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A Review of the NIOSH Lifting Equation and Ergonomics Analysis

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Abstract. The revised NIOSH Lifting Equation developed in 1991 is an ergonomic intervention assessment tool that used to calculate the recommended weight limit (RWL) for lifting tasks and to identify the hazardous lifting tasks. But this equation application is limited to those conditions for which it was designed and the different populations have different anthropometric distributions. This research will propose a solution to determine the effect of different manual lifting tasks on biomechanical, physiological and psychophysical limitation and develop the new automatic system tool to calculate the ideal RWL for Malaysian people for the working tasks perform. This new system tool which design according to the criteria of Malaysian people can increase the safe working environment for the workers.

Introduction

Manual lifting has been recognized as one of the major contributors to injury in most industries. It is due to lack of attention on safety awareness in the workplace. These injuries affect employees and also impose heavy costs on employers and society. To reduce this problem, in 1981, the National Institute of Occupational Safety and Health (NIOSH) had published working guidelines for manual lifting. A lifting equation was produced in evaluating the risk related to manual lifting tasks. The guide was revised in 1991 by adding several task conditions and the equation were also updated.

The NIOSH standard has been followed and practiced worldwide. However, the guide and lifting equation were designed and developed in the United States. Studies have shown that different populations have different anthropometric distributions. Three criteria which are physiological, biomechanical and psychophysical were used in defining the lifting equation and method to analyze the manual lifting task problem. These measurements which this model was based on, may not be accurate for Malaysian population. This project is to investigate the effect of manual lifting on biomechanical, physiological and psychophysical limitations in Malaysia population.

Ergonomic Assessment Tools

Occupational safety and health concept has been evolving since 1978 where the first report on several occupational health related surveys and the corresponding amount of insurance carried in the USA was published. Manual lifting has been recognized as one of the major contributors to injury in the workplace. Operations related to manual handling include the acts of lifting, lowering, carrying, pushing, pulling, and holding items. Injury in workers during weight lifting has been recognized as a main contribute at work places. The injuries include low back pain and spine problem [2,3]. In observation method, the lifting task was evaluated using four basic approaches in

establishing the lifting standard which are epidemiological, physiological, biomechanical and psychophysical.

In recent year, numerous researches on ergonomic assessment tools have been developed and used for the work of analyzing many activities of life either in a job as part of regular work in working area or activities during normal lifestyle. Manual handling injuries occur in most working environments including industrial sectors such as in aluminum industry, construction, mold maker, manufacturing, food processing, distribution operations, warehousing, retail and also workers in agriculture, restaurants, health care and childcare sectors [1-9].

Various postural analysis tools are available for assessing exposure of workers to the risks and potentially hazardous task within their workstation. The assessment tools have been shown to be valuable methods for reducing occupational diseases and increasing productivity in industry. The postural analysis tools are classified into the observation method and direct measurement method [7]. The ergonomic based risk factor assessment methods such as Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), Liberty Mutual Tables, NIOSH lifting equation and other assessment methods [3,5,7,9]

The National Institute for Occupational Safety and Health (NIOSH) has published a recommended lifting equation in 1981 and a revised version in 1991. It is to indicate safe lifting limits and has been a valid tool in evaluating risk during lifting tasks. There are big challenges in developing the standard in evaluating human lifting capacity. Various studies have been reported in developing a comprehensive lifting model. The NIOSH 1991 revised lifting equation added two factors which are asymmetry and coupling on top of the 1981 equation factors which are horizontal, vertical, distance and frequency [4].

NIOSH Lifting Equation can be used to evaluate a complete manual lifting task or parts of the task so as to reduce the overall possibility of lower back pain or injury. To aid in the prevention of lifting-related lower back injury, NIOSH developed the Revised NIOSH Lifting Equation (RNLE), to calculate a recommended weight limit (RWL), and lifting index (LI) used for estimating the physical demands of the job [1,3].

The working posture can be evaluated by the RULA analysis. It was combined with Revised NIOSH Lifting Equation in designing the model to detect the risk factors that contribute to the Musculoskeletal Disorders (MSDs) such as force, vibration, repetition, contact stress, awkward postures, extreme temperatures and static postures [6,7]. The results found that MSDs experienced by the worker are caused by manual materials handling tasks and the combined system designed capable to reduce the risk of MSDs for manual materials handling tasks in the manufacturing industry. Working postures also can be assessed using Electromyography (EMG) to determine the muscles activity due to workstation design [6]. EMG is the study of muscle activity through analysis of the electrical signals emanated during muscular contraction. EMG measures the electrical signal associated with the activation of the muscles. This may be a voluntary muscle contraction. The EMG activity of voluntary muscle contraction is related to tension.

