◈ **Application Papers**

Workload Measurement of Lifting Task by Lifting Index Simulator

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ABSTRACT

Today, the number of automated machine has rapidly increased in industrial workplaces. Nevertheless, workers are often required to handle materials manually. Technical information for using the revised NIOSH lifting equation to evaluate a variety of two - handed Manual Material Handling (MMH) tasks was investigated. The NIOSH suggested the Lifting Index that provides a relative estimate of the level of physical stress associated with a particular manual lifting task. To measure operator's workload in lifting task, Lifting Index Simulator(LIS) was developed based upon the revised NIOSH lifting equation in this study. The purpose of this study was to develop LIS and use the NIOSH lifting equation in our workplace.

1. INTRODUCTION

Many systems and equipments will not function without the presence of humans who can be prime movers, controllers and decision makers. In spite of the technological advances and extensive use of the moving and loading machines in industrial workplaces, many workers are still required to handle materials manually in their daily jobs. This creates a potential danger to workers and may expose them to occupational injury or illness. In most manual material handling(MMH) tasks, the worker must assume an awkward posture to perform the task and/or his entire muscular system must brought into action.

The back injuries took account for 64% of overexertion in lifting out of total cases (OSHA data on occupational injury and illness incident rate in 1998). It was found that the back was the most dangerous body part for overexertion in lifting. The majority of lifting injuries was found to operators, fabricators and laborers(42%). The portion of injuries for the group took account almost half out of total injuries of lifting. The major portion of the lifting injuries were found in
service industry(27%) and second major portion were in manufacturing industry. The 3-5 days away from work took account for greatest part of lifting injury(22%) and more than

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31 days(19%) were second major portion days away from work by lifting injury.

To measure the fatigue of lifting workers, Lifting Index Simulator was created under the NIOSH revised lifting equation. The development of simulator for the safe lifting performance is desirable in this study.

The Purpose of this paper was to reduce the chronical low back pain for the manual material handlers.

The objectives of the study was to:

(1) examine variables under NIOSH Lifting Equation,
(2) create Lifting Index Simulator and
(3) suggest safe lifting recommendations in workplace.

2. CAUSES OF BACK PAIN AND INJURY

Overexertion back injuries are rarely the result of a single event or accident. In some cases, an accident may have resulted in a pulled muscle. But the muscle really didn't become bothersome until after several weeks or months of repetitive lifting or awkward work postures. In other cases, months or years of repetitive lifting, pushing, pulling and carrying didn't become noticeable until a single lift produced significant pain from a bulging or ruptured disc.

The low back is especially susceptible to breakdown due to the mechanics of the human body and the type of tissue and structures that make up the spine. The upper body can be thought of as a lever arm and the low back as the fulcrum point at which the trunk rotates around. For this reason, the compressive forces on the spine are the greatest in this region and consequently can cause the most damage to the discs that sit between each vertebrae. For instance, lifting a 20 lbs bag of flour 20" away from the body produces approximately 400 lbs. of compressive force on the disc at the fulcrum point. This is 20 times the weight of the actual object lifted. In this case it is not only the distance of the sack of flour from the body that contributes to the large compressive force, but also the weight of the trunk as it's bent forward. Not only do the muscles in the back have to work to support the flour sack, but also the weight of the upper body. For this reason, even if a person is not lifting an object, large compressive forces are produced just to main the trunk in a forward bent posture. Therefore, tasks that require employees to work in forward bent postures, also contribute to the risk of developing low back pain.

Many risk factors associated with the onset of LBP have been identified. They vary widely based on the population studied and the conditions under which the study was conducted. Whether these factors represent the cause of injury, events leading to injury, or results of the disability is unclear.

Specifically, in workplace LBP is often associated with industrial-type activities, such as driving heavy equipment and lifting. With lifting injuries, one of the most obvious risk factors is the weight of the objects. Heavier objects require more muscle force to stabilize the trunk and produce greater compressive forces on the spine. Heavier objects are also more hazardous to handle for the following reasons:

(1) Heavier objects requires more strength to handle which limits the number of employees who can safely handle them.

