

# Niosh Lifting Equation for Assessing Manual Material Handling Technique in a Warehouse Company

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**Abstract:** Every warehouse company must protect their employees from possible health risks especially the loaders or carriers to avoid work related musculoskeletal disorders. This research aimed to determine the factors that affect the safety of carriers or loaders inside a certain warehouse. Proper lifting techniques were studied to provide safer methods compared to current worker's execution or method. The primary data were obtained from the respondents through observations, interviews, and survey questionnaires such as Nordic Questionnaire. Time and motion study was used to determine how safety affects the time of each worker in finishing the job. To assess safety, NIOSH lifting equation is used, an ergonomic tool that equates to the required weight limit and lifting index of the loaders or carriers that execute manual material handling. The results of the study showed that all the respondents had high lifting index based on the pre-assessment test of NIOSH lifting equation which means that they are at high risk. After implementation of proper lifting techniques, post-assessment test showed that the respondents had yielded lower lifting index. The findings revealed that aging and length of stay in the warehouse are factors highly affecting workers' capacity of lifting and safety. Older workers are more at risk than younger ones when it comes to physical activities. The longer the exposure in lifting and carrying, the more risks it is for the body. A safety procedure guideline was developed and recommended to the company to avoid health issues or musculoskeletal disorders among loaders and carriers inside the warehouse.

**Keywords:** Work Related Musculoskeletal Disorders, NIOSH Lifting Equation, Lifting Index

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## 1. Introduction

Manual Material Handling or MMH is one of the most difficult tasks for the workers and one of the most physically demanding work because of repetitive movements, awkward postures, forceful exertion etc. It is the main cause of work-related musculoskeletal disorder [1]. MMH is the leading source of injuries in the workplace between 24% and 35% [2]. The work environment can be the main reason why workers have health problems.

Different kinds of MSDs must be assessed to determine the appropriate ergonomic tool to be used. The NIOSH or the National Institute of Occupational Safety and Health developed a technique to reduce the effects of lower back pain (LBP) and work-related musculoskeletal disorders (WSMD).

This indicates the work practices guide for manual lifting [3]. To assess the factors that affect the efficiency of the workers in a certain warehouse in the Philippines, the NIOSH Lifting Equation was used.

Musculoskeletal Disorders are due to manual material handling practiced by warehouse carriers or loaders. The risks were mostly caused by non-ergonomically way of material handling. It can affect the workers' safety and pose health risks. The demographic profile of the workers such as age, height, and number of years in their current position were determined as well as the current method being used by the carriers or loaders in the liquor section of a warehouse. Relationship between the demographic profile of the workers

and their safety in the workplace was also determined. Pre-assessment and Post Assessment using NIOSH was evaluated to determine the best safety procedure guidelines for recommendation to the company.

## 2. Materials and Methods

For attainment of the objectives of the study, a descriptive method of research with primary data gathered from the respondents through the use of observations and interviews among the population of the study. A process chart was used as a representation of the sequence of steps, work flows, working processes, systems and procedure. It served as a tool for examining the process in detail to identify areas of possible improvement. Time and Motion Study was used to measure the time necessary for a job or task to be completed using the best method. This tool helped the team to evaluate if there is an improvement with the pre-assessment and post-assessment of the study. NIOSH lifting equation used worksheet to collect data from the respondents.

Since the data collected may be discrete and contain actual numbers, descriptive statistics were used. Pearson R Correlation was used on this study to determine the relationship of level of awareness of proper manual material handling and level of implementation safety procedure. The formula is stated below:

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2] - (\sum x)^2} \sqrt{[n\sum y^2] - (\sum y)^2}} \quad (1)$$

To test the significance of  $r$ , T- test was used,

$$t = \frac{r \sqrt{n-2}}{\sqrt{1-r^2}} \quad (2)$$

## 3. Results and Discussion

### 3.1. Demographic Profile of the Respondents

Table 1. Profile of the respondents in terms of age.

