Journal of Ergonomics

Shahu, J Ergonomics 2016, 6:2
DOI: 10.4172/2165-7556.1000159

Review Article

Open Access

The NIOSH Lifting Equation for Manual Lifting and Its Applications

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Received date: October 31, 2015; **Accepted date:** March 21, 2016; **Published date:** March 27, 2016

Abstract

The literature on the problems caused by frequent lifting and lowering tasks has grown rapidly in the past few decades. This paper focuses on presenting literature on the NIOSH Lifting Equation, which is used for calculating injure-free lifting capabilities for workers who perform two-handed manual lifting tasks and using the study as a basis for applying it to a manufacturing company Technocrats India, Nagpur. The papers acquired for the study focus on the importance of the equation to reduce the effect of Low Back Pain (LBP) associated with various lifting operations. The result of the study is a systematic research and compilation of various aspects of the equation and its applications at construction sites and industrial organizations and its use at a manufacturing company where the manufacturing process comprises the machining of the Cylinder Body part and Valve body part. The equation will be used for these to know the effect of the work on workers. The final assessment of the study is that for successful outcomes for reduction in Work related Musculoskeletal Disorders (WMSDs) and LBP, the equation should be thoroughly considered for manual lifting practices.

Keywords: NIOSH lifting equation; Work related musculoskeletal disorders; Manual lifting; Low back pain

Introduction

The National Institute of Occupational Safety and Health (NIOSH) felt the need for the development of a technique to mitigate the effects of Low Back Pain (LBP) and Work related Musculoskeletal Disorders (WMSDs) associated with lifting and lowering tasks [1-5]. It published the Work Practices Guide for Manual Lifting. The WPG included a summary of literature regarding lifting operations before 1981 [6]. The NIOSH lifting equation was first developed in 1981 and was called the standard NIOSH lifting equation, the equation was then reformed in 1991 and was called the revised NIOSH lifting equation [1]. The revised NIOSH lifting equation included aspects such as asymmetry, coupling, frequency, etc. for manual lifting [7]. These parameters proved to be of greater importance and more training is required for their use [8]. The equation was designed to provide a limit beyond which there would be a need to take ergonomic measures to curtail the risks [5]. A study indicated that approximately 650,000 workers every year suffer injuries and illnesses caused by overexertion, repetition etc. which have caused the US businesses to incur compensations between $15 to $20 billion dollars a year [1] Back injuries prevail as most common and costly in agriculture too, i.e., California agriculture has an average of 3,350 back injuries each year which accounts for more than $30 million [9]. The lifting equation is applicable to two-handed lifting tasks. One- and two-handed repetitive lifting tasks form a part of many occupations. Thus the metabolic demands of one- and two-handed tasks should be clearly understood to know if they would provide similar outcomes because a job design which would take this into consideration would prevent injuries related to lifting tasks.

Various other Manual Material Handling (MMH) methods exist of which NIOSH forms a part. A few of these methods include Snook Tables, ACGIH TLV, WA L&I, 3DSSPP, etc. of which Snook Tables, NIOSH and ACGIH TLV are compared below. Also, some of the other well-known and used tools for assessing physical hazards at workplace include:

Well known and used tools for assessing physical hazards at workplace

- **Arbetplatsprovaren:** A Swedish language, internet-based survey of physical and psychosocial aspects of the workplace.
- **Arbetsmiljön i skolan:** A Swedish language checklist tool for improving school work environments.
- **Cumulative Trauma Disorder–Risk Assessment (CTD-RAM):** Upper limb assessment tool for predicting injury incidence rates. This assessment model predicts injury incidence rates and assesses job risk. It further quantifies risk factors by strength, fatigue, and posture. The CTD-RAM specifies acceptable limits on work design for a given individual.
- **ErgoIntelligence and Ergomaster:** Software tools implementing a number of different checklist tools.
- **ErgoEquations (Online Ergonomic Tools-Office Solutions):** Contains an ergonomic analysis for musculoskeletal complaints, including the Discomfort survey, which assesses discomfort levels before and after implementing ergonomic solutions to document effectiveness; employee training; and ergonomic program documentation and planning.
- **Ergonomiska Checklista Datorarbete:** A simple checklist for evaluation of computer workplaces.
- **Ergonomitermometer:** A Swedish language tool using a ‘thermometer’ metaphor to help assess risk levels. This site contains a number of other ‘work environment’ checklists adapted to various sectors.
- **ISO/TS 20646-1:** A procedure for reducing work-related musculoskeletal disorders including a risk assessment checklist. The checklist considers lifting, carrying, and work requiring high physical force.

