APPLICATION OF THE NIOSH REVISED LIFTING EQUATION TO ONE-HANDED LIFTING TASKS

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ABSTRACT

This study investigated the ability of the Revised NIOSH Lifting Equation (RNLE) to measure this risk of low back injury as verified by employee health outcomes. The RNLE was predictive with an odds ratio of 5.1 (1.6-16.0, 95% CI). The RNLE was modified to allow analysis of one-handed and two-handed, asymmetric lifts. Predictive performance for these methods was promising with an odds ratio of 3.1 (1.3-7.3, 95% CI). These changes to the RNLE show promise for increasing both the usability and utility of the RNLE.

INTRODUCTION AND BACKGROUND

The purpose of this research was to determine if the Revised NIOSH Lifting Equation (RNLE) could be used to effectively evaluate one-handed and two-handed asymmetric lifts. Two proposed methods were tested using a database of automotive manual material handling (MMH) jobs. A tool capable of analyzing one-handed and two-handed, asymmetric lifts would improve workplace surveillance of lifting tasks by allowing more jobs to be analyzed.

There is significant evidence that ergonomic risk factors such as posture, force, and repetition are causally related to musculoskeletal disorders of the low back (Burdorf & Sorok, 1997; Fathallah et al., 1998a,b; Li et al., 1999; NIOSH, 1997; Herrin et al., 1986; Hoogendoorn et al., 1999; Neumann et al., 1999; Rosenstock, 1997; Vingard et al., 2000). There are several ergonomic tools currently in use that purport to measure the risk of manual materials handling, specifically the risk of low back injury (Capodaglia et al., 1997; Fathallah et al., 1998a,b; Grieco et al., 1997; Herrin et al., 1986; Hildago et al., 1997; Levander et al., 1999; Marras et al., 1999; Mital et al., 1997; Neumann et al., 1999; Norman et al., 1998; Potvin, 1997; Shoaf et al., 1997; Waters et al., 1994; Waters et al., 1999; Zurada et al., 1997). Perhaps no ergonomic model has been used for this purpose more than the Revised NIOSH Lifting Equation (Waters, et al., 1993). This study investigates the ability of the Revised NIOSH Lifting Equation to measure risk by predicting employee health outcomes, specifically visits to on-site medical personnel regarding low back pain and injury symptoms. The RNLE was tested using an existing database of MMH jobs with known health outcomes.

The Revised NIOSH Lifting Equation is used to evaluate MMH tasks, specifically two-handed lifting tasks (Waters et al., 1993). 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:

RWL = LC x HM x VM x DM x AM x FM x CM
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).

LI = Actual Object Weight / RWL

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 et al., 1994, p 768).

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 and adding to it incrementally based on the lifting indices of the other tasks modified by the relative frequencies of the tasks.

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 will be greatly reduced. In this study, only 64% of the jobs that had lifting tasks were capable of analysis using the NRLE. This inability to analyze jobs with one-handed tasks is viewed as a major drawback. Levender et al., (1999) also suggested the potential for using the RNLE in measuring one-handed lifts. Their rationale was to include many manufacturing jobs that did not meet the stated 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 of areas or departments where injuries may be a concern. Injury data used in this study were historical and included low back related first-time medical visits for a one-year period retrospectively form the date of the data collection.

NRLE output data have been computed for the sub-set of tasks involving manual materials handling, specifically lifting, lowering, and carrying. Two methods of estimating the RNLE for one-handed and non-symmetric two-handed lifts were explored. Both involved computing a lifting index for each hand independently using a load constant of 25.5 pounds (51 pounds/2). The two individual lifting indices were then combined to produce an effective lifting index in two ways: (1) averaging the LIs of each of the hands and (2) taking the maximum LI for either hand. Taking the maximum hand LI may over-estimate the LI for one-handed lifts, but it is hypothesized that the awkward posture and asymmetric load associated with one-handed lifts can present risks similar to those produced by two-handed LIs of the same magnitude. It should be noted that for situations in which the individual standard RNLE would apply, both of these methods produce results identical to the NRLE.

RESULTS

The RNLE was applied to jobs where appropriate lifting tasks (as defined by NIOSH – only two-handed, symmetric lifting tasks) were present (163 jobs). Corresponding injury data were available for 162 of those jobs. The RNLE was able to predict back injuries with odds an ratio of 4.6 (1.7 – 12.5, 95% confidence interval) for a cumulative lifting index (CLI) of 3.0. In a similar study (Marras et al., 1999), the Revised NIOSH Lifting Equation was found to be predictive of low back disorders with an odds ratio of 3.1 (2.6-3.8, 95% confidence interval) when comparing high risk (lifting index >=3.0) and low risk (lifting index <=1.0) jobs. When comparing high (>=3.0 CLI) and low (<=1.0 CLI) risk jobs, an odds ratio of 5.1 (1.6-16.0, 95% CI) was found.