(2) When an object is too heavy for an employee to easily move, he/she may attempt to force the object to move by assuming an awkward posture or using momentum to jerk or twist. Abruptly twisting the back while lifting or quickly accelerating objects produces even larger forces on the spine, and greatly increases the risk of muscle and ligament strains and sprains as well as wear and tear on the discs.

(3) Heavier objects require more energy to handle and can cause early whole-body and muscle fatigue. As an employee becomes fatigued, he/she will more likely to make errors, use improper lifting techniques and causes an accident that could produce more severe consequences than a back injury.

These are just a few of the potential side effects of allowing employees to handle objects that are beyond their physical capabilities. The next section will describe additional workplace risk factors that can contribute to back pain. Provided with a description and example of each risk factor, are examples of control methods for eliminating or reducing the employees exposure to each risk factor.

3. NIOSH LIFTING EQUATION

Technical information for using the revised lifting equation to evaluate a variety of two - handled manual material handling tasks is investigated in this chapter

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3.1 Definition of Terms

The following list of brief definitions is useful in applying the revised NIOSH lifting equation. [Figure 1] shows indication of base point.

(1) **Lifting Task** is defined as the act of manually grasping an object of definable size and mass with two hands, and vertically moving the object without mechanical assistance.

(2) **Load Weight(L)** is the weight of the object to be lifted, in pounds or kilograms, including the container.

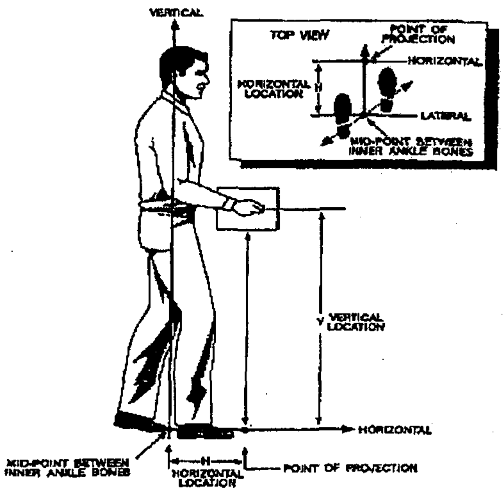
(3) **Horizontal Location(H)** is the distance of hands away from the mid-point between the ankles, in inches or centimeters (measure at the (measure at the origin and destination of lift).

(4) **Vertical Location(V)** is the distance of the hands above the floor, in inches or centimeters (measure at the origin and destination of lift).

(5) **Vertical Travel Distance(D)** is the absolute value of the distance between the vertical heights at the destination and origin of the lift, in inches or centimeters.

(6) **Asymmetry Angle(A)** is the angular measure of how far the object is displaces from the front (mid-sagittal plane) of the worker's body at the beginning or ending of the lift, in degrees (measure at the origin and destination of lift). The asymmetry angle is defined by the location of the load relative to the worker's mid-sagittal plane, as defined by the neutral body posture, rather than the position of the feet or the extent of body twist.

(7) **Neutral Body Position** describes the position of the body when the hands are directly in front of the body and there is minimal twisting at the legs, torso, or shoulders.



[Figure 1] Definitions of lifting variableslegs, torso, or shoulders.

(8) **Lifting Frequency(F)** is the average number of lifts per minute over a 15 minute period

(9) **Lifting Duration** is three-tiered classification of lifting duration specified by the distribution of work-time and recovery-time (work pattern). Duration is classified as either short (1 hour), moderate (1-2 hours), or long (2-8 hours), depending on the work pattern.

(10) **Coupling Classification** is the classification of the quality of the hand-to-object coupling (e. g., handle, cut-out, or grip). Coupling quality is classified as good, fair, or poor.

(11) **Significant Control** is defined as a condition requiring precision placement of the load at the definition of the lift. This is usually the case when a) the worker has to re-grasp the load near the destination of the lift, or b) the worker has to momentarily hold the object at the destination, or c) the worker has to carefully position or guide the load at the destination.