- **Job Hazard Pro** (Production Technology Engineering and Management Services): Evaluates potentially harmful situations in the plant or office.
- **Keyserling Checklist:** A classic, simple, risk factor checklist easily adapted to users' needs.
- **Manual Handling Assessment Chart (MAC):** Like the NIOSH equation this allows easy assessment of MMH tasks.
- **Manual Handling Guidance:** Checklists for task, equipment, environment and individual risk factors. The Manual Handling Guidance checklists can be used to identify risk factors for manual handling.
- **Manual Tasks Risk Assessment Tool (ManTRA):** A checklist from the University of Queensland.
- **NIOSH Survey:** A musculoskeletal checklist by the US NIOSH.
- **OCRA:** A short checklist-based index for assessing risk due to repetitive movements.
- **Ovako Working Posture Analysis System (OWAS):** For rapid assessment of postural loads at work.
- **PLIBEL:** A 1-page checklist, mostly of physical risk factors, available in several different languages. This is a method for the identification of musculoskeletal stress factors and risks.
- **Quick Exposure Checklist (QEC):** For assessing risk factors for work-related musculoskeletal disorders.
- **Rapid Entire Body Assessment Tool (REBA):** Similar to RULA but with a whole body focus.
- **Rapid Upper Limb Assessment Tool (RULA):** Provides a 'score' for upper limb demands by McAtamney and Corlett.
- **Risk Filter:** From the UK Health and Safety Executive, this two stage tool focuses on upper limb MSD risk.
- **Strain Index:** Combines time, repetition, load, and posture into a single index focused on hand/wrist load.
- **Work Environment Survey Tool (WEST):** Provides both traditional ergonomic and occupational hygiene analysis possibilities.

Comparison of Snook Tables, NIOSH equation and ACGIH TLV

An example including 2 different milk cases was considered to compare the three MMH methods. The details of the two milk cases are given in Table 1 and the values of the horizontal distance and vertical height are given in Table 2.

Characteristics of Containers		
Characteristic	23 L case	15 L case
Weight	26 kg	17 kg
Wide	33 cm	33 cm
Long	48 cm	33 cm
Tall	28 cm	28 cm
Handle distance from bottom of case	25 cm	25 cm
Cases to a pallet	30	45
Pallet stacking	3 rows wide/5 cases high/2 rows deep	3 rows wide/5 cases high/3 rows deep

Table 1: Characteristics of containers.

Horizontal Distance in cm (as defined by the tool)	Vertical Height in cm (floor to handle height)
23	25
23	53
30	81
30	109
30	137
30	165
30	193

Table 2: Hand grasps task measurements of horizontal distance for a given vertical height.

The EI values were calculated to get the outcome. An EI greater than 1.0 reveals the extent to which the load exceeds a recommended weight. The outcome of the study is given in the Table 3.

Vertical Height	NIOSH		ACGIH TLV		Snook	
Lift Origin (cm)	15 l	23 l	15 l	23 l	15 l	23 l
25	1.17	1.79	1.23	1.88	1.58	2.15
53	1.14	1.74	0.96	1.46	1.58	2.15
81	1.15	1.75	1.23	1.88	1.58	2.15
109	1.18	1.80	1.08	1.64	1.58	2.15
137	1.24	1.89	1.08	1.64	1.58	2.15
165	1.34	2.05	2.46	3.75	2.11	2.76
193	1.52	2.32	2.46	3.75	2.11	2.76

Table 3: EI Values of each tool, at each vertical height origin, for both the 15 l and 23 l cases.

All analytical tools predicted a greater musculoskeletal risk with the heavier load (23 L) versus the lighter load (15 L). ACGIH TLV and Snook are easier to apply, but NIOSH risk predictions are more sensitive to incremental changes in lift input values.

Comparison of Standard and Revised Equation

Comparison between 1981 standard NIOSH lifting equation and the revised NIOSH lifting equation has been given in Table 4 [7].

