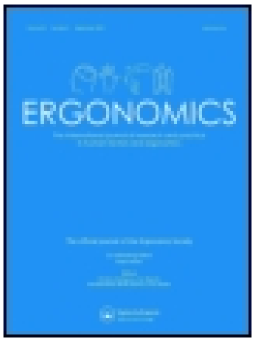

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New procedure for assessing sequential manual lifting jobs using the revised NIOSH lifting equation

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A sequential manual lifting job is defined as a job where workers rotate between a series of manual lifting rotation slots or elements at specified time intervals during the course of a work shift. The original NIOSH lifting equation lacked a method for assessing the physical demands of these types of jobs. This paper presents the sequential lifting index (SLI), a new conceptual method for assessing the physical demands for sequential manual lifting jobs. The new method is similar to the composite lifting index (CLI) method that was provided by NIOSH for assessing multi-task jobs. The SLI method expands upon the methods originally provided by NIOSH by providing a simple method for estimating the relative magnitude of physical stress for sequential manual lifting jobs. It should also be useful in assisting safety and health specialists to prioritize or rank hazardous jobs within a plant.

Keywords: Manual lifting; Lifting index; Job rotation; Sequential exposure

1. Introduction

Historically, the National Institute for Occupational Safety and Health (NIOSH) has recognized the problem of work-related back injuries, and published the Work Practices Guide for Manual Lifting (WPG) in 1981 (NIOSH 1981). The NIOSH WPG contained a summary of the lifting-related literature before 1981; analytical procedures and a lifting equation for calculating a recommended weight for specified two-handed, symmetrical lifting tasks; and an approach for controlling the hazards of low back injury from manual lifting. The approach to hazard control was coupled to the action limit (AL), a resultant term that denoted the recommended weight derived from the lifting equation.

In 1985, NIOSH convened an *ad hoc* committee of experts who reviewed the current literature on lifting, including the NIOSH WPG. (The *ad hoc* 1991 NIOSH Lifting Committee members included: M.M. Ayoub, Donald B. Chaffin, Colin G. Drury, Arun Garg, and Suzanne Rodgers. NIOSH representatives included Vern Putz-Anderson and

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Thomas R. Waters.) The *ad hoc* committee recommended criteria for defining the lifting capacity of healthy workers and they used the criteria to formulate the revised lifting equation. (For this document, the revised 1991 NIOSH lifting equation will be identified simply as 'the revised lifting equation.' The abbreviation WPG will continue to be used as the reference to the earlier NIOSH lifting equation, which was documented in a publication entitled Work Practices Guide for Manual Lifting (NIOSH, 1981)). Subsequently, NIOSH staff developed the documentation for the equation and played a prominent role in recommending methods for interpreting the results of the lifting equation. The rationale and criterion for the development of the revised NIOSH lifting equation (RNLE) are provided in a journal article entitled: 'Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks,' (Waters *et al.* 1993). Detailed information about using the revised lifting equation is contained in a NIOSH report (Waters *et al.* 1994).

The RNLE consists of two primary products, the recommended weight limit (RWL) and the lifting index (LI). The RWL is the principal product of the revised NIOSH lifting equation. 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 (LBP). By 'healthy workers,' we mean workers who are free of adverse health conditions that would increase their risk of musculoskeletal injury.

The concept behind the revised NIOSH lifting equation is to start with a recommended weight that is considered safe for an 'ideal' lift (i.e. load constant equal to 23 kg or 51 lbs) and then reduce the weight as the task becomes more stressful (i.e. as the task-related factors become less favorable). The precise formulation of the revised lifting equation for calculating the RWL is based on a multiplicative model that provides a weighting (multiplier) for each of six 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). The weightings are expressed as coefficients that serve to decrease the load constant, which represents the maximum recommended load weight to be lifted under ideal conditions. The second primary product of the RNLE is the LI. The LI is a term that provides a relative estimate of the level of physical stress associated with a particular manual lifting task. The estimate of the level of physical stress is defined by the relationship of the weight of the load lifted and the recommended weight limit. The LI is defined by the following equation:

$$\mathrm{LI} = \frac{\text{Load Weight}}{\text{Recommended Weight Limit}} = \frac{\mathrm{L}}{\mathrm{RWL}}$$

Where Load Weight(L) = weight of the object lifted (lbs or kg).