Besides, the Rapid Entire Body Assessment (REBA) tool and the NIOSH equation were also used to assess the risk of developing MSDs. The research has been conducted in the vaccine production center warehouse to find possible targets for improvement through the application of general work space design and ergonomics principles [4]. All the postures evaluated with REBA and analyzed with the NIOSH equation in defining the high risk and medium risk level of the job.

Table 1 Summary of an Approach of Lifting Model

Researcher	Year	System	Method of Data Collection	Observation Procedures	Industry
M. H. Edin	2008	1) RULA 2) NIOSH Lifting Equation	1) Semi structure interviews 2) Questionnaire 3) Pictures 4) Videos	Body position and postures for lower back pains	Construction building

L.H. Shy	2008	1) RULA 2) NIOSH Lifting Equation	1) Biomechanical stress 2) Interview 3) Working posture	Neck and lower back pains	Mold maker in manufacturing industry
S. Rud	2011	1) RULA 2) REBA analysis 3) NIOSH Lifting Equation	1) Behavior observation 2) Video analysis	Subject male and female 1) Posture 2) Force 3) Coupling 4) Duration 5) Repetition activities	Cargo bins in aviation industry
S. H. Musa	2011	1) NIOSH Lifting Equation	1) Pictures 2) Behavior observation	Posture	Aluminium Industry
B.J William	2011	1) NIOSH Lifting Equation	1) Written evaluations 2) Informal interviews 3) Behavior observation	1) 415 subjects 2) 4 training condition 3) 22 training groups	Education
A.T. Ali	2012	1) NIOSH Lifting Equation 2) RULA	1) Videos	Postures 1) Shoulder 2) Neck 3) Wrist 4) Elbow	Electronic Frame Manufacturing
S. Boda, et al.	2012	1) NIOSH Lifting Equation	1) Questionnaire 2) Structured interviews 3) Videos	1) 897 adults 2) Subject male and female 3) Age (18-65) 4) Postures	Manufacturing, Food processing, Distribution operations
Y. T. Medina and S. Vina	2012	1) REBA analysis 2) NIOSH Lifting Equation	1) Videos	Postures	Vaccine production warehouse

Revised NIOSH Lifting Equation

The Revised NIOSH lifting equation is a tool used to identify, evaluate or classify risks associated with a lifting task and reduce the incidence rate and severity of low back injuries to workers. The revised NIOSH lifting equation (RNLE) consists of two basic indicators which are the Recommended Weight Limit (RWL) and Lifting Index (LI). The RWL is the main indicator 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 lift over a period of time (up to 8 hours) without an increased risk of developing lifting related low back pain or injury, given all other task parameters remain unchanged. The concept behind the revised NIOSH lifting equation is to start with a recommended weight that is considered safe for an ideal lift (load constant equal to 23 kg or 51 lbs) and then reduces the weight as the task becomes more stressful.

1) Recommended Weight Limit (RWL)

RNLE proposed a recommended weight limit (RWL) as a guide for evaluating manual lifting tasks. The 1991 NIOSH lifting equation is composed of multipliers that are based on input values. The recommended weight limit is the product of a load constant and the six multipliers as shown in Table 2. The RWL is defined by the following equation:

$$= \quad \times \quad \times \quad \times \quad \times \quad \times \quad \times \qquad (1)$$

Where :

Table 2

Multiplier	Abbreviation	Metric
Load Constant	LC	23 kg
Horizontal	HM	25/H
Vertical	VM	1 – (0.003|V-75|)
Distance	DM	0.82 + (4.5/D)
Asymmetric	AM	1 – (0.0032 * A)
Frequency	FM	
Coupling	CM	1.0, 0.95, 0.90

2) Lifting Index (LI)

The LI is a term that provides a relative estimate of the physical stress associated with a manual lifting job. 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. As the magnitude of the LI increases, the level of the risk for a given worker increases, and a greater percentage of the workforce is likely to be at risk for developing lifting-related low back pain.