When using a lifting index of 1.0 as the cut point, good sensitivity (0.73) was achieved, but specificity (0.37) was poor. These results are similar to previous research where a sensitivity of 0.73 and a specificity of 0.55 were found (Marras et al., 1999). When a lifting index of 3.0 was used as the cut point, sensitivity dropped to 0.24 and specificity increased to 0.93.

Of the 667 automotive jobs in the database, a total of 255 jobs required lifting of some sort. Of these, 184 (72%) had lifts capable of analysis with the Revised NIOSH Lifting Equation. However, 21 of the 184 jobs with tasks capable of RNLE analysis also had lifting tasks not capable of analysis with the RNLE (one-handed lifts or hands with differing loads and positions). Therefore, only 64% (163) of the jobs in the database were actually capable of analysis with the RNLE. Jobs with at least one one-handed lift or a lift with differing loads in each hand accounted for 91 jobs (36% of jobs with lifting). It is the intention of this research project to increase the number of jobs for which a simple risk assessment can be conducted.

The application of the RNLE concept to individual hands produced results similar (identical for two-handed symmetric lifts) to those obtained when applying the RNLE to two-handed symmetric lifts only, such as the RNLE model intended. This is exciting since the number of jobs with lifting tasks that could be analyzed increased from 163 (184 had two-handed lifting tasks, but only 163 had only two-handed lifting tasks) to 255. Of the 255 jobs with lifting tasks, 254 had reliable health outcomes that could be used in this analysis.

Using the average lifting index for each hand to represent each task, yielded an odds ratio of 3.1 (1.3 –7.3, 95% CI) when comparing jobs with a cumulative lifting index (CLI) below 1.0 to those above 3.0. This is the same odds ratio found Marras (1999) when comparing jobs with CLIs below 1.0 to those above 3.0.

Using the maximum lifting index for each hand to represent each task, also yielded an odds ratio of 3.1 (1.3-7.4, 95% CI) when comparing jobs with a cumulative lifting index (CLI) below 1.0 to those above 3.0. Results for the two-handed lifts only, however, were significantly better, with an odds ratio of 5.1 (1.6-16.0, 95% CI). This may have been because many of the one-handed lifting jobs had very low weight, but relatively high lifting frequencies and, therefore, relatively high lifting indices despite low weight. The two-handed lifts tended to be heavier weights. This may have tended to overestimate the low-back risk of some one-handed lifting jobs. Perhaps ignoring the lower-weight lifts (e.g., less than 5 pounds) would have improved the performance of the one-handed lifting models.

DISCUSSION AND LIMITATIONS

In the original automotive study, data were collected to satisfy many ergonomic tools. Where possible, these data were measured and collected specifically as prescribed by each ergonomic tool. However, due to logistical constraints, mostly associated with limited on-site time, some ergonomic data were collected in a manner slightly different than the original authors may have stipulated or anticipated. Every effort was made to ensure that any differences in data collection did not substantially alter RNLE outputs, however this may have produced a systematic misclassification of cases and controls.

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. 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 injury 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 RNLE still performed well given this potential for misclassification.

The inclusion of jobs with relatively low weight, but high lifting frequencies may have effected the performance of the one-handed lifting models. Future work should seek to determine if there is a "weight threshold" below which jobs should be excluded from lifting analysis.

The requirement of the RNLE that lifts be made with two-hands may be too limiting. There are many jobs with tasks that require one-handed lifting or the lifting of two separate items simultaneously. In addition, workstation layout or worker preference (or desire to maintain production speed) may encourage a one-handed lift rather than a two-handed lift. A model that incorporates both two-handed and one-handed lifts would therefore be more useful by including more jobs. These proposed methods for evaluating one-handed lifts provide options for evaluating additional MMH tasks, thereby adding to the utility of the modified RNLE.

CONCLUSIONS AND RECOMMENDATIONS

The Revised NIOSH Lifting Equation has demonstrated significant odds ratios for the prediction of low back injuries. In addition, it appears that the RNLE can be modified to allow analysis of one-handed and two-handed asymmetric lifts without greatly hindering performance. This will increase the applicability of the model, allowing analysis of many additional manual materials handling tasks. More work is needed to determine if performance of the one-handed lifting models can be improved to that of the two-handed RNLE.

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