 95%CI)
2	2.6 (0.9-7.9, 95%CI)
1 vs. 2	4.1 (1.3-12.6, 95% CI)

The results for the second model were slightly more predictive. These results are summarized in Table 2 below.

The ULI does appear to be predictive of low back pain and seems to have some advantages over the NIOSH Revised Lifting Equation (NRLE). The ULI is relatively simple and intuitive to apply, it can be applied to one-handed lifting and lifting with unevenly loaded hands, and is not affected by how the tasks are analyzed.

Table 2. Results for ULI = $BCFLI_{max} + \sum(BCFLI)^2/1000$

LI	Odds Ratio
1	4.2 (2.4-7.3, 95%CI)
1.5	3.2 (1.5-6.8, 95%CI)
2	2.6 (0.9-7.9, 95%CI)
1 vs. 2	4.2 (1.4-12.8, 95% CI)

DISCUSSION AND LIMITATIONS

The automotive company's health and employment data were not always maintained at a level adequate to determine with certainty which job in a department or area was the cause of an injury or a report of low back pain. Data were coded to reflect the level of certainty of relationship with the study jobs. Only those jobs for which the researchers, after consultation with area supervisors, were reasonably certain of the relationship of an injury were used in the analysis. However, it is possible that some jobs were misclassified with regard to low back pain status. In addition, the transfer of injured workers from relatively stressful jobs to less stressful jobs may also result in some error as the "healthiest" or "strongest" workers may be placed on the more stressful jobs. However, these limitations are present in virtually all work places and the ULI still performed well given this potential for misclassification. There is a plan underway to apply the ULI to a database of manual materials handling jobs with better-defined health outcomes. Individuals will be linked directly to jobs and physicians will determine low back pain outcomes.

The inclusion of jobs with relatively low weight, but high lifting frequencies may have affected the performance of the ULI models. Future work should seek to determine if there is a "weight threshold" below which jobs should be excluded from lifting analysis. For this study, "low-weight" lifting tasks were not removed.

CONCLUSIONS AND RECOMMENDATIONS

The ULI equations demonstrated significant odds ratios for the prediction of low back pain. In addition, the ULI allows the analysis of one-handed and two-handed asymmetric lifts, increasing the applicability of the model and allowing analysis of many additional manual materials handling tasks. The ULI risk assessment is not affected by how lifting tasks are grouped or analyzed and it does not "crash" as the NRLE does when multiplier limits are exceeded. Estimation of low back pain risk is greatly simplified allowing application to a greater number of jobs in shorter amount of time. ULI outputs are related in terms of BCF which is widely recognized and used as a metric for low back pain risk. Work continues to improve the ULI concept and to develop more user-friendly data collection forms and spreadsheets for computing ULIs.

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