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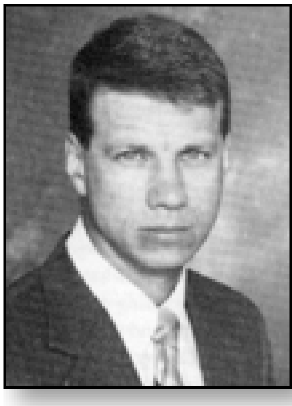

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Introduction

Ergonomics is the application of scientific principles, methods, and data drawn from a variety of disciplines for the development of engineering systems in which people play a significant role (Kroemer, 1994). The Institute for Occupational Ergonomics (1999) defines ergonomics as an understanding of the needs, limitations, and abilities of people, and the use of this understanding for the design of products and environments in which people live.

Ergonomics evaluations in industrial settings have recently received increased attention due to the cost incurred as a result of repetitive motion injuries. Jeffress (1999) indicated that approximately 650,000 workers every year suffer serious injuries and illnesses caused by overexertion, repetition, and other types of physical stress. Such injuries cost U.S. businesses between $15 to $20 billion dollars a year in workman compensation. According to the US Department of Labor, back injuries accounted for nearly 20% of all injuries and illnesses in the workplace. In the UK, similar numbers appear with 27% of all reported accidents involving manual handling. During 1982, 42% of all back injuries due to lifting occurred in manufacturing settings (US Dept. Labor, 1982).

In 1981, the National Institute for Occupational Safety and Health (NIOSH) recognized the need for increased attention in work-related back injuries and published the *Work Practices Guide for Manual Lifting*. A revision of manual lifting practices was published in 1991 entitled *Scientific Support Documentation for the Revised 1991 NIOSH Lifting Equation*. A final lifting equation was published as the *Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks* in 1993. The revised NIOSH equation is primarily concerned with the application of ergonomic measurements and equations for the protection of workers employed in a wide range of lifting tasks. As the number of work-related musculoskeletal disorders (WMSDs) increase and scientific evidence validating that WMSDs can be reduced with ergonomic intervention programs, OSHA has taken recent action to draft a national ergonomic regulation (National Research Council, 1999). Additionally, individual states are proposing ergonomic standards. North Carolina is currently proposing an ergonomic law requiring employers to provide ergonomic training within ninety days of employment (“North Carolina”, 1998).

Acronyms

WMSD	Work-Related Musculoskeletal Disorders
RWL	Recommended Weight Limit
NIOSH	National Institute for Occupational Safety and Health
LC	Load Constant
HM	Horizontal Multiplier
VM	Vertical Multiplier
DM	Distance Multiplier
AM	Asymmetric Multiplier
FM	Frequency Multiplier
CM	Coupling Multiplier
FIRWL	Frequency Independent Recommended Weight Limit
FILI	Frequency Independent Lifting Index
STRWL	Single Task Recommended Weight Limit
STLI	Single Task Lifting Index
CLI	Composite Lifting Index

Purpose

The purpose of this paper is to provide Industrial Technology (IT) educators with a sample case study of an industrial lift station using the NIOSH method for ergonomic analysis. Knowledge of ergonomic factors is significant to IT graduates. Shaw (1995) noted that many IT graduates enter into supervisory positions requiring competencies related to health and safety, and an understanding of ergonomic factors. This case study, developed by IT students in an ergonomics course, represents an applied ergonomic on-the-job assessment tool useful to students.

Job Description

The NISOH job description requires cycle times and sequence of operations of the person performing the job. The general job description for the lift station investigated required lifting boxes of varying size and weight, and placing those boxes at various heights onto skids. The carrying distance for placement also varied. Boxes received from a conveyor system are sorted and carried to skids for shipment to appropriate departments. The rate of picking and placing of boxes averaged between 3 to 4 boxes per minute per person. Assumptions include: (1) the control of the load is not required at the destination, (2) the worker does not twist when picking and placing the cartons, (3) the worker can get very close to each carton and place his/her hip against the carton for support, (4) the conveyor line is kept full, minimizing the walking distance for pickup, (5) there is no significant control required at the destination. Figure 1 shows a drawing of the lifting station layout.

Job Analysis

Job analysis requires a detailed examination of the tasks. The purpose of task analysis is to make a step-by-step investigation of the demands made on an operator, for a particular task or group of tasks. Tasks can be broken down into two elements, description and analysis. Task descriptions document each element of an operation, and task analysis determines the demands made on the operator by the task, for comparison to human capabilities (Drury, 1983). Results from a task analysis are applied to the NIOSH equation in determining task variables. Due to the various sizes and weights of the boxes, the load values were averaged and grouped into three categories.