The LI was provided for estimating the physical demand for a job that was defined as a 'single-task' manual lifting job. A single-task job was defined as a job in which the task variables do not significantly vary from lift to lift, or only one lift is of interest (e.g. worst case analysis.) The developers of the RNLE also provided a formula for calculating the composite lifting index (CLI) for assessing multi-task lifting jobs that were defined as jobs in which there are significant differences in lifting tasks that are done concurrently, such as a palletizing job, where the vertical height can vary from lift to lift. No method was provided, however, for estimating the physical demands for lifting jobs in which the worker moves between workstations or job elements during the shift and where the lifting characteristics vary between the elements that are done in sequence. That is, jobs where a worker may perform a series of lifts at a specific workstation for a fixed period of time (either single or multi-task), and then transfer or rotate to another workstation or job element to perform a different series of lifting tasks (either single- or multi-task). These types of lifting jobs are called sequential lifting jobs and a different method is needed to calculate the relative physical demands for these types of manual lifting jobs than those originally presented by NIOSH (Waters *et al.* 1994). In a paper reporting on a cross-sectional study of lifting and LBP, Waters and colleagues stated that because there was no procedure currently available for evaluating sequential lifting exposures, they were forced to assign workers an LI exposure value with the greatest LI value during the shift. They stated that this could result in overestimation of LI, which would bias the risk estimate toward the null (Waters *et al.* 1999). Thus, a procedure for assessing the physical demands for lifting jobs where workers rotate between job elements in sequence is needed. The purpose of this paper is to present a new theoretical procedure for assessing the physical demands for sequential manual lifting jobs that was not previously available. The new method is termed the sequential lifting index (SLI). As with the previously proposed CLI formula, the new SLI method is a conceptual procedure that is based on expert opinion that will require validation as a risk assessment method.

2. Rationale for SLI formula

From a biomechanical perspective, it has been shown that repetitive spine loading, such as the type of loading that occurs during repetitive lifting, reduces the strength of the spine tissues and increases the risk of damage resulting from fatigue failure (Brinckmann *et al.* 1987). It has also been shown that when the load is reduced, the tissue begins to recover its original strength. This effect likely results from the hysteresis that occurs when viscoelastic tissues, such as the spinal tissues, are repetitively loaded and unloaded. For this reason, we hypothesize that the order of exposure of variable levels of load (i.e. varying periods of high and low loads) should be considered when calculating the RWL for a job with rotation.

From a physiological point of view, it is clear that jobs with rotation will have variable levels of physiological demand. For example, during a period of heavy lifting, aerobic metabolism will not be able to keep up with the energy demands of the system, and the system will resort to anaerobic metabolism. If the period of heavy lifting lasts too long, all of the anaerobic metabolites may be used up, resulting in physiological fatigue. If periods of heavy lifting are followed by periods of lighter lifting, however, the system may be able to rely more on aerobic metabolism and not have to shift over to anaerobic metabolism, thereby saving some of the anaerobic metabolites to maintain a high level of physiological capacity. This effect was discussed by Rodgers in *Ergonomic Design for Work* (Eastman Kodak 1986). As with the biomechanical loads, we hypothesize that the order of exposure of variable levels of demand (i.e. varying periods of high and low loads) should be considered when calculating the recommended weight limit for a job with rotation.