Age	Frequency	Percentage	Rank
26-31	6	40	1
32-37	2	13.3	4
38-43	4	26.7	2
44-49	3	20	3
Total	15	100	

As shown in the table regarding the age composition of the respondents, 6 out of 15 respondents (40%) are 26-31 years old, 4 or 26.7% are 38-43 years old, 3 or 20% are 44-49 years old and 2 or 13.3% are 32-37 years old.

Age should be considered since it is known that muscular strength declines from middle age onwards [4]. Middle-aged people are particularly prone to low-back problems owing to the instability of their lumbar motion segments. Aging process leads to a decrease in muscle mass and strength. Loss of strength is directly connected with reduction of muscle mass. The muscular system accounts approximately 40% of the total body mass and human body's cell mass consists in 75% of

muscle cells [5].

Table 2. Profile of the respondents in terms of height.

Height (cm)	Frequency	Percentage	Rank
154.94-162.08	3	20	2.5
162.09-166.23	6	40	1
166.24-170.38	3	20	2.5
170.39-174.53	2	13.3	4
174.54-178.68	1	6.7	5
Total	15	100%	

The above table above shows the height of the respondents in which 6 out of 15 (40%) stand 162.09-166.23 cm, 3 or 20% stand 166.24-170.38 cm, 3 or 20% stand 154.94-162.08 cm, 2 or 13.3% stand 170.39-174.53 cm, and 1 or 6.7% stand 174.54-178.68 cm.

Shorter people are less likely to have lower back pain or break a hip [6]. One possible reason taller people have a bigger chance of a hip fracture is their high center of gravity. That not only makes them more likely to fall, but it also may make them hit the ground with more force if they do.

Table 3. Profile of the respondents in terms of number of months in the current position.

Months in the current position	Frequency	Percentage	Rank
68-91	6	40	1
92-115	4	26.7	2
116-139	1	6.7	5
140-163	2	13.3	3.5
164-187	2	13.3	3.5
Total	15	100	

The table above shows the number of months in the current position. Mostly or 6 out of 15 respondents (40%) are in their current position for 68-91 months, 4 or 26.7% for 92-115 months, 2 or 13.3% for 140-163 months, 2 or 13.3% for 164-187 months, 1 or and 6.7% for 116-139 months.

### 3.2. The Current Method of the Carriers or Loaders

Process:		Process Analysis Chart					
Scope of Analysis							
Product Name							
Subject of Analysis ( ) Product (✓) Worker							
No	Process Detail	Processing/Tasks	Transport/Moving	Stagnation/Waiting	Storage	Time	Dist.
1	Worker reach the box from the pallet	●	→	D	▽	0.0242	
2	Hold the box	●	→	D	▽	0.0097	
3	Lift the box	●	→	D	▽	0.0198	
4	Transport the box to pallet	○	→	D	▽	0.029	3.5ft
5	Position the box	●	→	D	▽	0.0187	
6	Release the box	●	→	D	▽	0.0053	
7	Preparation of hand jack	●	→	D	▽	0.0908	
8	Transport pallet to the sealing area using hand jack	○	→	D	▽	0.3048	36ft
9		○	→	D	▽		
10		○	→	D	▽		
Total No. of Process		6	2	0	0		
Total Time		0.1685	0.3338	0	0	LT	Dist.

Figure 1. Process Chart.

The effects of combining the activities of lifting, lowering, pushing, pulling, and carrying into one work task; the resulting acceptable loads limits were quite different for the separate tasks compared with several of their combinations [7]. Manual handling at work includes lifting, putting down,

carrying or moving, pushing or pulling of loads by one or more workers during the larger part of the work shift. Despite current technological advancements manual handling occurs in almost all working environments, workers are exposed to the risk of carrying or moving heavy loads for at least a quarter of their working time.

No.	Left-Hand Description	Therblig	Symbol	Therblig	Right-Hand Description
1			○	TE	Transport Empty
2			○	G	Grasp
3			○	P	Position
4	Transport Empty	TE	○		
5	Grasp	G	○		
6	Position	P	○		
7	Hold	H	○	○	H
8	Transport Loaded	TL	○	○	TL
9	Pre-position	PP	○	○	PP
10	Release Load	RL	○	○	RL
11	Transport Empty	TE	○	○	TE

Figure 2. Therbligs Process Chart.