NIOSH Method of Lifting Analysis

The revised NIOSH manual lifting equation is a tool to provide industrial safety and ergonomic practitioners with meaningful data on the maximum weight limits of two-handed manual lifting. The main component of the NIOSH standard is the determination of recommended weight limit (RWL). RWL is defined for a specific set of tasks or task "as the weight of the load that nearly all healthy workers can perform over a period of time up to eight hours without an increased risk of developing lower back pain" (Walters, 1998, p.4).

The RWL consists of the following multipliers RWL = (LC) x (HM) x (VM) x (DM) x (AM) x (FM) x (CM). Multipliers are determined by task variables. H, V, D, A, F, and C are task variables which measure various characteristics of a job. *H* equals the horizontal distance from the mid-point of the line joining the inner ankle bone to a point on the floor directly below the mid-point of the hand grasps. *V* is the vertical height of the hands above the floor. Figure 2 shows the graphical representation of the *H* and *V* task

Figure 1. Lifting Station Layout

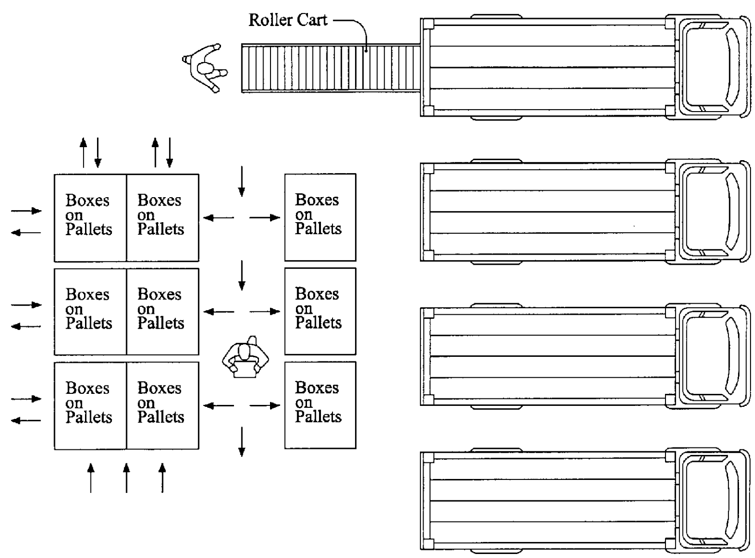
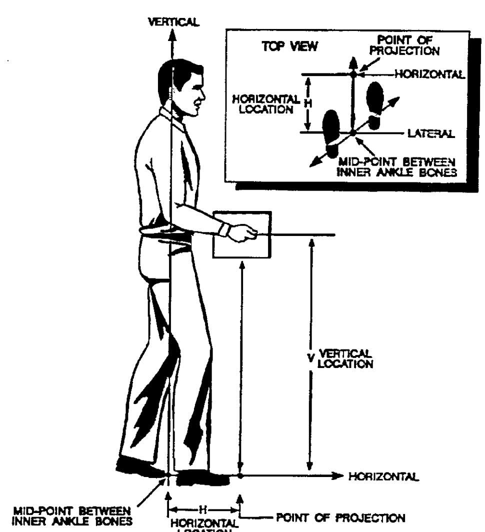


Figure 2. Graphical Representation of Hand Location



variables. *D* is the distance component and is defined as the vertical travel distance of the hands between the lift origin and destination. *A* is the asymmetry component and refers to angular displacement or twisting of the body where the lift begins and ends. *F* is the frequency component and is defined as the number of lifts per minute.

Equations and charts determine multipliers for each task variable. The horizontal multiplier *HM* is 10/H for H measured in inches. If H is less than or equal to 10 inches, the multiplier is 1.0. The vertical multiplier *VM* is the absolute value or deviation of V measured at the origin, from an optimum height of 30 inches. The *VM* equation is 1 - (0.0075 | V - 30 |) and when *V* is at 30 inches VM is equal to 1.0. The distance multiplier *DM* is (0.82 + (1.8/D) and *DM* is equal to 1.0 when D is at 10 inches. The asymmetric multiplier *AM* is 1-0.0032A where AM has a maximum of 1.0 when the load in directly in front of the body and decreases as the angle of asymmetry (A) increases. The *CM* is the coupling component and describes the hand-to-object ease of gripping. A good grip coupling reduces the maximum grasp force and increases the acceptable weight limit.

Single task analysis uses the RWL equation and should be used when task variables do not vary significantly from task to task. Examples include a repetitive pick and place operations with constant load dimensions, weights, place location, and repetitive body motions (Walters, 1994). Figures 3 and 4 show the values of the remaining multipliers (FM) and (CM).