To our knowledge, the psychophysical method has not been used to examine jobs with variable loads that occur over the course of a work shift. Some researchers have suggested that psychophysical methods are considered to be an integration of the biomechanical and physiological loads, as perceived by a worker (Ayoub *et al.* 1983, Karwowski and Ayoub 1984). Based on this assumption, we hypothesize that the psychophysical effect would be similar to that for the biomechanical and physiological factors and a similar response would be observed for psychophysical measures. That is, the order of exposure of variable levels of load (i.e. varying periods of high and low loads) would likely have an effect on psychophysical response. Therefore, we believe that any approach for assessing sequential jobs should be sensitive to these order effects.

As with the existing CLI formula, it is important to use the appropriate frequency multiplier value when calculating the LI for a job. This is especially true when the worker rotates between job elements with different physical demands. In order to do this for lifts that occur in sequence over a shift, a method or procedure is needed to calculate the appropriate frequency multiplier that takes into consideration the biomechanical, psychophysical, and physiological demands of the job as a whole, but also accounts for the relative time exposures for the various elements of the job. In order to do this, the SLI formula was derived based on the following assumptions (1) the physiological demand for a series of sequential lifting elements performed over a shift would be different (i.e., either higher or lower) than what it would be if lifting was performed at only one element (rotation slot) over the entire shift; (2) this difference would be a function of the amount of time spent in each of the individual sequential lifting elements; and (3) the physiological demand for a job with sequential lifting elements would be a function of the sequence of the elements, as they relate to the workload and recovery patterns. If the primary driver for the difference between sequential job elements is biomechanical load, then the SLI will reflect this effect due to the lack of impact on the frequency multiplier. That is, the SLI will be nearly equal to the maximum LI for any one element in the job.

3. Proposed methods for assessing sequential lifting jobs

An example of a sequential lifting job would be one in which a worker lifts one product at the end of an assembly line for a fixed period of time (e.g. 1 h), and then changes products for a fixed period of time, and so on. Another example of a sequential lifting job would be one in which a worker performs a series of lifts at one workstation (e.g. a palletizing job) and then rotates to another workstation and performs a different set of lifting tasks (e.g. a different palletizing job). In such situations, the existing LI and CLI calculations cannot be used to estimate the physical demand of the job. For these types of jobs, each rotation position will be considered to be a job element. A hypothetical example of this type of situation is shown below where a worker rotates at regular intervals between two different manual lifting workstations (elements), each with its own unique set of physical demands.

A = Job element with heavy manual lifting.
B = Job element with light manual lifting.

The following are examples of possible work sequences that may occur for a complete work shift (assume each letter represents 1 hour and lunch = 1 h).

1. A B A B (lunch) A B A B
2. A A B B (lunch) A A B B
3. A A A B (lunch) A A A B
4. B B B A (lunch) B B B A
5. A A A A (lunch) A A A A
6. B B B B (lunch) B B B B

For this type of job, the normal LI and CLI calculations will not provide an estimate of the overall physical demands of the job as a whole, but can only provide an assessment of any single element (i.e. element A or B) within the job. Therefore, a procedure is needed to account for the overall exposure due to the variable exposures during the shift.

Based on the criteria used to derive the RNLE, we explored several possible ways to use the lifting equation to assess jobs with sequential exposures. These approaches can be demonstrated using data from a hypothetical sequential lifting job. Assume the job consists of sequential lifting elements (rotations slots) A and B and a recovery or light duty time period or element C. Rotation slots A and B have the characteristics shown in table 1. (The following terms are taken from Waters *et al.*, 1994: LC- Load Constant (23 kg or 51 lbs), HM-Horizontal Multiplier, VM-Vertical Multipler, DM-Distance Multiplier, AM-Asymmetric Multiplier, CM-Coupling Multiplier, FIRWL-Frequency Independent Weight Limit).