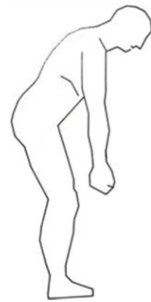


Figure 3. Current Execution.

The carriers or loaders manually lifted the box by bending his back to reach the box, grasp it with both of his hands then lift the box by straightening or lifting his box towards his body. Basically, the carriers or loader used his back to lift box not his feet and lift the box with their own way or strategy as fast as possible to finish their work. The abdominal and thoracic muscles play a major role in stabilising the spine when a weight is lifted. When a person leans forward to lift a weight, a moment of flexion is placed on the spine [8]. The heavier the weight, the greater the flexion strain.

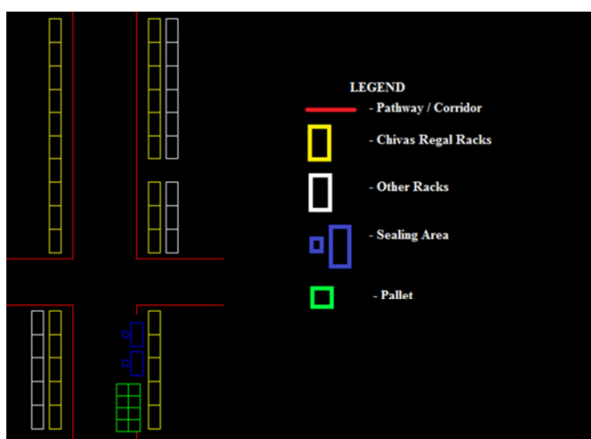


Figure 4. Floor Plan of Liquor section – warehouse.

### 3.3. The Result of Pre-Assessment (NIOSH) and Post-Assessment (NIOSH)

#### 3.3.1. The Result of Pre-Assessment (NIOSH)

Table 4. Results of respondents' required weight limit pre-assessment.

Required Weight Limit (lb.)	Frequency	Percentage	Rank
10.9-11.92	1	6.67	5
11.93-12.95	3	20	3
12.96-13.98	5	33.33	1
13.99-15.01	3	20	3
15.02-16.04	3	20	3
Total	15	100	

It is shown in the table the results of respondents' required weight limit from NIOSH lifting equation. Five out of 15 or 33.3% answered 12.96-13.98 lbs., 3 or 20% answered 11.93-12.95 lbs., 3 or 20% answered 13.99-15.01 lbs., 3 or 20% answered 15.02-16.04 lbs., and 1 or 6.67% answered 10.9-11.92 lbs.. Therefore, there was a high risk to the respondents.

The primary product of the NIOSH lifting equation is the Recommended Weight Limit (RWL), which defines the maximum acceptable weight (load) that nearly all healthy employees could lift over the course of an 8 hour shift without increasing the risk of musculoskeletal disorders (MSD) to the lower back [9]. For risk assessment, the recommended loads heavier than 25 kg are always to be considered a risk for Lower back pain while less than 3kg do not pose a risk. For loads between 3-25 kg, risk assessment shall be performed using the National Institute for Occupational Safety and Health (NIOSH) lifting equation. [10]

Table 5. Results of respondents' lifting Index pre-assessment.

Lifting Index	Frequency	Percentage	Rank
2.73-2.99	5	33.33	1
3.00-3.26	4	26.67	2.5
3.27-3.53	4	26.67	2.5
3.54-3.80	1	6.67	4.5
3.81-4.07	1	6.67	4.5
Total	15	100	

It is shown in the table the results of respondents' required lifting index from NIOSH lifting equation. Five or 33.3% got 2.73-2.99, 4 or 26.67% got 3-3.26, 4 or 26.67% got 3.27-3.53, 1 or 6.67% got 3.54-3.8, and 1 or 6.67% got 3.81-4.07. Therefore, there was a high risk to all the respondents.

A Lifting Index (LI) is calculated to provide a relative estimate of the level of physical stress and MSD risk associated with the manual lifting tasks evaluated.

Table 6. Results of evaluated respondents' lifting Index pre-assessment.