	Standard NIOSH Lifting Equation	Revised NIOSH Lifting Equation

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Standard Lifting Location	30 inches above the floor and 6 inches horizontally forward of the mid-point between the ankles	30 inches above the floor and the horizontal dimension has been increased to 10 inches
Load Constant	90 pounds (40 kg)	51 pounds (23 kg)
Calculated Limits	Action Limit (AL), Maximum Permissible Limit (MPL=v3AL)	Recommended Weight Limit (RWL), Lifting Index (LI<=1.0)
Multiplicative Weighting Factors	horizontal, vertical, distance, and frequency	two new ones - asymmetry and coupling
Analysis Procedure	Single-task analysis procedure	Multi-task analysis procedure

Table 4: Comparison of standard and revised NIOSH equation.

Use of NIOSH Equation for multi-task analysis

Multi-task analysis uses the single task RWL equation and additional indices to determine the overall cumulative physical demands of the lifting station. Multitask analysis is used in lifting operations where weights and heights vary [1].

Calculation of VLI for the NIOSH Equation

The Variable Lifting Index (VLI) can be calculated by first knowing the Frequency Independent Lifting Index (FILI) for each of the tasks that are selected for analysis, then depending upon the task variability each of the lifts is fitted into FILI categories (one to nine). These values and the corresponding frequency of lifts in each category are then input into the Composite Lifting Index (CLI) [4].

About the Equation

Calculations to be carried out to find outcomes of equation

The revised NIOSH lifting equation (1991) is used to evaluate the manual lifting tasks, [1-3]. The primary outcome of the lifting equation is the RWL which gives the limit of the maximum weight that all healthy workers can lift. Once the RWL is determined the Lifting index (LI) is calculated from it. The value of the LI suggests the level of stress that will be associated with the specified lifting task being evaluated, [10]. The equation is as follows, [2,10]:

RWL = LC (51 lbs) × HM × VM × DM × AM x FM × CM

LI = Weight / RWL

Details of variables, multipliers used in the equation

Waters et al. [3] explained the multipliers and the derivations of the equations which would use the respective variables to determine the multipliers [11], explained the variables with which the multipliers can be calculated. All of these have been specified in Table 5.

Variables	Description	Multiplier	Value in Centimetres	Value in Inches
H	Horizontal location of the object relative to the body	Horizontal Multiplier (HM)	HM = (25/H)	HM = (10/H)
V	Vertical location of the object relative to the floor	Vertical Multiplier (VM)	VM = (1 – 0.003 $\lvert$ V - 75 $\rvert$)	VM = (1 – 0.0075 $\lvert$ V - 30 $\rvert$)
D	Distance the object is moved vertically	Distance Multiplier (DM)	DM = (0.82 + (4.5 / D))	DM = (0.82 + (1.8 / D))
A	Asymmetry angle	Asymmetric Multiplier (AM)	AM = (1 - (0.0032A))	
F	Frequency and duration of lifting activity	Frequency Multiplier (FM)		
C	Coupling or quality of the workers grip on the object(good, fair, poor)	Coupling Multiplier (CM)		

Table 5: Details of variables used in the equation.

Interpretation of outcomes of the equation:

If the LI is less than 1.0, there are nominal or no chances of LBP or WMSDs to the working healthy employees. However, if the LI is greater than 1.0, there is an increased risk of such injuries, [11,12]. As explained by Waters et al. [3], the Load Constant is taken to be 51 lbs. This is considered to be the maximum recommended weight of the load that can be lifted by employees under ideal conditions. The frequency multipliers required for the equation can be determined from its respective table [3].

Use of NIOSH Equation for one- and two - handed lifting tasks

Sevene et al. compared the psychophysical and physiological work stress for identical lifting tasks which could be performed with either one or two hands. The result of the study is in Table 6 which shows no significant difference in terms of physiological and psychophysical stress, when good coupling exists. RPE is a scale that assesses work-related stress which is caused by a particular activity. It takes into account a combination of factors such as; perceived fitness, fatigue levels, environmental conditions, effort, etc.

Metabolic Parameters	Lifting conditions

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	Dominant Hand	Non-Dominant Hand	Both Hands
O_2 Consumption (ml/kg/min)	14.3	14.4	15.7
Liters of O_2/min	1.0	1.0	1.1
kCal/min	5.1	5.1	5.6
Heart Rate	103.4	105.4	107.1
RPE (Rating of Perceived Exertion)	9.4	10.0	9.4

Table 6: Metabolic parameters with respect to lifting conditions.