3.2 Recommended Weight Limit (RWL)

The RWL is defined for a specific set of task conditions as the weight of the load that nearly workers could perform over a substantial period of time (e. g., up to 8 hours) without an increased risk of developing lifting - related LBP.

The RWL is defined by the following equation :

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM$$

where:

	metric	US customary
Load Constant (LC)	23 kg	51 LB
Horizontal Multiplier (HM)	(25/H)	(10/H)
Vertical Multiplier (VM)	$1-(0.003[V-75)$	$1-(0.0075[V-30])$
Distance Multiplier (DM)	$0.82+(4.5/D)$	$0.82+(1.8/D)$
Asymmetric Multiplier (AM)	$1-(0.0032A)$	$1-(0.0032A)$
Frequency Multiplier (FM)		
Coupling Multiplier (CM)		

4. LIFTING INDEX SIMULATOR

4.1 Lifting Index (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.

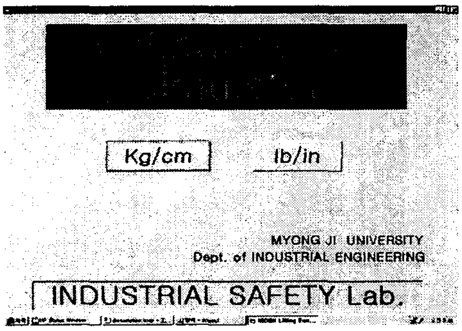
The LI is defined by the following equation:

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

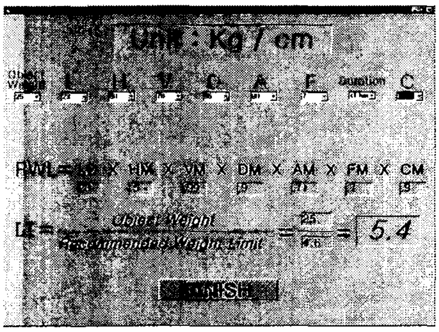
4.2 Lifting Index Simulator(LIS)

This program was created under Window 98 by Visual basic 6.0. [Figure 2] shows initial screen of LIS. This screen is composed of two measuring unit - metric and US customary. [Figure 3] show final result screen of LI of worker 1 in A company. The result of 5.4 indicates the lifting worker feels fatigue in the lifting job. Task redesign is needed for over 1.0 of LI. The maximum of LI should be 1.3.

After compared other software of motion analysis, this package has some of merit. Many equipments is needed for using of Vision 3000. However, only some of lifting dimensions (weight, horizontal distance, vertical distance, traveling distance, twist angles, frequency, duration and coupling) are needed for this LIS. Then, lifting index will be calculated.



[Figure 2] Initial screen of LIS



[Figure 3] Result screen of LIS

5. LIFTING HAZARD ASSESSMENT WORKSHEET

This sheet is designed to be a quick and easy method for determining maximum safe lift limits without going through the detailed process of measuring task variables and inputting them into the NIOSH lifting equation. A score of 6 or more means the lift is unsafe for some workers and consideration should be given to reducing the factors that score the highest on the worksheet. The worksheet is only designed for analyzing lifting where the object weight is 10 pounds or more.

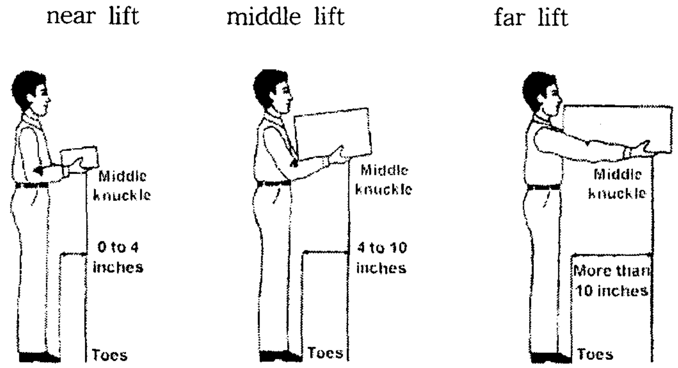
Lifting Hazard Assessment Worksheet

STEP 1:

Determine if the lift is Near, Middle or Far (body to hands)

Use an average horizontal distance if lift is made every 10 minutes or less.

