FIELD EVALUATION OF THE REVISED NIOSH LIFTING EQUATION

Patrick G. Dempsey[a], Gary S. Sorock[a], John P. Cotnam[a], M.M. Ayoub[b], Peter H. Westfall[b], Wayne Maynard[a], Fadi Fathallah[c], Niall O'Brien[a]
[a]Liberty Mutual Research Center for Safety & Health, Hopkinton, Massachusetts
[b]Texas Tech University, Lubbock, Texas
[c]University of California at Davis, Davis, California

The preliminary results of a prospective epidemiological study of the revised NIOSH lifting equation are presented. The baseline evaluations included assessment of lifting and lowering tasks with the revised NIOSH equation, as well as a questionnaire regarding personal variables. Subject follow-up was primarily accomplished through postal questionnaires, telephone interviews, and surveillance for workers' compensation claims for low-back disorders. The preliminary results reported are based on approximately 375 person-years of exposure; however, the follow-up period is still in progress. Important findings related to the usability of the revised NIOSH equation across several types of common exposures are also discussed.

INTRODUCTION

One of the most widely-discussed tools for assessing lifting and lowering tasks in industry is the revised NIOSH equation (Waters et al., 1993), a revision of the equation developed in 1981 (NIOSH, 1981). The equation is applicable to two-handed lifting and lowering tasks under certain conditions (e.g.: lifting/lowering without carrying, pushing or pulling; lifting/lowering in favorable ambient conditions). Despite widespread application in the United States, as well as proposed use in standards being developed, little information concerning the ability of the equation to predict the incidence or severity of low-back disorders is available. This information is critical if the equation is going to be used as a risk assessment tool, *per se*. Risk assessment requires estimation of the outcome of interest in a population for a given exposure level. In the case of the NIOSH equation, this indicates that an estimate of the incidence of low-back disorders for a given lifting index (LI) is required for a risk assessment.

There is only limited epidemiological data on the relationship between the revised NIOSH equation and the incidence of low-back outcomes. Waters et al. (1999) reported the results of a cross-sectional study of the relationship between the LI and one-year prevalence of low-back pain in 50 jobs at four sites. A significant prevalence proportion ratio was found when comparing jobs with LI values greater than 2.0 but less than or equal to 3.0 compared to the unexposed group. The results did not indicate a dose-response relationship, but the small sample sizes in some strata may have precluded statistical significance.

The goal of the present study was to prospectively investigate the relationship between the 1991 NIOSH equation and the incidence and severity of filing workers' compensation claims. The severity information, in particular, may be critical since a small percentage of low-back disability claims leads to a high percentage of the total costs. The severity information is not reported here since follow-up is continuing. A secondary aim was to evaluate the usability of the equation in a variety of industrial and service sectors.

METHODS

An exposure assessment protocol was developed to capture the frequency, duration, and magnitude of exposure to lifting and lowering tasks. Magnitude of lifting/lowering tasks was assumed to be captured by the LI. Frequency was assessed by measuring individual task frequencies, and duration was assessed through the hours of daily or weekly exposure to the task. In order to include more jobs, the equation restriction that no pushing, pulling or carrying tasks be performed was relaxed, and these tasks were assessed with psychophysical data. However, there was a requirement that jobs selected for inclusion in the study have a primary lifting and lowering component. For example, jobs with considerable pushing and pulling demands and little lifting or lowering demands were not included.

Originally, the job selection criteria used were aimed at selecting jobs for inclusion that had fairly stable exposure to two-handed lifting and lowering tasks. However, there were substantial difficulties finding suitable candidate jobs. Approximately 60 loss prevention professionals were trained to collect the data according to the protocol, and almost all reported trouble finding jobs suitable for inclusion in the study. All personnel were trained by the same individual for consistency. At that time, a survey was used to determine specific problems encountered. Table 1 gives the results of a survey of 40 jobs not suitable for the study. Although the survey was not comprehensive relative to different industries, the results paralleled the informal feedback the investigators received up to that point.