Criteria for Defining the Equation

Three criteria were used for defining the equations (both standard and revised equations, [3,13] namely:

- Biomechanical
- Psychophysical
- Physiological

Reasons for selection of the three criteria

These were selected because these factors affected the lifting operations majorly. Based on these criteria the various equations for knowing the multipliers were derived. Using these multipliers the Recommended Weight Limit (RWL) could be determined. Thus, the major use of these criteria was to know the RWL. RWL defines a limit for the weight that all healthy workers can lift while performing a lifting operation [3,13]. A study indicated that the revised NIOSH lifting equation describes the specific values used to establish a Recommended Weight Limit (RWL) and these were based on the three criteria [3].

The three disciplines with their cut-off values and design criteria are presented in a tabular form in Table 7.

Discipline	Design criterion	Cut-off value
Biomechanical	Maximum disc compression force	3.4 kN (770 lbs)
Physiological	Maximum energy expenditure	2.2-4.7 kcal/min
Psychophysical	Maximum acceptable weight	Acceptable to 75% female workers and about 99% male workers

Table 7: Criteria used to develop the lifting equation [3].

Reason for using a combination of the three criteria

The biomechanical criteria should maintain L5/S1 compression below 3400 N. The base of the spine is made up of the intricate L5/S1 vertebral segment [3,7]. The idea of using a combination of the three disciplines was to minimize the risks that tasks related to lifting can cause as either one of the three considered one at a time or even a combination of two would not mitigate the effects to an extent that would be protective of workers [3,13] Also these three criteria contradict one another to an extent, for example: metabolic data suggest is more efficient to lift heavier weights less frequently than to lift lighter weights more frequently; however, biomechanical studies suggest the load should be minimized by lifting lighter weights more frequently to reduce muscle and vertebral stresses. Also, when lifting from the floor, results from psychophysical studies suggest that workers can lift loads that are heavier than those estimated from biomechanical or physiological studies [3]. Thus, a combination of the three criteria is to be used [6,12] gave a graphical representation of the combination of the three criteria and how the RWL and Composite Acceptable Load (CAL) are determined based on it is shown below in Figure 1 [12].

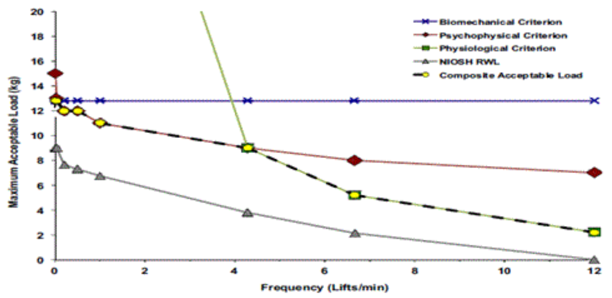

Figure 1: Example showing the integration of the biomechanical, psychophysical and physiological criteria to determine CAL values for each frequency for one condition (K-S range, D ¼ 51 cm, box width ¼ 75 cm). The composite acceptable load (CAL) was assumed to be the most conservative of the three criteria [12].

Assumptions

Phinder et al. [13] stated the following assumptions under which the NIOSH Lifting Equation is to be considered (these would not hold if the lifting factors were interdependent):

1. Lifting factors are independent of each other
2. Effects of multipliers are co-operative
3. Each factor contributes about the same amount of risk to the overall risk of low-back injury due to a given lifting task [13].

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General Applications

At construction sites to know maximum LI of all construction materials and make recommendations

Choi et al. [2] stated that; for construction workers to reduce their exposure to risks, they need to know the weights of common construction materials. Negligence of this would lead to pain or injuries among workers.

The results of the study are as given in Figure 2. It shows the Lifting Index (LI) with respect to various occupations carried out at the construction site.

Figure 2: Lifting Index with respect to occupation [2].

The maximum value of the Lifting Index is shown to be 7.3 for Dry Wall Installer so the risk factor for it is the most because the LI shows that it is too heavy. To improve the condition, the improvements that Choi et al. suggested were to

1. Use more than 2 workers
2. Use mechanical handling aids
3. Use 25% lighter weight drywall

At construction sites to compare LI for materials before and after making optimizations

Godwin et al. [11] gave the assessment of Work related Musculoskeletal Disorders (WMSDs) caused by lifting activities during building construction. The result before and after optimization are shown below in Table 8.

