AN EVALUATION OF MANUAL MATERIAL HANDLING OF PACKAGING MATERIALS AND ASSOCIATED INJURIES AT COMPANY XYZ

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Abstract

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The purpose of this study is to evaluate current manual material handling methods and alternative methods that could be used in handling the roll stock at Company XYZ. The company is a leader in the food industry producing over 15 million cases product a year. The company paid $136,000 for back injuries that occurred in the facility. The goals were evaluate the potential of back injuries to workers while manually handling roll stock

evaluate the effectiveness of automated methods of material handling to reduce injuries while handling roll stock. The methods used in this study included:

1. Met with safety coordinator and reviewed accident records for the FY 98 to FY 99 periods.
2. Met with employees to discuss what methods were being used to lift roll stock and the accidents that were occurring.
3. Conducted testing of back movement and measurement of the lifting using the LMM and Wagner force gauge.
4. Met with employees to evaluate results and discuss suggested solutions to the problem.
5. Met with management to review the results and to bring in hoist on a trial basis.
6. Conducted testing of back movement using the hoist.

With the data presented in this paper, the addition of a hoist at all of the manual roll stock locations would reduce the injuries and costs.

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Chapter 1

Research Problem and Objectives

Introduction

The pain associated with a back injury affects all aspects of your life, from working, or driving a car, to walking and sitting. Back injuries are one of the leading causes of lost workdays in industry today (Marras, W. S., Lavender, S. A., , Leurgans, S.

E., , Rajulu, S. L., Allreadm, W. G., Fathallah, F. A., & Ferguson, S.A.,.1993). The importance of reducing lower back injuries in the work place stem from its high prevalence in workers, its effects on workers in terms of pain and disabilities and its effects on the company in terms of worker compensation costs and lost days away from the job (Marras, W. S., Fine, L. J., Ferguson, S. A., & Waters, T. R. 1999). Studies of manual material handling (MMH) tasks have identified work intensity, static work, frequent bending and twisting, lifting, and pushing or pulling as occupational risk factors in lower back disorders (Marras et al. 1993)

According to the Bureau of Labor Statistics (BLS) of the Department of Labor, in 1994, of the cases involving days away from work, approximately 705,800 cases (32%) were caused by over exertion or repetitive motion. Specifically, 367,424 cases were caused by over exertion in lifting (65% affected the back), 93,325 by pushing or pulling (52% affected the back), 68,992 by over exertion of holding, carrying or turning objects (58% affected the back). Workers compensation costs associated with MMH have cost Company XYZ $136,000 in fiscal year (FY) 1999. The top MMH related injuries are back and shoulder strains from up righting roll stock. At company XYZ, frequent pushing, pulling, twisting, bending and lifting of heavy roll stock places a high importance on modifying or eliminating the current handling techniques. Roll stock is used in all three areas of the facility. Reduction of losses associated with roll stock will benefit not only the budgets of departments that use the roll stock but also by reducing stress on the employees that is associated with removing people that have been injured on the job. Loss of injured employees shows an increase in overtime, increase in work duties, and changes in the work flow due to a new team member that my not be as capable in the job as the usual employees.

Purpose of the Study

The purpose of this study is to evaluate current manual material handling methods and alternative methods that could be used in handling the roll stock at Company XYZ.

Goals of the Study

The goals of this study are:

1. Evaluate the potential of back injuries to workers while manually handling roll stock
2. Evaluate the effectiveness of automated methods of material handling to reduce injuries while handling roll stock.

Background and Significance

Company XYZ is a leader in the food industry. It currently employs 500 people and produced 9,500,000 cases of pudding and 5,800,000 cases of hot cocoa in FY 99. The company has three main packaging areas. In FY 99 the company paid $236,000 in worker compensation. Back injuries accounted for $136,000, of which $46,157 was from manual material handling of roll stock. The cost of back strains accounts for 55% of the workers compensation costs, but only 10% of the accidents. By investigating and implementing methods to reduce the MMH of roll stock, the company should see a decrease in worker compensation costs.

Limitations

The measurements taken by the Lumbar Motion Monitor (LMM) were done on only the lower two layers of the pallet. The temporary mounting of the hoist would only allow lifting of roll stock 36" off the ground.

Assumptions

The assumptions in this paper are:

1. all information reported from the accident reports and workers compensation records are accurate.
2. the effects on employees from handling of roll stock in Dry Packaging are the same in Wet Packaging and the Hassia areas.

Definitions

Dry packaging - The packaging area that is associated with all dry product packaging.

Duration - The length of time anything occurs.

Dynamic - Referring to the muscle action, active or with movement of the body part.

Frequency - The number of times an action is performed in a given period of time.

Hazard – a factor in the workplace that has the potential to cause injury.

Load - An object of weight handled.

Loss tab analysis - a systematic review of losses that pulls out the top three causes of loss due to the criteria selected.

Lumbar spine - The lower back region, often referred to as the "small of the back".

Roll stock - Rolls of packaging material.

Multipliers- Formulas with in a the NIOSH equation

Asymmetry - the angle in degrees of the object from the sagittal line

Coupling – the grasp of the hands on an object.