Multi-task Analysis

Multi-task analysis uses the single-task RWL equation and additional indexes to determine the overall cumulative or composite physical demands of the lifting station. Multi-task analysis is used in lifting operations where weights and heights vary. Multi-tasking equations were entered in an Excel spreadsheet for variable manipulation and optimization. Figure 5 shows a completed multi-task job analysis worksheet for the lift station investigated.

The FIRWL (Frequency Independent Recommended Weight Limit) for each task reflects the compressive force and muscle strength required for a single repetition of that task. The FIRWIL is obtained by multiplying LC x HM x VM x DM x AM x CM. The STRWL (Single Task Recommended Weight Limit) for each task reflects the overall demands of one task within the job and is calculated by multiplying the FIRWL x FM for each task. The FILI (Frequency Independent Lifting Index) identifies potential strength problems for infrequent lifts and is obtained by dividing the load (L) for each task by the respective FIRWL. The STLI (Single Task Lifting Index) for each task is computed by dividing the average load weight (L) for that task by the respective STRWL. The STLI is used to identify individual tasks with excessive physical demands. If any STLI value exceeds 1.0 then ergonomic changes may be needed to reduce the physical demands of the task.

Figure 3. Frequency Mulitiplier FM

Frequency Lifts min (F)	Work Duration					
	<= 1 Hour		>1 but <= 2 Hours		>2 but <= 8 Hours	
	V < 30	V = > 30	V < 30	V = > 30	V < 30	V = > 30
<=0.2	1.00	1.00	0.95	0.95	0.85	0.85
0.50	0.97	0.97	0.92	0.92	0.81	0.81
1.00	0.94	0.94	0.88	0.88	0.75	0.75
2.00	0.91	0.91	0.84	0.84	0.65	0.65
3.00	0.88	0.88	0.79	0.79	0.55	0.55
4.00	0.84	0.84	0.72	0.72	0.45	0.45
5.00	0.80	0.80	0.60	0.60	0.35	0.35
6.00	0.75	0.75	0.50	0.50	0.27	0.27
7.00	0.70	0.70	0.42	0.42	0.22	0.22
8.00	0.60	0.60	0.35	0.35	0.18	0.18
9.00	0.52	0.52	0.30	0.30	0.00	0.15
10.00	0.45	0.45	0.26	0.26	0.00	0.13
11.00	0.41	0.41	0.00	0.23	0.00	0.00
12.00	0.37	0.37	0.00	0.21	0.00	0.00
13.00	0.00	0.34	0.00	0.00	0.00	0.00
14.00	0.00	0.31	0.00	0.00	0.00	0.00
15.00	0.00	0.28	0.00	0.00	0.00	0.00
>15	0.00	0.00	0.00	0.00	0.00	0.00

Figure 4. Coupling Mulitiplier

Coupling Type	Coupling Multiplier	
	V < 30 inches (75 cm)	V = > 30 inches (75 cm)
Good	1.00	1.00
Fair	0.95	0.92
Poor	0.90	1.00

The CLI (Composite Lifting Index) determines the additive affect of several tasks and is obtained by renumbering the tasks in decreasing order of physical difficulty as indicated by the STLI of each task. The CLI equation is listed in step three of figure 5. Note the subscripts in the CLI equation refer to the renumbered STLI sequence and are summed to determine a combined frequency multiplier (FM). The *F* (frequency rate) for the new renumbered tasks (subscripts of the equation) are summed and for a total frequency rate. The appropriate FM is then obtained from figure 3.

Data Analysis & Redesign Suggestions

The Frequency Independent Lifting Index (FILI) of task one is less than 1.0, and is therefore not stressful in terms of strength requirements. The Single Task Lifting Index (STLI) of greater than 1.0 for tasks two and three indicate a stressful situation and the lift station design or procedure should be corrected. The frequency component for tasks 2 and 3 are significant. If the frequency component for tasks 2 and 3 were decreased, the Single Task Recommended Weight Limit (STRWL) would fall within acceptable limits. The analysis worksheet shows the multipliers of the smallest magnitude (i.e. those providing the greatest penalty) are HM of .40 for task 3 and HM of .50 for task 2. Based on this data the following recommendations are suggested:

- The lifting duration time which effects the frequency multiplier (FM) should be reduced to less than or equal to two hours. A break time is recommended between these two-hour shifts.
- As the boxes get larger in weight they also increase in size thus affecting the HM component. The *H* distance increases as the boxes get larger in size, requiring workers to overextend in order to obtain leverage, which increases stress in the lower back. A walking platform should be installed to raise the worker to the mean box height.
- It is recommended that roller conveyors be located in front of each skid row. With this design, workers take the boxes off of the feeding conveyor and place them on one of two side conveyors.
- The mean weight loads for the multi-tasking equations were divided into three categories. Workers are required to bend down to floor level and place the smaller boxes on skids. For larger boxes this bending distance is reduced. All boxes are required to be stacked a maximum of six feet thus the vertical distance (V) between the origin and destination location should be reduced. Skids should be raised so that boxes are placed at the standard “knuckle height” of 30 inches.