Object	Weight (kg)	LI = (Weight/RWL)	
		Normal Conditions (RWL = 6.83 kg)	Optimized Conditions (RWL = 23 kg)
Bag of Cement	50.0 kg	7.32	2.17
9-inch Hollow Block	20.80 kg	3.05	0.90
6-inch Hollow Block	16.70 kg	2.45	0.73
5-inch Solid Block	22.50 kg	3.29	0.93
6-inch Solid Block	26.67 kg	3.91	1.16
Full head pan of sand	37.80 kg	5.53	1.64
Full head pan of stone	30.30 kg	4.44	1.32

Table 8: Lifting Index for various objects before and after optimization [11].

At construction sites to calculate LI to know pain caused due to lifting tasks

Adeyemi et al. [14] catered to lifting tasks and pain caused due it among workers at construction sites in the South-western Nigeria. The results indicated the following:

More than 70% of the workers are at an increased risk of problems caused by lifting tasks. This is depicted in Figure 3.

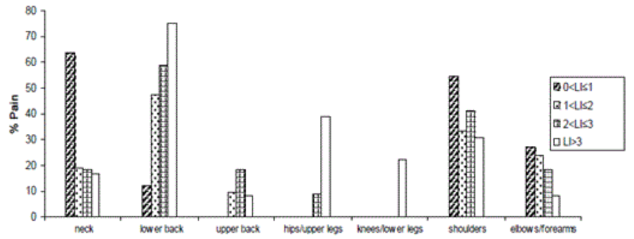

Figure 3: Pain in body regions in 12 months [14].

Level of ergonomics training to workers for working methods was found to be low. This is depicted in Figure 4.

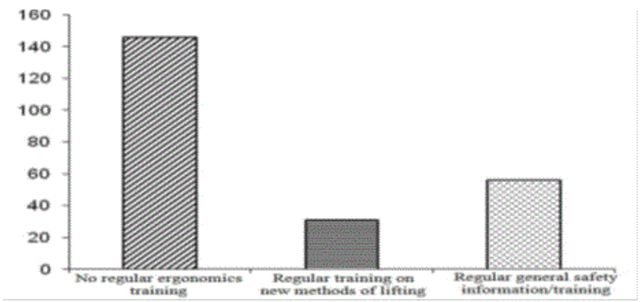

Figure 4: Response of workers to ergonomics training [14].

Redesigning of work methods was found to be necessary to reach the acceptable LI value.

At casting firms to calculate LI to assess risks due to various lifting tasks

Singh [15] studied the low back injury risk and work factors in few small scale casting firms of Northern India for a total of 40 workers. The result of the study was the risk level based on the Lifting Index calculated using the equation. Also, the percent of workers for whom actions need to be taken were calculated and the result is tabulated in the Table 9 [15].

Lifting Index	Risk level	Actions	Number of workers	Percentage of workers (%)
0-1	Safe	None necessary	6	15
2-Jan	Low	Necessary	13	32.5
3-Feb	Medium	Necessary soon	11	27.5
3 and above	High	Necessary now	10	25

Table 9: Lifting index values based on various tasks at the casting firms and their analysis [15].

At auto parts manufacturing firm to know LBP level before and after redesign

Meepradit et al. [16] considered 17 samples working in auto parts manufacturing. The job was to lift boxes of varying sizes, ranging from 15.7 to 28.7 pounds with duration of 1 h-4 h a day. The following were the outcomes of the study [16,17].

Questionnaires for workers for the analysis of musculoskeletal symptoms on a scale ranging from 0 (no pain) to 10 (worst pain) before and after redesign. The ergonomics redesigns included

1. Load being brought closer to the worker (by training);
2. Height of objects being placed to be raised (to reduce the vertical distance between the origin and destination of the lift);
3. Origin and destination of lift to be brought closer (to reduce the angle of twist).

The new procedures were trained to the workers. The result was a safer LI (<1.0) as shown on Table 10.

	Worker (n=17)	
Low Back Pain Level	Before redesign	After redesign
0	0	0
1	0	0
2	1	3
3	1	0
4	1	3
5	3	4
6	2	5
7	3	1
8	0	1
9	3	0
10	3	0

Table 10: Low Back Pain level among workers [16].