Static - Referring to muscle action, without movement of a part of the body.

Hassia area – The new pudding packaging area that uses Hassia brand equipment.

Thoracic spine - The area of the spine where the ribs are located.

Wet packaging - The pudding packaging area located in the old section of the facility.

Summary

Manual material handling injuries throughout industry can account for over one-third of the lost day accidents in industry today (Marras et al., 1993). This paper will look at the current methods that Company XYZ uses to handle the roll stock, determine the level that risk of back injuries exists and evaluate an alternative method to help reduce injuries caused by MMH. A review of current research being conducted to test lower back strain and a review of the technology to reduce injuries will be covered in Chapter 2.

Chapter II

Literature Review

Introduction

Preventing back injuries and other trauma to employees while handling materials is a major concern for companies today. How a company evaluates the job risks can affect the bottom line of a company. Misidentified risks such as under-rated job risk may be increasing the cost of workers compensation due to the injuries that could occur, in contrast, over-rated job risk may have the company spend money on job modifications that are not required. The purpose of this study is to evaluate current manual material handling methods and alternative methods that could be used to handling the roll stock at Company XYZ. The objectives of this study are to evaluate the potential of back injuries to workers while manually handling roll stock and to evaluate the effectiveness of automated methods of material handling to reduce injuries while handling roll stock. A review of current literature will cover the NIOSH lifting equation, alternative methods to the NIOSH equation, methods of measuring the lower back movement and review alternative methods to manual material handling.

Evaluate the potential of back injuries to workers while manually handling roll stock.

In 1981, the National Institute of Occupational Safety and Health (NIOSH) first developed an equation that allowed employers to evaluate lifting demands on the lower back that was published as the NIOSH Work Practices Guide of Manual Lifting (NIOSH Guide) (see Table 1) The model provided by the NIOSH Guide consisted of two parts. The first was an action limit (AL) calculation that indicated an increased risk of injury and fatigue to some individuals exists if employees are not carefully selected and trained for lifting task that are found to exceed the AL. The second part provided a maximum permissible limit (MPL) given the requirements of the work place. This gave an indicator of how much weight should be allowed based on the AL. Action limits were established and the load was judged to be either safe or to place the worker at risk (Keyserling and Chaffin,1986). The development of the guide provided employers a means to assess job risks in a consistent fashion.

The NIOSH Guide that was developed was based on four main criterions. Epidemiological research information indicated that some workers would be at an increased risk of injury on the job if the AL were exceeded. Biomechanics studies indicated disc compression forces at the L5/S1 vertebrae could be tolerated up to 770 pounds in most people. The AL calculation was developed with this in mind. The physiological studies showed the average metabolic energy required would be 3.5 kcal/min for jobs performed at the AL. Finally, the psychophysical studies showed that over 75 percent of the women and 99 percent of the men could lift loads at the AL. Four components made up the equation: the horizontal distance of the load from the worker, the vertical location of the load at the origin of the lift, the vertical distance traveled by the load, and the average frequency of lifting. The assumptions of the calculation were that the lift was smooth from start to finish, the lift was a two–handled lift and occurred in the sagittal plane, the load was of moderate width (about the distance from shoulder to shoulder), the lifting posture was unrestricted, good coupling was provided for the hands and a comfortable ambient environment. (Keyserling and Chaffin,1986).

Table 1. NIOSH Lifting Guide (1981) calculation:

(Keyserling and Chaffin,1986).

Action Limit

AL = 90(HF)(VF)(DF)(FF) pounds

90 = acceptable weight for occasional lifts, close to the body and standing erect		
Horizontal factor	HF	See graph 1 in Appendix D
Horizontal location at the beginning of the lift H = horizontal location in inches		
Vertical factor	VF	See graph 2 in Appendix D
Vertical location of the load at the beginning of the lift V = vertical location in inches		
Distance factor	DF	See graph 3 in Appendix D
D= (distance instance the load is lifted from the D at the destination) – (distance at the origin) in inches		
Frequency factor	FF	See graph 4 in Appendix D
F = average lifts per min,		

Maximum Permissible Level

MPL = 3AL

Any weight above the MPL is considered unacceptable and engineering controls should be sought to redesign the lifting conditions. The guide was used for 10 years, however employers were concerned with its limitations.

In 1991, NIOSH revised the equation because of the limitations that were observed in the types of lifting tasks. The 1981 Lifting guide could only be used mainly for sagittal plane lifts, could not address less than optimal hand placement and had a limited amount of work duration. The updated version was developed in 1991and published in 1993 as *Revised NIOSH Lifting Equation*. (See table 2.) The new equation calculates a recommended weight limit (RWL). The changes in the new equation included a load constant addition and modifications in the multipliers (specific formulas used in the equation) along with the addition of two multipliers— asymmetry (the angle of the object from the sagittal line) and a coupling (the grasp of the hands to the object) multipliers (Waters, Puntz-Anderson, Garg, and Fine, 1993).