Table 1. Results of survey (n=40) to determine reasons jobs were not amenable to inclusion in study.

Category	Percent of Jobs
Weights variable (> 10 lbs.)	63%
Job changes often	25%
Job Rotation	23%
Too many tasks to analyze	23%
No 2-handed lifting	15%
Frequency too high	15%
Workers not willing	3%
Language barriers	3%

In general, there were a number of jobs that could not be included in the study using the original protocol due to two primary factors: (1) many jobs do not have a distinct number of tasks that can be measured (e.g., warehouses, where there are an almost infinite number of distinct tasks and LI values), and (2) the parameters of lifting/lowering tasks in jobs with fairly similar day-to-day tasks change (e.g., a machine shop where the weights change, but the machining activities are fairly constant; a palletizing operation where the weights of product change daily or within the day). In these cases, the parameters are actually variables. Subsequently, the LI (or composite lifting index) is actually a variable that changes over time.

The criteria were revised to allow inclusion of jobs with dynamic lifting task contents (such as those typically found in warehouses), jobs with rotation of workers among several exposures, and jobs with variable weight demands. Protocols were developed to address each of these cases. The protocol for warehousing/complex jobs involved a procedure to sample 15 representative tasks. The job rotation protocol was designed to measure the rotations with the most stressful tasks and the longest duration. If all rotations had similar stress levels, the two rotations with the longest durations were assessed. The variable weight protocol was designed to capture the distribution of weights handled.

In addition to the exposure assessment of manual handling exposures, workers were also interviewed to capture personal variables. In addition to demographic variables, information on factors including smoking, regular exercise, back belt use, and driving were also captured. Following the baseline job assessment and interview, workers are followed up via postal questionnaire every three months to determine if they have reported a work-related injury or illness and whether or not they are still working the same job as when interviewed. In order to increase the response to the postal questionnaire, a lottery consisting of three $50 prizes are raffled after each mailing for those returning the questionnaire. Phone calls are made to non-respondents, and site visits or contact with site personnel are sometimes used to locate non-respondents.

The outcome measures used include OSHA 200 reports and workers' compensation claims during the follow-up period. Only the workers' compensation results will be discussed here. The primary outcome measure being studied is compensable low-back disorders. However, all workers' compensation claims are collected. Low-back claims due to traumatic events (such as the result of a fall or struck-by accident) are excluded. Also, subjects are removed from the study when a low-back claim is reported, including those attributed to traumatic events.

RESULTS

As of the end of 1999, 392 subjects from over 60 facilities throughout the United States completed baseline evaluations. Table 2 provides a summary of the demographics of the sample. Approximately 375 person-years of exposure have been recorded. The mean length of exposure for the analysis presented here was 48 weeks, with a standard deviation of 43 weeks. There was a loss to follow-up of approximately 13%; however, some of these subjects accumulated some exposure time. There was a total of 180 subjects (46%) out of the study due to job changes, not wanting to participate in the study any longer, or because they could no longer be contacted due to address changes, etc.

Table 2. Summary of subject demographics.

Gender	Mean Age (SD)	Mean Weight (SD)	Mean Height (SD)
Female	39.0 (9.7)	67.3 (14.1)	163.2 (8.4)
Male	36.2 (10.1)	85.3 (17.4)	178.1 (11.2)

SD = Standard deviation, height in cm., weight in kg.

Table 3. Summary statistics of the 1123 lifting and lowering tasks.

Variable	Mean	Std. Dev.	Minimum	Maximum
Weight (kg)	11.7	6.7	0.5	45.4
V - Origin (cm)	89.3	32.7	2.5	228.6
V - Destination (cm)	88.6	34.7	2.5	213.4
H - Origin (cm)	41.8	13.9	12.7	124.5
H - Destination (cm)	45.4	15.2	10.2	114.3
A - Origin (°)	15.1	21.6	0.0	110.0
A - Destination (°)	17.6	21.5	0.0	110.0
Frequency (lifts/min)	2.0	2.9	0.01	15.0

V = vertical location, H = horizontal location, A = asymmetry

Table 4. Summary of claims by exposure category.