To compare MAWL and Heart rate values of Construction workers and Household Workers

Maiti and Ray [18] conducted a study to know the Maximum Acceptable Weight Limit (MAWL) for ten Indian adult female Construction Workers (CW) and eight Indian adult Female household workers (HW). The results of the study are as shown in Figure 5. These women were regularly over-exerted at work. Their MAWL was found to be 15 kg which is half of the safe load limit (30 kg) for adult female workers.

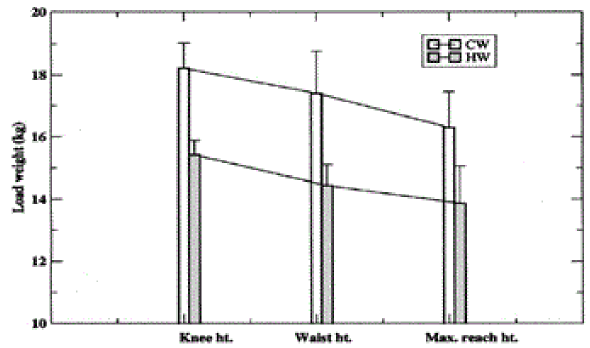

Figure 5: Average MAWL for three vertical distances for CW and HW [18].

The effect of work duration on heart rate is given in Figure 6. Heart Rate was calculated to help estimate the MAWL level for variable work duration [18].

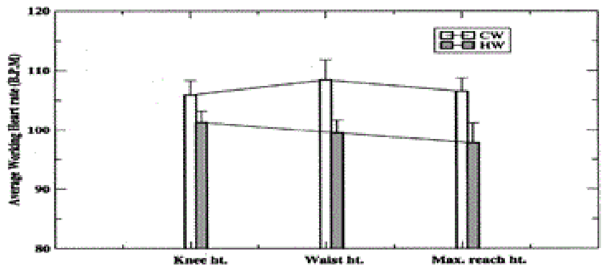

Figure 6: Average heart rate values for CW and HW [18].

At hospitals to know weight of patients that will be safe for nurses to lift.

Waters [6] took into consideration a study regarding the weight of patients that would be safe for nurses to lift. The results obtained under the following three conditions using the NIOSH Lifting Equation as shown in Table 11 are:

A nurse raising a patient's leg off the bed for surgery.

Patient's weight	Weight of leg	Weight patient can lift on his own	Maximum limit	Weight to be lifted by each nurse	Excess weight to be lifted by nurse(s)	Suggestions
A nurse raising a patient's leg off the bed for surgery						Use a leg lift or limb positioned
150 lbs	24 lbs	-	35 lbs	-	-	
200 lbs	31 lbs	-	35 lbs	-	-	
250 lbs	39 lbs	-	35 lbs	-	4 lbs	
300 lbs	47 lbs	-	35 lbs	-	12 lbs	
Two nurses helping a patient to stand from a chair						Use a lifting device or a sit-to-stand device
180 lbs	-	90 lbs	35 lbs	45 lbs	10 lbs	
Four nurses moving a fully dependent patient						
200 lbs	-	-	35 lbs	50 lbs	15 lbs	Use a lifting- assist device

Table 11: Weight beyond the maximum weight that the nurse has to lift.

Lifting of three boxes under specified conditions to calculate PWC of workers:

Singh et al. [18] considered a situation with the following considerations:

Frequency of lifts: 2, 5 and 8 lifts/min,

Weight of load: 7, 14 and 21 kg

Vertical height: waist, shoulder and maximum reach

Horizontal distance: 25, 40 and 55 cm

Laboratory condition: 21°C, 27°C and 33°C

Three rectangular box size: X (35 × 24 × 28 cm), Y (44 × 34 × 17 cm) and Z (58 × 38 × 24 cm)

These were considered for the evaluation of Physical Work Capacity (PWC) of Indian male workers during manual lifting [18].

The results of the study are shown in Table 12 [18].

	More significant factors	Less significant factors
Oxygen Intake	Lifting frequency (% contribution 43.28), Lifting load (11.34)	Box size (% contribution 1.23), Horizontal distance (0.30)

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Heart Rate	Lifting frequency (49.85), Vertical height (18.28), Environmental condition (11.12)	Horizontal distance (0.87)

Table 12: Effect of lifting variables on heart rate and oxygen intake.