The new NIOSH lifting equation provides for evaluating a wider range of work duration and lifting tasks. Waters, et al. (1993) stated the 1991 equation is based on the concept that the risks of lifting–related lower pack pain increase as the demands of the lifting task increase. The revised lifting equation use a single lifting index (LI) instead of the complex three dimensional matrix used in the 1981 equation. The lifting index provides a simple method of comparing the lifting demands associated with different lifting tasks. The LI is used as a guide to estimate the percentage of workforce that is likely to be at risk for developing a lifting related back injury.

Lifting Index:

LI = weight of the actual lift / RWL

If the LI:

< 1 the lift is acceptable, no modification needed.

Between 1 and 3 the lifting task has a potential for injury and recommended for modification.

> 3 the lifting task is high risk for injury and requires modification.

Table 2. NIOSH Lifting Equation (1991) calculation:

(Revised NIOSH Lifting Equation, 1993)

Recommended Weight Limit

RWL = LC x HM x VM x DM x AM x FM x CM

Variable		English	Metric
Load constant	LC	51 pounds	23 kg
Horizontal Multiplier	HM	10/H	25/H
H = measured in inches/centimeters from the mid point of the line joining the inner ankle bones to the point projected on the floor directly below the mid-point of the hand grasps. If H<10 inches (25 centimeters) then H = 10 (25)			
Vertical Multiplier	VM	1 - (0.0075 |V-30|)	1-(0.003 |V-75|)
V = the vertical height of the hands above the floor. Measured vertically from the floor to the mid point between the hand grasps.			
Distance Multiplier	DM	0.82 + (1.8 / D)	0.82 + (4.5 / D)
D = the vertical travel distance of the hands from the origin and destination of the lift. If the lifting task D = V (destination height) - V (origin height) If lowering task D = V (origin height) - V (destination height) If D < 10 inches (25 cm) then d = 10 (25) D must be between 10 and 70 inches (25 – 175 cm)			
Asymmetrical Multiplier	AM	1 – (0.0032A)	1 – (0.0032A)
A = angle between the sagittal mid point and the asymmetry line. Asymmetry line = the horizontal line that joins the mid-point between the ankle bones and the point projected on the floor directly below the mid-point of the hand grasps.			
Frequency multiplier	FM	See Table 1 in App. D	See Table 1 in Appendix D
Frequency multiplier = the number of lifts per min, the amount time engaged in the lifting activity and the vertical height of the lift from the floor. F = the average number of lifts made per minute over a 15 minute period.			
Coupling Multiplier	CM	See Table 1 in App. D	See Table 2 in Appendix D
This is dependent on the hand grasp and the force needed to hold onto the item.			

In the 1993 study by Waters, et al., it is stated there are three important limitations for the equation. First, a large amount of the equation is based on psychophysical data. Since the information is based on the perceived lifting stress, the psychophysical data may be an indicator of the workers ability to tolerance the stress rather than actual potential for lower back problems. Second, the physiological criterion is based on restricting energy expenditures to avoid whole body fatigue. This does not address the potential risk associated with cumulative effects of repetitive lifting, which may be independent of the level of whole body fatigue. Finally, if the three criteria for the equations were considered individually, they would probably not be protective of all workers. Waters et al. (1993) go on to state that the multiplicative nature of the equation has provided a finer equation that is more likely to protect healthy workers than the individual criterion. Even with the uncertainties and limitations, Waters, et al. (1993) believe the equation may be used to identify hazardous lifting jobs and can be used as a tool to evaluate several different lifting jobs for the purpose of redesign or employee placement. This study confirmed Chaffin and Anderson's (1984) study in which they stated job related strength testing or aerobic capacity testing can accurately identify workers who can perform lifting tasks with a LI greater than 1 without risk of injuries, but that the risk of injury is increased when the LI is greater than 3.0.

A study to add validity to the 1991 NIOSH Lifting Equation was completed by Marras, et al.(1999). This study had two specific objectives; 1) a comparison of the 1981 vs. 1991 NIOSH equations and 2) an evaluation of a psychophysical method of evaluating the level of risk to the workers. When the equations were compared, the addition of asymmetry multiplier had very little affected on the equation. The only variables that significantly contributed to both the 1981 and the 1993 models were the average box weight and average horizontal distance. These two are combined for average movement and contributed the most change in the odds ratio in the study. Odds ratios indicate the power of the factor or combination of factors to identify high risk versus low risk MMH situations. The 1981 Guide was found to do an excellent job of identifying the low–risk jobs. Ninety-one percent of the low-risk jobs in the study were correctly identified. In contrast, 10 percent of the high-risk jobs were correctly classified indicating a low sensitivity to changes in the task variables, thus giving a false sense of security for the high-risk jobs. In contrast, when the 1993 Lifting equation was evaluated by Marras et al. (1999), it was found to do a reasonable job of identifying the high-risk jobs, thus indicating an increase sensitivity to changes in task variables. Seventy-three percent of the high-risk jobs in the study were correctly classified. However, 45 percent of the low risk jobs were misidentified as high risk. This misidentification of low risk jobs will have little effect on the worker, however, the effect will be realized in the costs associated to the low risk jobs when these jobs modifications are evaluated for effectiveness and a decrease in worker compensation costs is not realized.