Use the largest horizontal distance if more than 10 minutes pass between lifts.



STEP 2: [Table 1]
Find the Lifting Zone and estimate the weight lifted (pounds)
Use an average weight if a lift is made every 10 minutes or less.
Use the heaviest weight if more than 10 minutes pass between lifts.
Enter 0 in the total score if the weight is less than 10 pounds.

[Table 1] Lifting zone and weight lifted

near lift		middle lift		far lift	
danger zone	more than 51 lbs 5 points*	danger zone	more than 35 lbs 6 points	danger zone	more than 28 lbs 6 points
caution zone	17 to 51 lbs 3 points	caution zone	12 to 35 lbs 3 points	caution zone	10 to 28 lbs 3 points
safe zone	less than 17 lbs 0 points	safe zone	less than 12 lbs 0 points	safe zone	less than 10 lbs 0 points
* If lifts are performed more than 15 times per shift, use 6 points. If 0, stop here.			step 2 score (enter 0, 3, 5 or 6):		

STEP 3: [Table 2]
Determine the points for other risk factors.
Use occasional lifts if more than 10 minutes pass between lifts.
Use the more than 1 hour points if the risk factor occurs with most lifts and lifting is performed for more than 1 hour.

6. LIFTING RECOMMENDATIONS

Most back problems occur over a period of time. Careful attention to lifting on the job and at home and regular exercise to maintain fitness and strength will help you maintain a healthy back. The following principles will assist in lowering risk of back injury due to lifting.

(1) Size up the load. Test it to see if you can lift it safely. Can you grasp it securely? Good handholds (cut-outs, handles) will make the load easier to lift. make sure the load is balanced in your hands.

(2) Get as close to the load as possible before lift it. If possible, slide the load towards you before picking it up.

[Table 2] Points for the other risk factors

Factor	Occasional Lifts Performed For 1 Hour or Less in Total Per Shift	Lifts Performed for More Than 1 Hour in Total Per Shift
Twist torso during lift	1	1
Lift one-handed	1	2
Lift unstable loads (people, liquids, or loads that shift around or have unequal weight distribution)	1	2
Lift between 1 to 5 times per minute	1	1
Lift more than 5 times per minute	2	3
Lift above the shoulder	1	2
Lift below the knuckle	1	2
Carry objects 10 to 30 feet	1	2
Carry objects farther than 30 feet	2	3
Lift while seated or kneeling	1	2
STEP 3 score:		
Total Score (Add scores from steps 2 and 3):		

(3) Make sure your footing is secure. Do not lift objects that obscure vision and footing.

(4) Do not twist while lifting. Move your feet so that they point in the direction of the lift as you turn.

(5) Lift smoothly and slowly. Do not jerk the load.

(6) Organize the work so as to avoid lifting from the floor or above shoulder level. Items to be handled should be between knee and shoulder height.

(7) Keep the load as close to your body as possible. If the load is large and cannot be placed between your knees as they are bent, bend at the hips and waist with your knees relaxed. It is more important to keep the load close than it is to bend your knees. One solution to lifting a larger load is to get another person to help you. A better solution is to use mechanical assistance (hand trucks, carts) to avoid lifting altogether.

(8) If you have a lot of lifting to do during the day, try not to do it all at once. Alternate lifting tasks with lighter work to give your body a chance to recover. Remember, mechanical assistance is just as important for repetitive lifting as it is for heavy lifting.
(9) Use the same principles when lowering or placing the load after lifting.
(10) Try to avoid carrying the load more than 10 feet without getting mechanical assistance. Use a dolly or cart.

7. CONCLUSIONS

Everyone might have been experienced LBP more than once during one's e life time. The less than 25% of LBP sufferers who do not improve spontaneously consume approximately 90% of the total health care resource and associated cost. Average cost per case was $40,000 in the United States. The total cost associated with back problems was $40 billion, and could be potentially reaching to $90 billion annually. The main cause of LBP was lifting among many factors. Considered variables are weight of lift, frequency of lifting, and twisting (0 and 90 degrees), etc. Without optimal lifting works, workers cannot work safely.