One approach to assess this job would be to use the 'peak LI or CLI value' of any job element observed across the work shift. In practice, this method would require the calculation of the LI or CLI for each element using the longest continuous exposure duration for that element. The LI or CLI for the job would be the peak or largest value for any of the elements. For a job consisting of the elements AABB from the data provided above, then the 'Peak' LI or CLI value for this job would be based on two hours exposure for either A or B. The 2-hr value for A is 3.02 and the 2-hr value for Element B is 1.32. Hence, the LI for this job using the peak method would be 3.02. For a job with the sequence ABAB, the peak would be 1.77 (i.e. the larger of 1.77 or 1.13). This method, however, is not sensitive to various elemental sequence patterns. For example, the sequences ACCC and ABAB would both result in a 'peak job LI or CLI value' of 1.77. Clearly, the pattern ABAB would be significantly more demanding than the pattern ACCC, which is not reflected by the 'Peak' calculations.

A second possible approach would be to use the 'average' of the LI and CLI values across all job elements performed in sequence. As with the 'peak' method, this method would require the calculation of the LI or CLI for each element using the longest continuous exposure duration for that element. Using this method the LI and CLI values would be averaged across the elements. Using the example data provided in table 1, the average LI or CLI for a job with the sequence AABB would be: $(3.02 + 1.32)/2.0 = 2.17$. As with the 'Peak' method, the 'Average' method is also not sensitive to the various task sequences. This can be seen by examining the 'Average' for the two sequences AABB and AACC. The 'Average' LI for sequences AABB and AACC are 2.17 and 3.02, respectively. Clearly, the sequence AABB should be greater than the sequence AACC, but this is not the case. Therefore, this approach would fail to accurately account for the variable sequence in job elements.

A third approach, which relies on a time-weighted SLI method, was also evaluated. The step-by-step SLI procedures for assessing jobs that are performed in sequence are listed below:

Step 1. The work pattern or rotation pattern should be documented on a timeline of the shift, as shown in table 2. The pattern should show how the worker rotates among the different work stations or tasks. In the example shown in table 2, A and B are manual lifting tasks, R represents a work break for lunch, and C represents a light duty task (i.e. a task without lifting).

Table 1. Lifting characteristics for rotation slots in hypothetical sequential job.

Slot	LC × HM × VM × DM × AM × CM	Freq	FIRWL	Load Wt	1-HR LI	2-HR LI	8-HR LI
A	$23 \times 0.83 \times 0.78 \times 0.88 \times 0.80 \times 0.90$	8	9.43	10	1.77	3.02	5.89
B	$23 \times 1.00 \times 0.93 \times 0.93 \times 0.88 \times 0.90$	4	15.76	15	1.13	1.32	2.12

Table 2. Example work pattern or rotation pattern.

2H		1H	1H	2H		1H	2H	
A	A	B	R	A	A	B	C	C
	MMH		LUNCH		MMH		RECOV	

When using this method, you must assume that no manual handling task (single or multiple) can last more than 4 h continuously without a recovery period (such as light duty or lunch). In cases where the total work time exceeds 8 hours, you can calculate the SLI value for each 4 h period and then take the larger of the values to represent the SLI for the job as a whole.

Step 2. Calculate the LI or CLI for each unique task category, as described by Waters *et al*. 1994. This is accomplished using the 'FM actual duration' value for each task. When a single task is performed for more than 1 continuous hour then the LI value for that task must be calculated using the duration category for that period, but when two identical tasks are separated by another task, then each category is calculated using its own duration. Considering the example in table 2, if the order is ABAB, then the LI for each letter would be calculated using the short duration (1 h category) frequency multiplier (FM). If the sequence was AABB, however, then the FM for each would be calculated using the moderate duration (1–2 h category) FM. Similarly, for the sequence AAAB, the FM for each would be calculated using the long duration (8-hr category).