When the data above was reviewed by Marras et al. (1999) using the psychophysical model, comparisons with the NIOSH equation could not be performed. This was due to the differences in logic of the psychophysical model and the NIOSH model; the NIOSH equation being a quantitative equation and psychophysical model being qualitative. The logic of the psychophysical model is that all job tasks should be designed so that 75 percent of the females should consider the task acceptable to them. When the job tasks in the study were evaluated, 60 percent of the high-risk jobs were found to be acceptable to 75 percent of the females, and the 91 percent of low-risk jobs were acceptable to 75 percent of the females. The outcome of the evaluation of the jobs using this method could lead to injuries due to the misidentified high risk jobs. Even with the similarities of the two models, the 1991 revised lifting equation does a better job at identifying risks in high-risk jobs than that of the 1981 equation or the psychophysical model. Consequently, this identification of hazards will help employers decrease back disorders by screening the jobs before workers are injured.

Many studies have been performed which examined the relationship between back disorders, lifting, and occurrence of the forceful movements. Most use a combination of observation and direct measurement, or interview and questionnaire data. Punnette, Fine, Keyserling, Herrin and Chaffin (1991) analyzed the relationship between back pain and occupational exposure in auto assembly workers using symptom interviews and medical evaluations. The study reviewed video tape and work cycles using a specific set of nine separate lifting activities that required at least 10 pounds to be held in the hands. Age, gender, length of employment, recreation activities, and medical history were documented. The study showed that the amount of time spent in non-neutral postures ranging from mild to severe flexion and bending is strongly associated with the development of back disorders. A strong correlation of increased risk to back injuries was observed when both intensity and duration of exposure occurred simultaneously.

In a similar study to Punnet et al. (1991), Liles, Deivanayagam, Ayoub and Mahajan (1984) used a job severity index (JSI to evaluate the lifting exposures associated with manual material handling positions in 453 individuals. The JSI is a measurement of physical stress levels associated with lifting tasks and a ratio between job demands and the lifting capacities of the person performing the job. The results showed that as the job demands of lifting increased, the back injuries increased, in return the JSI also increased. Waters, et al. (1993) supported this study with a study that found a strong correlation with JSI's and the NIOSH lifting index. This data indicates that the use of assessment tools to evaluate job severity and lifting tasks can be used in predicting the likelihood that a back injuries can occur.

Predicting injuries and measuring exactly the stress needed to create the injury are not always the simplest task. There is strong evidence that low-back disorders are associated with work related lifting and forceful movement. Methods to evaluate the movement of the lower back are limited. The researcher found most studies were based on static motion. Very limited data exists on the actual motion of the back. Methods that do analyze the actual motion of the back are the video based computer motion analysis system, and the lumbar motion monitor. In a study by Marras, Lavender, Leurgans, Rajulu, Allreadm, Fathallah, and Ferguson (1993) the problem associated with the cost of the computer-based system is discussed. Often computer-based systems are too expensive for companies to use as a viable means of measurement during on-the-job hazard analysis. Marras et al. (1993), outline the use of an instrument that was designed for use in the work place that was cost effective and had practical application. The lumbar motion monitor (LMM) is a three-dimensional truck motion monitor that looks at the sagittal, side bending and rotational forces affecting the back. The LMM ties the epidemiological finding of other researchers with quantitative biomechanical data to give a quantitative measurement on the motion and forces of the lower back. The Marras et al. (1993) study looked at 403 industrial jobs for 48 manufacturing companies throughout the Midwestern United States as well as repetitive jobs without job rotation. Jobs were divided into high and low risk LBD categories and whenever possible medical reports were used to categorize the risk. Results of the study showed an association between the biomechanical factors and the risk of developing a low back disorder.

Marras, et al. (1993) findings indicate that it is possible to identify and describe movement of the lower lumbar spine while the employee is performing the lifting task or job. Assumptions used by the NIOSH lifting guide, of slow, smooth lifting are not consistent with the types of motion that was observed when the LLM was used. It also showed that key factors in the job could be identified such as momentum, lift rate, and lateral trunk velocity, sagittal trunk angle and trunk twisting velocity. When looked at individually, these factors have a reliability of predicting the outcome of a lift that is very low. The study indicated when these factors are combined the predicting of outcomes and situations that could contribute to LBDs are very high and reliable (Marras, et al., 1993).

The use of qualitative and quantitative means of evaluation can be used to predict job hazards and to decrease the risk to employees. The use of assessment tools and instrumentation can also be used to prove the effectiveness of modifications in jobs and lifting tasks. By applying the same concepts and techniques in measuring the employees when using the automated equipment, measurements with the LMM can quantify the level of improvements that are realized. The next section will look at evaluation of automated methods of material handling.