Singh et al. [18] also gave suggestions on ways to improve physiological cost of workers. A few of them are:

1. Beyond 5 lifts/min, reduce frequency of lift as per anthropometric detail of worker
2. For weight more than 23 kg, use two or more workers
3. Heavier objects to not be lifted above shoulder height
4. Proper handles to boxes and training to use them to be provided, etc.

At wine yard to know risk involved during lifting and make improvements

Meyers et al. [9] suggested that manual wine-grape harvesting is highly strenuous and physically demanding work, involving risks of chronic back injury. The findings showed the physical impact of work had a large increase in WMSD symptoms on workers during the standard-tub trial (70% of workers reporting symptoms). Thus, the standard tubs were replaced by smaller picking tubs, the outcome was that the LI reduced from 3.4 to 2.4 [9].

Application at Technocrats India

Based on the above study of the NIOSH Equation, it is being applied at Technocrats India, Nagpur which is a partnership firm established in 1986 at Mumbai. It manufactures various types of components for automotive sector, Agriculture sector, Earth moving sector, Defense Industries, etc. The company has started a new fully equipped plant in Nagpur, Maharashtra in April 2008.

Of the various components, the components presently being manufactured are the Hydraulic Cylinder Head and the Valve body parts for one of its esteemed client, Mahindra and Mahindra Ltd. Due to excessive lifting and lowering tasks that had been observed over a period of time, the equation was put to use in the company.

Initially the plant layout was designed for the company to specifically know the flow of materials and their handling by various operators for both, the cylinder head and the valve body parts (Figure 7).

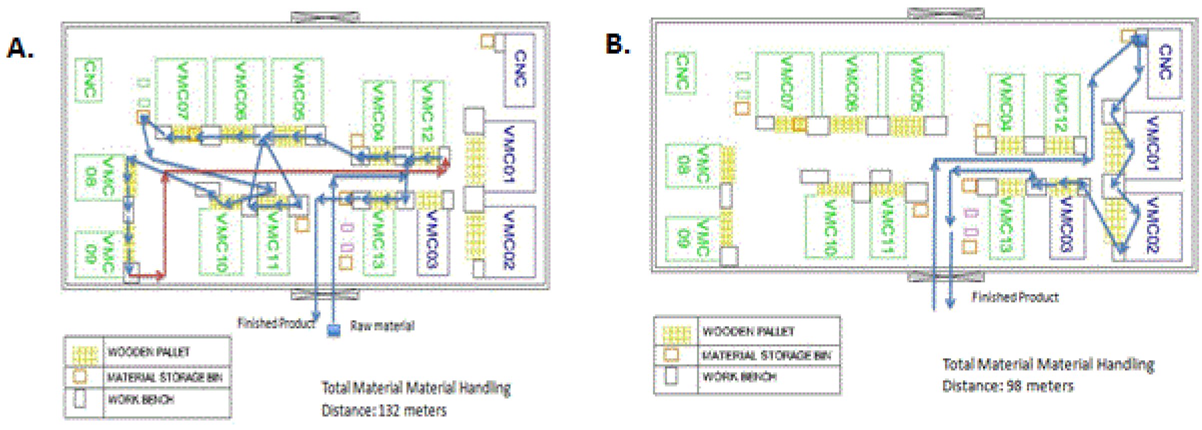

Figure 7: Flow of material: Valve body part and Cylinder body part respectively.

For frequency of lifts the following calculations were carried out as given in Table 13.

Operation	Man Allocation	TMU	Online	Offine	Spraying Op	Process Time (Min)	Cycle Time	Output/Shift	Output/Day
CNC	1	1200	0.52	0.03	0.17	3.38	4.07	165	329
VMC01	1	1417	0.65	0.03	0.17	3.35	4.22	159	320
VMC02	1	1450	0.67	0.03	0.17	3.35	4.19	160	320
VMC03	1	1233	0.54	0.03	0.17	3.45	4.16	161	322
Conventional Drilling M/C	1	1756	1.02	0.03	0	0.72	1.74	384	769

					18.37	159	320

Table 13: Task allocation: Cylinder body part.