Step 3. Calculate the maximum lifting index (LImax) for each task category (e.g. tasks A and B). The LImax is calculated using the 'FM total duration' value, which is derived from the FM table based on the frequency of the task and the duration category associated with the longest continuous lifting period (AAB) is 8 h. Therefore, the FM total duration for Task A is 0.18. In Case 2, however, the frequency for Task B is 4 per minute and the longest continuous lifting period (BB) is 2 h, resulting in an FM total duration value of 0.72.

Step 4. Calculate the time fraction (TF) for each task category by dividing the task duration in minutes by 240 min (e.g. for AABC, the $TFA = 120/240 = 0.50$ and $TFB = 60/240 = 0.25$).

Step 5. Re-order tasks by the LImax values for the tasks in a descending order. Set the largest LImax to be LImax1 and its corresponding LI to be LI1. Set the second largest LImax to be LImax2 and so on. For the sample rotation pattern AABC (Case 1 below), the LImax (5.89) for task A is the largest and re-ordered to be Task 1. The LImax (2.11) for task B is the second largest and re-ordered to be Task 2. Therefore, LI1 is set to be equal to the LI (3.03) for task A. LImax1 and LImax2 are set to be the LImax for Tasks A and B, respectively.

Step 6. Calculate the SLI using the following formula:

$$\mathrm{SLI} = \mathrm{LI1} + (\mathrm{LImax} - \mathrm{LI1}) \times \mathrm{K}$$

$$\text{Where } \mathrm{K} = \frac{\sum \mathrm{LImax1} \times \mathrm{TF1} + \mathrm{LImax2} \times \mathrm{TF2} + \cdots\cdots + \mathrm{LImaxn} \times \mathrm{TFn}}{\mathrm{LImax1}}$$

Please note that:

(a) LImax1 is the highest LImax, and LI1 is its corresponding LI. It may be that LI1 is not the highest in absolute terms, but this does not bias the calculations that follow.

(b) The time fraction (TF) is calculated on 240 min, because in most actual working environments no continuous lifting task usually take place for periods longer than 4 h. Moreover, the use of 240 min as denominator in the calculation of TF enables a better evaluation of the SLI.

(c) K is a weighting factor calculated by multiplying the LImax of each task by the corresponding TF, adding together the resulting values and then dividing them by the LImax1.

(d) If the work pattern for an overall job is such that there are sufficient recovery periods to insure that the job always stays in the short duration category (i.e. sufficient recovery means that the duration of any task category is 1 hour or less followed by a recovery period of equal duration), then the SLI is equal to the greatest of all LImax or CLImax. In this special case, the LImax1 becomes LI1, which cancels out the term (LImax1-LI) in the formula. Therefore, the SLI is equal to LI1. Since the LI1 is set to be the greatest LI among all tasks, the SLI for this job would be set to the greatest of the LI values for all the tasks. For example, if the job rotation is something like A C B C, from the example above, where C is a sufficient recovery period for tasks A and B, then the LI for the job would be either the LI for task A or Task B, whichever is greatest.

4. Example

Assume a job consists of sequential tasks, A and B, and a recovery or light duty task C. The SLI is calculated for various sequences shown below.

Case 1. Sequence AABC. Assuming each letter represents 55 min, the SLI for this job would be calculated as follows.

Task	LC × HM × VM × DM × AM × CM	F Lifts/ min	FIRWL	Load Wt	FM actual duration	LI	FM total duration	LImax	TF	Order by LImax
A	23 × 0.83 × 0.78 × 0.88 × 0.80 × 0.90	8	9.43	10	0.35	3.03	0.18	5.89	.46	1
B	23 × 1.00 × 0.93 × 0.93 × 0.88 × 0.90	4	15.76	15	0.84	1.13	0.45	2.11	.23	2

$$\mathrm{SLI} = \mathrm{LI1} + (\mathrm{LImax1} - \mathrm{LI1}) \times \mathrm{K}$$

$$\mathrm{SLI} = \mathrm{LI1} + (\mathrm{LImax1} - \mathrm{LI1}) \times \frac{\mathrm{LImax1} \times \mathrm{TF1} + \mathrm{LImax2} \times \mathrm{TF2}}{\mathrm{LImax1}}$$

$$\mathrm{SLI} = 3.03 + (5.89 - 3.03) \times \frac{5.89 \times 0.46 + 2.11 \times 0.23}{5.89}$$

$$\mathrm{SLI} = 4.58$$

Case 2. Sequence ACBB. The SLI would be calculated as follows.