Evaluate the Effectiveness of Automated Methods of Material Handling

Material handling devices (MHD) such as hoists and loading balance arms have become very popular in the industry to eliminate the need for lifting by workers. The goal of a hoist is to reduce the stress on the worker's body. Chaffin, Stump, Nussbaum and Baker (1999) suggest that while the use of such devices may decrease stress on some parts of the body, hoists may actually increase stress to the back when the employees are learning how to use the new hoists. This is due to the inertia created by movement of the load. Chaffin, et al. (1999) used an EMG to evaluate the trunk movement of 12 workers that were performing new job tasks that utilized a pneumatic hoist and an articulated arm. The study indicated there is a learning curve for new employees when hoists or other mechanical means are used for the first time. Slower learning curves were observed in the torso muscle over other muscles that were tested. It was also observed that the greatest reduction on the L4/L5 disc compression forces could be achieved with the use of either hoists when compared to not using a hoist at all. Thus, the study indicated that the body may require a longer period of time to develop low-risk movements for using the hoists. Once such movements are learned, the forces on the back are reduced, decreasing the potential for injury of the back when using the hoist.

In a study that looked at inertia and its effect on the body, Resnic and Chaffin (1995) found that the stress on the body changed from the lower back to the hands when using pushcarts. The results of this study indicated that an increase in peak hand forces occurred when subjects used pushcarts to maneuver materials. Increased force by the hands appears to be necessary to control the inertia of the load and MHD being utilized.

A study by Granata, Marras and Kirking (1996) looked at the how the length of time the employee had working with material handling affected the movement of the employee and the load. Granata, et al. (1996) found that experienced materials handling workers lifted loads in a smoother and more fluid motion than less experienced workers. But, when these same workers were lifting and moving objects suspended from hoists that were designed to eliminate most of the weight of the object, the lift was neither smooth nor a fluid motion. The MHDs introduced a new and separate set of forces on the body when performing complex horizontal movements. The new forces actually increase the risk factors, further complicating the dynamic forces of MHDs on the worker.

Often MHDs are not perfect replacements, such a spring balancer that cannot perfectly compensate for the load weight’s vertical force. Compensation for this type of limitation has been to use pneumatic or hydraulic power to support an object attached to the MHD. Load balancing MHDs automatically sense and a compensate the objects weight, then supply the correct amount of lift allowing the worker to supply only a small amount of force to raise or lower the load. Chaffin et al. (1999) study indicates that when using MHDs there is a learning curve for the movements. It also indicates that the more complex the movement with MHDs, the slower the learning curve will be.

In lieu of the more expensive alternatives, the use of back belts for many companies has been viewed as an inexpensive method to help reduce the risk of back injuries. In a pamphlet from NIOSH (1997), they state that companies should not rely on the use of back belts as a “cure all” for back injuries. NIOSH also explains in the pamphlet that scientific data can neither support nor refute the effectiveness of back belts due to lack of scientific research. In a search of the literature, there was very little available to review. Kraus (1996) credits the mandatory use of back belts in a chain of large retail hardware stores with substantially reducing the rate of lower back injuries. Thus supplying scientific data to support the claims back belts reduce back injuries.

NIOSH indicated in a publication on the home page, NIOSH Facts- Back Belts June 1997, that there is a lack of data to support the use of a back belt. According to the information on the web page, various companies claim that back belts reduce forces on the spine, as well as increase intra-abdominal pressure that counter balances the compensating force being exerted downward on the spine. None of these claims have conclusive research to back them up per NIOSH. The known facts about back belts do include their stiffening of the spine by preventing movement and consequently holding the ligaments and other tissues in place. Back belts also reduce the employee’s ability to bend; the theory given by NIOSH is that by reducing the ability to bend as far forward as possible, the loading of the spine will be reduced. It appears that the belts help to restrict the side to side bending and twisting motions of the back. NIOSH does indicate that there may actually be an increase of potential injury due to the false sense of security that the back brace may give. Due to the lack of substantial research into back belts with minimal conclusive information, NIOSH does not recommend the use of back belts to prevent injuries in workers who have never been injured. (June, 1997)

Summary

Reducing back injuries caused from manual handling materials is a major concern for companies today. The act of under or over rating lift hazards are likely to have a significant effect to costs in a company. This literature review showed viable methods to evaluate lifts before they occur thus allowing employers to design workstations to accommodate workers before the lifting tasks are implemented. The NIOSH lifting guide is currently the primary method available for job assessment that is used by industry. In addition, a variety of testing equipment such as the LMM are available to evaluate current lifting tasks with regards to their potential risk of causing back injuries. The use of a LMM can show real time stress on the back while performing the lift of question, thus, allowing companies to evaluate and compare lifting task with the alternative developed to reduce the hazards.

The objectives of the literature review were to present research for the NIOSH lifting equation, research several methods that could be used to evaluate MMH jobs and help determine the use of alternative methods to handle the roll stock at Company XYZ. In Chapter 3, the NIOSH lifting equation and Lumbar Motion Monitor will be utilized to evaluate the manual and automated methods of handling roll stock for company XYZ.

Chapter III

Methodology

Introduction

The purpose of this study was to evaluate the manual material handling methods of operators in regards to roll stock and evaluate an alternative method to help eliminate the injuries caused by improper lifting or over exertion during lifting.

The two main objectives to this project were:

1. evaluate the potential of back injuries to workers while manually handling roll stock.
2. evaluate the effectiveness of reducing strain to the back by using an automated method to handle roll stock.

The methods and procedures used to identify risk and appropriate control systems are explained under the following headings of a) method of study, b) population and samples, c) data collection techniques, d) procedures followed, and e) method of analysis.