Lifting Index	Frequency	Percentage	Rank
LI < 1.0 – Normal risk to employee	0	0	2
LI > 1.0 High risk to employee	15	100	1
Total	15	100%	

It is shown in the table the results of evaluated respondents'

Lifting Index. The result  $LI > 1.0$  revealed that 15 out of 15 respondents (100%) are at High Risk and 0 or 0%  $LI < 1.0$  for Normal risk to employee.

A Lifting Index value of less than 1.0 indicates a nominal risk to healthy employees. A Lifting Index of 1.0 or more denotes that the task is high risk for some fraction of the population [11]. As the LI increases, the level of low back injury risk increases correspondingly. Therefore, the goal is to design all lifting jobs to accomplish a LI of less than 1.0.

### 3.3.2. The Result of Post-Assessment (NIOSH)

*Table 7. Results of respondents' required weight limit post-assessment.*

Required Weight Limit	Frequency	Percentage	Rank
40.61-42.11	1	6.67	4.5
42.12-43.62	2	13.33	3
43.63-45.13	7	46.67	1
45.14-46.64	4	26.67	2
46.65-48.15	1	6.67	4.5
Total	15	100	

It is shown in the table the results of respondents' required weight limit from NIOSH lifting equation. Out of 15 respondents, 7 or 46.67% have 43.63-45.13 lbs. required weight limit, 4 or 26.67% have 45.14-46.64 lbs., 2 or 13.33% have 42.12-43.62 lbs., 1 or have 40.61-42.11 lbs., 1 or 6.67% have 46.65-48.15 lbs.. Therefore, there was a normal risk to all employees.

The primary product of the NIOSH lifting equation is the Recommended Weight Limit (RWL), which defines the maximum acceptable weight (load) that nearly all healthy employees could lift over the course of an 8 hour shift without increasing the risk of musculoskeletal disorders (MSD) to the lower back [12]. For risk assessment, the recommended loads heavier than 25 kg always are to be considered a risk for Lower back pain while less than 3kg do not pose a risk. For loads between 3-25 kg, risk assessment shall be performed using the National Institute for Occupational Safety and Health (NIOSH) lifting equation [13].

*Table 8. Results of respondents' lifting Index.*

Lifting Index	Frequency	Percentage	Rank
0.91-0.94	3	20	3
0.95-0.98	5	33.33	2
0.99-1.02	7	46.67	1
Total	15	100	

It is shown in the table the results of respondents' required lifting index from NIOSH lifting equation. Seven or 46.67% obtained 0.99-1.02, 5 or 33.33% obtained 0.95-0.98, and 3 or 20% obtained 0.91-0.94. Therefore, there was a normal risk to all employees.

A Lifting Index (LI) is calculated to provide a relative estimate of the level of physical stress and MSD risk associated with the manual lifting tasks evaluated [14].

It is shown in the table the results of evaluated respondents' Lifting Index with (100%)  $LI < 1.0$  – Normal risk to employee is 15 out of 15 respondents and (0%)  $LI > 1.0$  High risk to

employee is 0.

A Lifting Index value of less than 1.0 indicates a nominal risk to healthy employees. A Lifting Index of 1.0 or more denotes that the task is high risk for some fraction of the population. As the LI increases, the level of low back injury risk increases correspondingly. Therefore, the goal is to design all lifting jobs to accomplish a LI of less than 1.0.

*Table 9. Results of evaluated respondents' lifting Index post-assessment.*

Lifting Index	Frequency	Percentage	Rank
$LI < 1.0$ – Normal risk to employee	15	100	1
$LI > 1.0$ High risk to employee	0	0	2
Total	15	100	

Secondly, the supporting tools are the Nordic Standard questionnaire and the time study. The results of the Nordic Standard questionnaire revealed that the most hurt part of the respondent's body are the lower back, upper back, shoulders, and arms. The percentage of answering yes in pain are: Neck 33%, Shoulders 87%, Arms 87%, Wrists/Hands 73%, Upper Back 87%, Lower Back 93%, Hips/Thighs 67%, Knees 53%, and Ankles/Feet 33%. This also shows that most of them did not seek medical help or attention for their felt pain and only 1 out of 14 of the respondents has consulted a physician.