The LI is defined as below:

$$\mathbf{LI} = \frac{\textbf{Load Weight}}{\textbf{Recommended Weight Limit}} = \frac{\mathbf{L}}{\mathbf{RWL}} \qquad (2)$$

Criteria Selection

There are three fundamental approaches of lifting equation are which are:

1. Biomechanical Approach:
   - Internal and external forces on the body during lifting tasks
   - Design task that does not exceed the capacity of the musculoskeletal system.
2. Physiological Approach:
   - Energy expenditure to limit loads for repetitive lifting
   - Muscle activities (EMG signals) measurement during tasks performance
   - Spine, biceps muscle
3. Psychophysical Approach:
   - Defining the workers' strength and capacity to perform manual lifting task at different frequencies for different durations, that are ‘acceptable’ to the majority of workers. (Requires workers to adjust the weight, frequency etc.)
   - Questionnaire, Interview

Proposed System

This research is mainly aimed to design the system based on the Malaysian population worker in industry. A lifting model based on Figure 1 will be developed and validated for the Malaysian population and will be compared with the 1991 Revised NIOSH lifting equation. This study involves the Recommended Weight Limit (RWL) and Lifting Index (LI) calculation as a standard to benchmark.

The relevant task variables such as load, frequency, distance, and posture on lifting task procedures will be carefully measured and recorded in experiments using a psychophysical, biomechanical and psychophysical methods. It is useful to help our people in preventing and protect the major cause of musculoskeletal disorders.

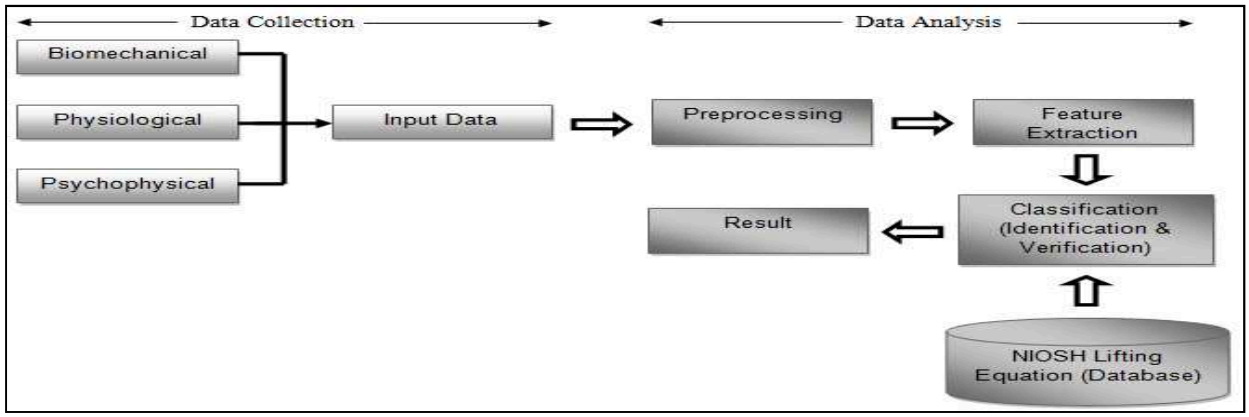

Figure 1

Different manual lifting tasks will be designed and data will be collected based on the biomechanical, physiological and psychophysical approaches. Subjects will be recruited from various working backgrounds among the Malaysian population. The selected industrial workers from male and female workers will perform the tasks at different procedures. At the end of the project, an automatic tool will be developed that can calculate the safety risk during manual lifting tasks.

Step of defining the recommended weight limit (RWL) for the task:

1) Determine the weight of the load.
2) Assess the six components of the lifting task.
3) Calculating Recommended Weight Limit (RWL).
4) Compare the weight of the load against determined Recommended Weight Limit for the task.

Conclusion

The current research shows the implementation of the revised NIOSH lifting equation as a methodological tool for safety and health to evaluate the lifting task problems for the workers. The proposed system tool developed ideally associated to evaluate and validate the lifting model for Malaysian worker in creating the safe working environment while complete their tasks and compare to NIOSH Lifting Equation. The designed equation will help to assist Malaysian people to the acceptable RWL and LI and to prevent the hazardous problem due to their lifting task. The system tool will propose the suggestion to reduce the hazard after analyzing each of the lifting tasks to protect the workers. The new system tool for Malaysian hopefully can contribute to help workers in reducing the problem related to listing task.

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