Method of Study

A review of literature was completed to gain information on biomechanics of the back and shoulders, current methods used in industry to evaluate back motion, and equipment that can be used to reduce the hazards. This information was used to evaluate the motion of the back when handling the heavy roll stock and to identify alternative methods of handling the roll stock to reduce the need to lift or push the roll stock.

Population and Samples

The current employees affected at company XYZ are the wet packaging operators, dry packaging operators, and the Hassia operators. These employees are made up of 52 males and 6 females, with the ages ranging from 21 - 63 years old, and height ranging from 4’11” to 6’5”. Dry packaging operators were chosen as test subjects because the roll stock that they handle is the lightest of the three areas. This stratagy would give a best case scenario of results. If the results indicated that a change was needed, it is assumed that the other areas that deal with substantially heavier materials would also require the same or more substantial changes. In addition, a review of the associated records indicates that the dry packaging area is experiencing the highest losses associated with MMH.

Data Collection Techniques

An information survey was completed with the Safety Manager of company XYZ. The survey covered worker compensation losses, the illness and injury reports and the OSHA 200 log. The information gathered by this study was tabulated by hand. This survey was used to develop a loss tab analysis from the accident and worker compensation records.

Group discussions with dry and wet packaging employees were held to explain the project, how the LMM monitoring was to be conducted, and to gather ideas for changing the current methods used to lift the roll stock. Methods for the current lifting methods and suggestions for solutions were documented and maintained for review by the employees at a later date. The discussions were open to all hourly employees and management was not in attendance.

A Wagner Force Dial, model FDL Push - Pull Gage was used to test probable weight per lift for the roll stock. The pounds of force needed to pull the roll across the pallet 6 inches and the pounds of force needed to lift the roll stock into the upright position were recorded. The test was repeated three times in each direction. Data was manually recorded and averaged.

Back monitoring was performed using a Chattanooga Lumbar Motion Monitor (LMM) model LMM II. The testing was performed on an employee at the start of second shift. Automatic measurements for side bending velocity, degree of sagittal flexion, and rotational velocities were recorded by the LMM. Information on lifting rate, weight of object, height of object at the beginning and end of the lift, horizontal distance along with the operator's vital statistics (e.g. height, weight, sex, and age) were entered into the program before the lifting task was started.

The small Chattanooga LMM exoskeleton was placed on to a 4'11" tall, 105 lb. female employee. It was attached with the assistance of a harness located on the back of the employee with the top of the exoskeleton at the top harness between the shoulder blades and the bottom harness located about 2 inches below the top of the hipbone. The data recorder was attached and readings were recorded continuously. Data was then transferred to the laptop computer and verified. The same process was repeated on the 5'11", 155-pound male employee, the Large Chattanooga Lumbar Motion Monitor (LMM) exoskeleton was used.

<u>Procedures Followed</u>

Following are the steps used to conduct this study.

1. Met with safety coordinator and reviewed accident records for the FY 97 to FY 99 periods.
2. Met with employees
    i) Developed the Task Analysis. (See appendix A)

ii) Made comparisons of roll stock in all areas.

iii) Reviewed employee techniques currently being used.*

iv) Developed test protocol.

3. Conducted testing of back movement and measurement of the lifting and pulling forces using the test protocol.

4. Met with employees to evaluate results and discuss suggested solutions to the problem.

5. Met with management and vendor to bring in hoist on a trial basis.

6. Conducted testing of back movement using the hoist.

*Note: Lifting methods with the employees vary. The method most commonly used by the employees was used for testing and is described in the test protocol.

Test protocol for the LMM:

1. Attach the LMM exoskeleton to the employee.
2. Remove plastic wrap on the roll stock from the third layer of the pallet.**
3. Slide the roll stock slightly off the pallet approximately six inches.
4. Place hands under the portion of the roll that is off the pallet and push the roll into an upright position. The core of the roll should be horizontal to the floor. (See appendix A)
5. Pull the roll stock to the edge of the pallet so it could be placed onto a cart for transport to the packaging machine.
6. The movement was repeated three times.

7. Data was collected and analyzed by the LMM's statistical program.

   **Note: The height of the temporary mounting of the hoist only allowed for the bottom two layers to be lifted. Only the bottom two layers were tested for comparison.

Test protocol for the Force Dial:

1. Place the hook in the core of the roll.
2. Pull the roll six inches forward.
3. Record maximum force.
4. Place the hook on the bottom of the roll.
5. Push up on the roll from the bottom until the roll is in the upright position.
6. Record the maximum force.
7. Steps one through six were repeated three times.

Method of Analysis

A Loss tab analysis was conducted from the workers compensation records, accident reports and OSHA 200 logs at the facility. The criteria selected included worker compensation costs, types of accidents, and location of accidents. The LLM results were automatically recorded and analyzed using data recorders and a computer program supplied by the manufacturer of the LMM. Data was graphed and evaluated for improvements.

Summary

The purpose of this study was to evaluate the methods to move roll stock and evaluate an alternative method to help eliminate the injuries caused by improper lifting or over exertion during lifting. The objectives were to evaluate the potential for back injuries to workers while manually handling roll stock and to evaluate the effectiveness of automated methods of material handling to reduce injuries while handling roll stock. Chapter 4 will present the data collected and conclusions that were developed from that data.