A total of 38 operators form a part of the machining, of which 8 are for the cylinder body part machining. Measurements for the variables for Cylinder body part have been given in Table 13, 14a and 14b. Based on these the RWL and LI were calculated. Measurements and calculations for valve body part will be carried out in the further phases of the work.

Origin is for the operator lifting the part from the bin/table and placing it into the CNC. Destination is for the operator removing the part from the CNC and placing it on the table where it is inspected and then stacked.

ID	V	VM	H	HM	D	DM	A	AM	C	CM	L	Dur	F	FM	RWL	LI
1	39.37	0.93	3.97	1	4.17	1	83	0.71	Poor	0.9	17.63	8	0.3	0.81	11.07	1.59
2	11.85	0.85	7.91	1	3.97	1	87	0.71	Poor	0.9	17.63	8	0.32	0.81	10.11	1.74
3	39.37	0.93	4.17	1	4.13	1	79	0.76	Poor	0.9	17.63	8	0.33	0.81	11.85	1.49
4	16.37	0.89	7.99	1	8.11	1	84	0.71	Poor	0.9	17.63	8	0.27	0.81	10.59	1.66
5	12.16	0.85	15.35	0.67	4.13	1	88	0.71	Poor	0.9	17.63	8	0.3	0.81	6.77	2.6
6	39.37	0.93	8.07	1	4.09	1	86	0.71	Poor	0.9	17.63	8	0.33	0.81	11.07	1.59
7	16.06	0.89	12.2	0.83	4.17	1	87	0.71	Poor	0.9	17.63	8	0.3	0.81	8.79	2.01
8	16.18	0.89	4.56	1	4.96	1	84	0.71	Poor	0.9	17.63	8	0.3	0.81	10.59	1.66

Table 14a: LI calculations for cylinder body part (Origin).

ID	V	VM	H	HM	D	DM	A	AM	C	CM	L	Dur	F	FM	RWL	LI
1	8.18	0.85	4.09	1	4.33	1	88	0.71	Poor	0.9	17.63	8	0.3	0.81	10.118	1.74
2	9.05	0.85	7.99	1	7.95	1	83	0.71	Poor	0.9	17.63	8	0.28	0.81	10.118	1.74
3	8.18	0.85	4.09	1	4.33	1	82	0.76	Poor	0.9	17.63	8	0.27	0.81	10.831	1.63
4	11.92	0.85	8.18	1	7.95	1	89	0.71	Poor	0.9	17.63	8	0.3	0.81	10.118	1.74
5	8.03	0.85	8.03	1	3.97	1	76	0.76	Poor	0.9	17.63	8	0.3	0.81	10.831	1.63
6	8.42	0.85	3.97	1	4.33	1	78	0.76	Poor	0.9	17.63	8	0.27	0.81	10.831	1.63
7	8.97	0.85	4.05	1	7.91	1	82	0.76	Poor	0.9	17.63	8	0.3	0.81	10.831	1.63
8	12.16	0.85	7.91	1	7.67	1	85	0.71	Poor	0.9	17.63	12	0.28	0.81	10.118	1.74

Table 14b: LI calculations for cylinder body part (Destination).

The result after using the equation shows that for the Cylinder body part for all 8 operators, the LI came out to be greater than 1.0. This indicates there is a risk of LBP and other injuries to the workers associated with the lifting tasks (both at the origin and the destination).

The increased LI was majorly seen because of the poor coupling, the angle of asymmetry and the vertical location of the object. The horizontal location, the distance of lift and the frequency of lifts were found to be within proper limits.

In order to mitigate the effects so as to reduce the LI, it has been suggested to use roller conveyers to move the part easily. Also, it was suggested to provide tables with appropriate height for placing the object both at the origin and the destination and it was advised to provide proper rest periods at regular intervals [19-21].

Conclusion

The NIOSH Lifting Equation has its application in a variety of fields to reduce the Low Back Pain caused by manual lifting tasks at workplaces. The study based on these applications is being used to know effectiveness of lifting tasks in order to ensure safe working practices of workers at Technocrats. The result shows increased LI for all the 8 operators working on the Cylinder Body part machining. Suggestions regarding using proper heighted tables and roller conveyers were made so that the working will be more protective of workers.

Future Work

On carrying out a detailed study on Cylinder Body part, the results were found to be not very safe for workers so a detailed study will also be carried out for the Valve body part to know the effects of it on the operators.

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