In order to measure workload of lifting workers, LI was evaluated with LIS by Visual Basic 6.0 under the revised NIOSH lifting equations. The recommended LI is 1.0. However, LI of the worker 1, collected in A company, was 5.4. Therefore, the task of the worker 1 is needed redesign.

The lifting hazard assessment worksheet for determining maximum safe lift limits was suggested. The lifting hazard worksheet consists of three steps. Also, ten lifting recommendations were suggested. The recommendations will assist in lowering risks of back injury due to lifting.

Top and middle managers should concern working environment in order to reduce industrial injuries and protect employees from potential hazards. The LIS developed through this study will be helpful for safety managers to perform their activities of low back pain prevention.

REFERENCES

[1] Ayoub, M.A., (1982) "Control of Manual Lifting Hazards: I. Training in Safe Handling", *Journal of Occupational Medicine*, 24(8), pp. 573-577.
[2] Ayoub, M.M. and Mital, A., (1989) *Manual Material Handling*, Taylor and Francis, London.
[3] Baker, H.R. and Baker, B.M., (1961) "Prevention of back Injuries through Pre-placement Examinations" *Industrial Medicine and Surgery,* 24, pp. 486-490.
[4] Chaffin, D.B. and Andersson, G.B.J., (1991) *Occupational Biomechanics*, John Wiley & Sons, New York.

[5] Chaffin, D.B. and Ayoub, M.M., (1975) "The Problem of Manual Material Handling. *Industrial Engineering Journal*, 7(7), pp. 24-29.

[6] Chaffin, D.B., Herrin, G.D., Keyserling, W.M. and Garg, A., (1977) "A Method for Evaluating the Biomechanical Stresses Resulting from Manual Materials Handling Jobs", *American Industrial Hygiene Association Journal,* 38(12), pp. 662-675.

[7] Garg, A., Chaffin, D.B. and Freivalds, A., (1982) "Biomechanical Stresses from Maual Load Lifting : A Static vs. Dynamic Evaluation", *IEE Transactions*, 14(4), pp. 272-281.

[8] Jomoah, I.M., (1994) "Comprehensive Study of Static and Dynamic Stresses for Symmetric and Asymmetric Lifting Activities", Ph.D. Dissertation, University of Miami, Coral Gables, Florida.

[9] Khalil, T.M., Abdel-Moty, E.M., Rosomoff, R.S. and Rosomoff, H.L., (1993) *Ergonomics in Back Pain: A Guide to Prevention and Rehabilitation,* Van Nostrand Reinhold, New York, NY.

[10] Mital, A., Nicholson, A.S., and Ayoub, M.M., (1993) *A Guide to Manual Materials Handling*, Taylor & Francis, London.

[11] National Institute for Occupational Safety and Health (NIOSH), (1981) *Work Practices Guide for Manual Lifting,* Edited by D.W. Badges, U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, Division of Biomedical and Behavior Sciences, Cincinnati, National Institute of Occupational Safety and Health, DHH(NIOSH) Publication No. 81-122.

[12] National Safety Council, *Accident Facts,*

[13] Tichauer, E.A., (1971) "A Pilot Study of the Biomechanics of Lifting in Simulated Industrial Work Situations", *Journal of Safety Research*, 3(3), 98-115.

[14] US Department of Labor, (1998), OSHA Data on BLS Case and Demographic Characteristics for Workplace Injury and Illness involving Days away from work.

[15] Waters, T.R., Putz-Anderson, V. and Garg, A., (1994) "Applications Manual for the Revised NIOSH Lifting Equation.

[16] Webster, B.S. and Snook, S.H., (1991) "The Cost of Compensable Low Back Pain", *Journal of Occupational Medicine*, 32, pp. 13-15.

[17] http://www.lni.wa.gov/wisha/ergo/lifting/lessons.htm