CHAPTER IV

Results and Discussion

Introduction

The purpose of this study is to evaluate current manual material handling methods and alternative methods that could be used to handle the roll stock at Company XYZ. The objectives of this study are 1) evaluate the potential for back injuries in workers while manually handling roll stock and 2) evaluate the effectiveness of an automated method to handle roll stock to reduce strain to the back. The dry packaging area was chosen for testing and evaluation because of the location and lower physical risk to the subjects that is associated with the area (i.e. dry floors instead of wet and a decreased number of hazardous chemicals in the immediate area). The learnings and equipment can be transferred easily into the Wet packaging and Hassia area.

Assessments that were done included discussions with employees to evaluate current methods of lifting and to discuss potential solutions to the problems, a Loss Tab analysis, a NIOSH lifting equation calculation, and force measurements using a Wagner force gauge and the Chattanooga Lumbar Motion Monitor. Data was collected for the NIOSH calculations using a Wagner force gauge. Data from the LMM was collected while the employee was performing routine lifts. Only the data from the bottom two layers of a pallet was collected due to the restricted height of the temporary mounting for the hoist.

Discussions with employees

In discussions with the Safety Manager and a review of the accident records and workers compensation log, a trend in high losses and repeated causes of accidents was found to occur in the manual material handling of the roll stock. The management was very willing for a further review of the causes and possible changes that could be performed to eliminate or reduce the cost of this injury. A team leader was set up from the dry packaging operators and communications with this person lead to meetings with the other employees in the area.

Meetings were set up with operators in both wet and dry packaging to discuss the current methods of lifting and the accidents that have been occurring. From these discussions three methods to move the roll stock were identified. The first was the most commonly used lift and used for the LMM and force gauge analysis. This procedure consisted of pulling the roll of paper off the edge of the pallet approximately six inches then lifting from the bottom of the roll to move the roll from a vertical to horizontal position. The second method consisted of placing a metal bar approximately 48 inches long into the core of the roll and pulling the roll over. The bar was used as a lever to maneuver the roll. While observing the maneuver, several of the shorter operators would climb on top of the pallet, approximately 60 inches off the floor, place the metal bar into the roll and pull, twist and maneuver the 120 pound roll into an upright position. While observing this method, it was noted that the potential for falling off the pallet was very high because the operator had to bend into a position to get the roll in the upright position that was considered to be unsafe given the conditions. The supervisor did not know that the employee was climbing on to of the pallet, for quality and safety reasons the supervisor of the area discontinued this up righting methods. The third method, only used by one operator, consisted of pulling the roll away from the other rolls then picking the roll up in his arms and carrying it to the machine. The management also discontinued the use of this method.

After discussions with the operators and supervision, it was decided to look into the use of a hoist with a rotatable head that would take most of the movement out to the lift. A Yale 1/2 ton electric chain hoist with a multiaxis lift arm was rented and mounted on a movable rack that allowed the lifting of the bottom two layers of the pallet.

Loss Tab Analysis

From a review of the accident records and worker compensation log, an analysis of the accidents was completed. The records indicate a 45% increase in worker compensation losses from FY 98 to FY 99 (see table 3). The increase in losses was found to exist in all three production areas of the facility. The top reason for injuries in FY 99 was manual handling of roll stock, which accounted for $34,442 in worker compensation costs. The company does not track the extra costs associated with accidents such as materials damaged due to the accident, lost production time due to the accident, or overtime costs to cover the injured employees that were off work for a total of 158 days.

Table 3. Loss Tab Analysis

Total Losses		FY 99	FY 98	% increase
Total cost of losses		$236,000	$163,000	45%
Number of recordable accidents		35	32	9%
Top Three Injury Types		FY 99	FY 98	% increase
Back strains		$129,724	$37,152	249%
Cumulative trauma disorders		$43,857	$19,928	120%
Cuts and burns		$29,213	$4,444	557%
Total of top three injury types		$202,794	$61,524	230%
Percent of total losses		86%	38%	226%
Top Causes of Loss FY 99		% of total losses	# of accidents	% of total accidents
Material handling of roll stock	$34,442	14.59%	5	14.29%
Pinched finger	$13,492	5.72%	1	2.86%
Material handling of barrels	$11,715	4.96%	1	2.86%
Total cost of top three causes	$59,649	25.28%	7	20.00%

Wagner Force Gauge

Seeing the need to evaluate changes in the handling of roll stock, the testing conducted at the facility quantifies the need to change the current procedures. A Wagner Force Dial, model FDL Push - Pull Gage was used to evaluate the pounds of forces placed on the hands and back while pulling and pushing. Measurements were taken with Wagner force gauge pulling the roll stock across the pallet and pushing up form the bottom of the roll, both movements in the same manner the operator would be pushing and pulling the roll-stock into the upright position.

It was found that an average of 70 pounds of pressure was needed to pull one roll of pouch paper approximately six inches across the pallet and 65 pounds of force was required to rotate a 120 pound roll of pouch paper into the upright position. This information was then used in the NIOSH lifting equation calculations.