Task	LC × HM × VM × DM × AM × CM	F Lifts/ min	FIRWL	Load Wt	FM actual duration	LI	FM total duration	LImax	TF	Order by LImax
A	23 × 0.83 × 0.78 × 0.88 × 0.80 × 0.90	8	9.43	10	0.60	1.77	0.35	3.03	.23	1
B	23 × 1.00 × 0.93 × 0.93 × 0.88 × 0.90	4	15.76	15	0.72	1.32	0.72	1.32	.46	2

$$SLI = LI1 + (LImax1 - LI1) \times K$$
$$SLI = LI1 + (LImax1 - LI1) \times \frac{LImax1 \times TF1 + LImax2 \times TF2}{LImax1}$$
$$SLI = 1.77 + (5.89 - 1.77) \times \frac{5.89 \times 0.23 + 2.11 \times 0.46}{5.89}$$
$$SLI = 3.40$$

Case 3. Sequence AABB. The SLI would be calculated as follows.

Task	LC × HM × VM × DM × AM × CM	F Lifts/ min	FIRWL	Load Wt	FM actual duration	LI	FM total duration	LImax	TF	Order by LImax
A	23 × 0.83 × 0.78 × 0.88 × 0.80 × 0.90	8	9.43	10	0.35	3.03	0.18	5.89	.46	1
B	23 × 1.00 × 0.93 × 0.93 × 0.88 × 0.90	4	15.76	15	0.72	1.32	0.45	2.11	.46	2

$$SLI = LI1 + (LImax1 - LI1) \times K$$
$$SLI = LI1 + (LImax1 - LI1) \times \frac{LImax1 \times TF1 + LImax2 \times TF2}{LImax1}$$
$$SLI = 3.03 + (5.89 - 3.03) \times \frac{5.89 \times 0.46 + 2.11 \times 0.46}{5.89}$$
$$SLI = 4.82$$

Using the appropriate LI values for each task and the new SLI procedures listed above, the following SLI values are calculated for various sequences of tasks A, B, and C.

Sequence	SLI
BCCC=	1.13
BBCC=	1.32
ACCC=	1.77
BBBC=	2.11
ABCC=	2.19
AACC=	3.03
BBAC=	3.40
BBBA=	3.73
BABA=	4.34
ABAB=	4.34
AABC=	4.58
BBAA=	4.82
AABB=	4.82
AAAC=	5.89
AAAB=	5.89
AAAA=	5.89

Remember, that when a task is performed more than 1 hour, the FM value for the actual time period is used. That is, when AA was performed in the case 1 above, the FMactual was 0.35, whereas in the case 2 it was 0.6. Similarly, in case 1 above, the FMactual for B was 0.91, whereas for case 2 it was 0.84. Based on our assessment of the SLI response across different sequence patterns, it appears to be sensitive to variations in the sequence of tasks across the work shift.

5. Discussion

According to the documentation for the RNLE, 'the LI [or CLI] can be used to estimate the relative magnitude of physical stress for a task or a job. The greater the LI, the smaller the fraction of workers capable of safely sustaining the level of physical demand for the lifting job.' Unfortunately, the LI or CLI did not apply to jobs with sequential lifting tasks, as described in this document. Therefore, the new SLI method is proposed to expand upon the original RNLE by providing a method for estimating the physical demands of jobs that was not previously available. It should be noted that neither the original CLI method for the RNLE (Waters *et al.* 1994), nor the SLI method proposed in this paper has been comprehensively validated as a risk assessment tool at the workplace. Nevertheless, the proposed SLI method should provide useful information about the physical demands of lifting jobs where workers rotate between workstations and/or tasks as part of their jobs.