Summary

The goal of this study was to determine ergonomic acceptable limits according to the NISOH method for an industrial lifting station. The data collected demonstrates that the frequency component for tasks two and three is excessive and should be reduced through a reduction of the duration of the lifting time. The horizontal distance *H* is excessive with larger sized boxes and should be decreased. The vertical distance multiplier as a function of the distance an object travels before placement is excessive and should be reduced.

Results of the study show that several factors require examination to determine an ergonomically correct lifting station. Each of these factors (multipliers) is summarized into an overall cumulative lifting index of the lifting station. An examination of the cumulative indexes reveals areas of concentration in order to reduce overall task stress and lower back related injuries.

References

North Carolina (1998). North Carolina pressing to become second state with ergonomics standard. CTD NEWS September, p 1-3.

Dury, C. G. (1983). Task Analysis methods in industry. Applied Ergonomics, 14.1, 19-28.

Institute for Occupational Ergonomics (1999). Department of Manufacturing Engineering and Operations Management University of Nottingham UK, http://www.ccc.nottingham.ac.uk/~epzwww/Research/ioe/index.html

Jeffress, C. (1999). Statement of Charles N. Jeffress, Assistant Secretary of Labor for Occupational Safety and Health 3/4/99. Office of Public Affairs. US Department of Labor,

Kromer K. (1994). Ergonomics, how to design for ease and efficiency, New Jersey: Prentice Hall.

National Research Council (1999). Work-Related Musculoskeletal Disorders: A

Review of the Evidence. Steering Committee for the Workshop on Work-Related Musculoskeletal Injuries. The Research Base, Committee on Human Factors, National Research Council. National Academy Press.

Shaw, R. (1995). Industrial Supervision Competencies for Industrial Technology Programs. Journal of Industrial Technology. p18.

US Dept. Labor (1982). Back injuries associated with lifting. Washington, Bureau of Labor Statistics, Bulletin no. 2144.

Walters, T and Anderson, V. (1998). Assessment of manual lifting - The NIOSH approach. In Karwowski & Salvendy (Eds.), Ergonomics in Manufacturing, (pp 206-207).

Walters, T (1994). Applications manual for the revised NIOSH equation. U.S. Department of Health and Human Services, publication No. 94-110.

Figure 5. Multi-Task Job Analysis Worksheet

MULTI-TASK JOB ANALYSIS WORKSHEET

Department Receiving

Job Title

Analyst's Name

Date

Job Description

Lifting boxes off a conveyor and placing them on shipping skids.

STEP 1. Measure and Record Task Variable Data

Task No.	Object Weight (lbs)		Hand Location (in)				Vertical Distance	Asymmetry Angle (degs)		Frequency Rate	Duration	Coupling
			Origin		Destination			Origin	Dest.	lifts/min.	Hrs.	C
	L (avg)	L (Max)	H	V	H	V	D	A	A	F		Poor
1	10	12	14	36		12	24	0	0	4	3.5	Poor
2	21	16	20	40		36	4	0	0	3	3.5	Poor
3	31	34	25	44		72	28	0	0	2	3.5	

STEP 2. Compute multipliers and FIRWL, STRWL, FILI, and STLI for Each Task

Task No.	LC X	HM X	VM X	DM X	AM X	CM	FIRWL x FM		STRWL	FILI = L / FIRWL	STLI = L / STRWL	New Task No.	F
1	51	0.71	0.96	0.90	1.00	1.00	31.14	0.45	14.01	0.32	0.71	3	4
2	51	0.50	0.93	1.00	1.00	1.00	23.59	0.95	22.41	0.89	0.94	2	3
3	51	0.40	0.90	0.88	1.00	1.00	16.15	0.55	8.88	1.92	3.49	1	2

STEP 3. Compute the Composite Lifting Index for the Job. (After renumbering tasks)

CLI =	$STLI_1$ +	$\Delta FILI_2$ +	$\Delta FILI_3$ +	$\Delta FILI_4$	
		$FILI_2$ (1 / $FM_{1,2}$ - 1 / FM_1)	**$FILI_3$ (1 / $FM_{1,2,3}$ - 1 / $FM_{1,2}$)**	**$FILI_4$ (1 / $FM_{1,2,3,4}$ - 1 / $FM_{1,2,3}$)**	
		0.99*(1/0.35) - (1/0.65)	0.36*(1/.15) - (1/0.35)		
CLI =	3.49	1.29010989	-0.457142857		4.32