	LI Category			
	$0 < LI \leq 1$	$1 < LI \leq 2$	$2 < LI \leq 3$	$3 < LI$
Exposure hours	147920	155919	173365	289592
# WC Claims	1	1	1	6
Rate/100 FTE	1.35	1.28	1.15	4.14

WC = workers' compensation, FTE = Full-time equivalent

Of the personal variables that have been studied with regards to low-back disorder risk, the history of previous low-back problems appears to be one of the more consistent risk factors found across different studies (Dempsey et al., 1997). Subjects were asked at the baseline interview if they had filed a workers' compensation claim in the past 12 months. A positive response was indicated for 5.4% of the subjects. None of the nine subjects that filed a workers' compensation claim during the follow-up period reported a positive response to this question.

The LI calculations discussed below are based on 1123 lifting and lowering tasks assessed during the baseline job evaluations. Table 3 provides descriptive statistics for the parameters of these tasks. The parameters were measured according to the descriptions given by Waters et al. (1994). For all tasks, both the origin and destination measures were taken, even if significant control was rated as 'No.' It is interesting to note that duration was rated as 'Long' for 79% of the tasks. This may be a reflection of the recommendation that jobs selected for inclusion in the study should be comprised mainly of materials handling. Coupling was rated "Poor' for 20% of tasks, 'Fair' for 72% of tasks, and 'Good' for 9% of tasks. Significant control was rated as 'No' for 63% of tasks and 'Yes' for 37% of tasks.

Table 4 provides the rates of filing workers' compensation claims for low-back disorders during the follow-up period. The method used was to consider 2000 hours as one full-time equivalent. This is the method used by the Occupational Safety and Health Administration.

CONCLUSIONS

At this time, the authors consider the epidemiological results preliminary. The follow-up period is continuing, and the additional exposure time will likely enhance the statistical reliability of these results. It should be noted that Table 4 does not provide any control for potential confounding variables, and that the trend is statistically only marginally significant ($p = 0.08$ using logistic regression with ln(LI) as the predictor variable).

Based upon our application of the revised NIOSH equation in a wide variety of industrial and service sectors, we believe that some conclusions on the usability of the equation are warranted. The first conclusion is that the restriction of the equation that jobs with pushing, pulling, or carrying tasks should not be analyzed with the equation is very limiting. If this limitation is strictly followed, considerably fewer jobs are amenable to analysis with the equation. Although the jobs selected for this study were required to have primary lifting or lowering components, 44% of the subjects also had pushing, pulling, and/or carrying tasks. Carrying, in particular, is a common task performed when lifting and lowering demands are present. Carrying is often required by palletizing tasks, loading and unloading tasks, as well as some production tasks.

The most important issue appears to be that the equation and the Composite Lifting Index (CLI) technique are not applicable to quite a few industrial MMH exposures. The CLI does not apply to exposures that occur at different times such as with job rotation and other job designs where workers do not perform the same MMH tasks throughout the day. One approach for such situations is to use a time-weighted average of CLIs for the different task groups. For instance, two distinct palletizing operations could be weighted by the hours per day spent on each operation.

Similarly, the CLI procedure is not applicable to exposures involving many distinct lifting tasks that constantly change. These types of exposures appear to be most common in the transportation and storage sectors. Loading and unloading trucks, shipping and receiving jobs, as well as various warehouse jobs (e.g., order picker) are examples of exposures with these characteristics. This finding is not specific to the revised NIOSH equation, but also applies to other assessment methods that assume that the parameters of tasks do not change, or that the tasks do not change throughout the day. For such exposures, time- and frequency-weighted averages, integrating stresses, or using sampling methods may be more appropriate (Dempsey, 1999). Perhaps an even better solution is to develop more systemic approaches to the assessment of MMH exposures with complex characteristics.

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Human Factors and Ergonomics Society
P.O. Box 1369
Santa Monica, CA 90406-1369 USA
310/394-1811, fax 310/394-2410
info@hfes.org
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