The Time Study covers the time of each worker to transfer boxes from rack to pallet with given 5 trials. The pre-assessment with their current lifting technique and the post-assessment with the researchers' recommended lifting techniques. As shown on the two results, the average of each worker to do the task only has small difference in time. Pre-assessment has an average of 5.5572 seconds and the Post-assessment has an average of 5.355867. Most of the workers show a lower time average with the post-assessment using the researchers' lifting techniques.

### 3.4. The Relationship Between Demographic Profile and Safety of the Carriers or Loaders

*Table 10. Gathered Data for Demographic Profile and Safety.*

Worker	Age	Height	Length of stay	Lifting Index
1	26	170.31	73	2.735
2	28	162.08	75	2.738
3	28	170.35	80	2.740
4	29	162.44	79	2.807
5	30	168.23	82	2.939
6	31	178.68	90	3.002
7	32	166.55	93	3.109
8	37	175.48	113	3.174
9	38	158.36	95	3.200
10	38	168.45	93	3.266
11	41	170.26	135	3.323
12	43	162.48	145	3.396
13	44	166.29	163	3.397
14	46	154.29	165	3.560
15	49	170.40	187	3.997

It is shown in the table 10 the relationship of the

demographic profile and safety of the respondents. The demographics came from the company and the data of safety came from the lifting index of the NIOSH lifting equation. It shows that all the data and information gathered by the researchers are diverse.

It is shown in Table 11 that the age and length of stay have a very strong positive relationship with safety. Older workers are more at risk than younger ones when it comes to physical

activities. The longer the exposure in lifting and carrying, the riskier it is for the body. The height and safety have a very weak negative relationship with safety that contradicts the findings of Ratini that shorter people are less likely to have lower back pain or break a hip. One possible reason taller people have a bigger chance of a hip fracture is their high center of gravity. That not only makes them more likely to fall, but it also may make them hit the ground with more force if they do.

*Table 11. Relationship of Demographic Profile and Safety.*

Independent Variable (x)	Dependent Variable (y)	Pearson Value	Relationship	T-Value	T-Test Results $\alpha = 0.05$
Age	Lifting Index	0.9629	Very Strong Positive	12.86520825	Significant
Height		-0.1356	Very Weak Negative	-0.49347061	Not significant
Length of Stay		0.9258	Very Strong Positive	8.83041895	Significant

## 4. Conclusions

In this paper, the ergonomic problems encountered in manual material handling in a warehouse was studied. It was found out all of the carriers or loaders employed in the liquor section of the warehouse are male. The height, age, and length of stay of the carriers or loaders in the company are diverse so the researchers used this data and information in assessment relating to their safety. It was also revealed that they are already exposed to stress and safety issue related on lifting loads. It can be noted that the current execution in manual material handling of the carriers or loaders is ergonomically incorrect which means they are more prone to work related musculoskeletal disorders. From the Pre-assessment of the NIOSH Lifting equation, all of the carriers' or loaders' lifting index are greater than 1 which indicates that they are at high risk meaning they are lifting the boxes above the recommended weight limit or with incorrect execution of lifting or carrying. As obtained from the Post-assessment of the NIOSH Lifting equation, all of the carriers' or loaders' lifting index are less than 1 that indicates they are at normal risk. It was also found out that the age and length of stay in the current position of the respondents' highly affect their safety. Aging can affect the ability of the workers to do manual material handling and other physical activities. Older workers are more at risk than younger ones when it comes to physical activities. The longer the exposure in lifting and carrying, the riskier it is for the body. Due to absence of company's Safety Procedure Guidelines, the carriers or loaders of the warehouse have higher risk of developing Musculoskeletal Disorders that may cause long term health issues and lessen the workers' effectiveness at work.

Some corresponding recommendation can be made according to the above conclusions. For the profile variables of the workers that may affect carrier's or loader's safety at work, the weight and health conditions or medical history must be considered. To widen the scope of the study, other persons involved in manual material handling such as truck loaders should also be considered. Other ergonomic tools such as Manual Handling assessment charts as MAC too and WISHA lifting equation of revaluating manual material

handling may also be used to compare results.

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