It can be seen that task sequence can be critical in some situations. For example, the sequences ABAB and AABB have the exact same amount of total lifting, but the sequence ABAB has a lower SLI (4.34) than the sequence AABB (4.82). Conversely, the SLI for the sequences BABA and ABAB are the same (4.34), as are the SLI values for the sequences BBAA and AABB (4.82). Thus, it is important to recognize that there may be a sequence effect on the SLI calculation, depending upon the pattern of workloads. The difference results from the recovery that occurs when a demanding (heavy) lifting task is separated by a less demanding (light) lifting task. In the sequence ABAB, where A is a heavy task and B is a less demanding task, the SLI method shows that the overall loading is less than if the heavy task is done continuously for two hours, such as in the AABB sequence. This suggests that the SLI method could be used to assist in design of rotation patterns to insure minimization of the overall loading on the worker over the entire shift.

It can be seen in the example presented earlier that the SLI method may not always be sensitive to differences in jobs when any single category exceeds a continuous exposure greater than 2 h. For example, the SLI for the sequences BBBC and BBBA are 2.11 and 3.73, respectively, whereas the SLI for the sequences AAAC, AAAB and AAAA are all 5.89. This is due to the design of work duration classifications for the RNLE. There is no distinction between work duration classifications for work duration between 2 and 8 hours. Any jobs that are performed continuously for more than 2 hours are considered to be at the same level of risk of developing low back disorders.

Finally, it should be noted that it is difficult to compare an SLI value to what the value would be if the LI or CLI was used, since the LI and CLI do not apply to jobs with rotation. However, it can be shown that the SLI would be lower than the LI or CLI would have been for a job if the analyst had assumed a worst case scenario (i.e. if the analyst assumed that the entire period was performed on the task with the greatest LI value). On the other hand, the SLI value would be higher than the LI or CLI if the analyst assumed that the entire period was performed for the task with the lower LI or CLI. Clearly, this comparison is dependent upon the assumption of the analyst. For this reason, we believe the new SLI will provide a much more accurate and useful method for assessing jobs with lifting tasks performed in rotation.

6. Conclusions

The NIOSH lifting equation has been shown to be a useful tool for assessing the physical demands of two-handed manual lifting tasks. However, the LI and CLI methods previously published by NIOSH do not allow assessment of jobs in which workers rotate between tasks or workstations. Therefore, we developed the SLI method for assessing jobs with rotation between work stations. As with all ergonomic exposure assessment methods, the SLI method has limitations. Moreover, the SLI method has not been validated as a risk assessment tool. Nevertheless, we believe that the SLI method will expand the usability of the RNLEs and allow users to better assess the physical demands of complex jobs that was not previously available. Although the SLI method is more complex than the previous LI and CLI methods, due to the fact that more data will have to be collected on the various tasks, we believe that it provides useful information to users to help expand their capability to assess complex manual lifting jobs in industry. Based on our preliminary analysis of the SLI method, we concluded that the SLI is capable of differentiating between the physical demands of complex lifting jobs involving worker rotation schemes during a shift. However, further evaluation of the effectiveness of the SLI as a lifting assessment tool is needed.

Finally, although the SLI equation was not developed for the purpose of assessing risk of LBP, it likely will be used for this purpose by some users. Therefore, we believe that laboratory and field studies are needed to examine the validity of the SLI method as an MSD risk assessment tool (e.g. low back and shoulder disorders) resulting from exposure to physically demanding sequential lifting jobs. These studies should focus on how well the SLI method addresses the basic physiological, biomechanical, and psychophysical criteria for sequential jobs across a wide spectrum of frequencies and loading conditions.

Disclaimer

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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