NIOSH Lifting Equation

Data collected from the Wagner force gauge was used in the NIOSH lifting equation to calculate the Recommended Weight Limit(RWL) and the Lifting Index (LI). The ratio between recommended weight and the weight of the object lifted indicated the need to change the current procedures. See appendix E for the complete work sheet calculations. The average RWL at the origin of the lift was 36.52 pounds. This weight is the maximum weight given the lifting conditions that is considered safe for most employees. Currently, the employees are lifting over 3 times this weight. When the lifting index is reviews for the same set of conditions, an average LI of 3.4 is calculated for the origin. According to NIOSH, any lift over 1.0 but less than 3.0 may cause injuries and should be looked at for modifications and any lift over 3.0 is considered hazardous and modifications need to be made. (see table 4).

Table 4. Recommended Weight Limit and Lifting index

	Recommended Weight Limit per calculation (RWL)		Lifting index (LI)		Actual weight being of roll stock
	Origin	Destination	Origin	Destination	
Top layer	33.8	28.9	3.6	4.2	120
2nd layer	38.6	33.8	3.1	3.6	120
3rd layer	37.4	38.6	3.2	3.1	120
Bottom layer	32.5	37.4	3.7	3.2	120
Averages	36.52	34.67	3.4	3.53	120

Chattanooga Lumbar Motion Monitor

The NIOSH calculations indicate the need for change. To confirm this need, a Chattanooga Lumbar Motion Monitor was used to evaluate the forces on the back. Two operators were fitted with the exoskeletons of the LMM. Testing was conducted on the current methods as well as an alternative method of handling roll stock. The movement of the back except in the sagittal range of motion on the bottom layer, shows a dramatic decreases when the hoist was used to lift the roll stock (see table 5).

Table 5. Third and bottom layer average movement by measurement type

	Range of Motion (degrees)					
	3rd Layer (averages)			Bottom Layer (average)		
	before hoist	after hoist	% change	before hoist	After hoist	% change
Side Bending	63	2	96.83%	63	28	55.56%
Sagittal	65	1	98.46%	78	79	-1.28%
Rotational	39	5	87.18%	15	6	60.00%
	Velocity (degrees/seconds)					
	3rd Layer (averages)			Bottom Layer (average)		
	before hoist	after hoist	% change	before hoist	after hoist	% change
Side Bending	330	0	100.00%	290	37	87.24%
Sagittal	135	4	97.04%	117	89	23.93%
Rotational	200	4	98.00%	37	14	62.16%
	Acceleration (degrees/seconds^2)					
	3rd Layer (averages)			Bottom Layer (average)		
	before hoist	after hoist	% change	before hoist	after hoist	% change
Side Bending	2074	140	93.25%	1686	158	90.63%
Sagittal	564	420	25.53%	468	422	9.83%
Rotational	1114	4	99.64%	262	74	71.76%

With the decreases in the movement of the back shown in the average movement, a calculation that predicts the probability of loss (PL) for an individual lift was compiled. The PL calculation indicates the probability of a severe accident occurring when the lift is made (see table 6).

Table 6. Probability of Loss Calculation for the Third and Bottom Layer.

	3rd Layer		
	Lift without the Hoist	Lift with the Hoist	Percent Change
Average Rotational Velocity (Degrees/Seconds)	9.10	0	100.00%
Maximum Movement Arm (Ft-Lb.)	43.75	12.5	71.43%
Maximum Sagittal (Degrees)	523.00	0	100.00%
Maximum Side Bending (Degrees/Seconds)	371.65	0	100.00%
Average Probability Of Loss	55.50	1	98.20%
	4th Layer		
	Lift without the hoist	Lift with the hoist	% Decrease
Average Rotational Velocity (Degrees/Seconds)	7.50	0.8	68.00%
Maximum Movement Arm (Feet-pounds)	87.50	3.7	95.77%
Maximum Sagittal (Degrees)	84.50	53	28.38%
Maximum Side Bending (Degrees/Seconds)	378.35	37.5	87.10%
Average Probability Of Loss	63.00	26	52.73%

Summary

The loss tab analysis indicated the main areas of worker compensation loss with manual material handling at the top of the list. The NIOSH lifting equation shows a need to modify the lifting of roll stock in dry packaging and can be carried out to all areas of the facility that deal with roll stock. Confirmation that the current lifting techniques need to be modified was shown by the results of the LMM data collection and analysis. The alternative to manual lifting, the hoist, was reviewed and shown also through the LMM data that it is a viable alternative to the manual lifting. Chapter 5 will review the data and make recommendations for modifications.

CHAPTER V

Recommendations

Restatement of the Problem

The pain associated with a back injury affects all aspects of everyday life, and is one of the leading causes of lost workdays in industry today. Studies of manual material handling (MMH) tasks have identified work intensity, static work, frequent bending and twisting, lifting, and pushing or pulling as occupational risk factors in lower back disorders (Marras et al. 1993).

The purpose of this study was to evaluate the current manual material handling methods and alternatives methods that could be used in handling the roll stock at Company XYZ. The goals were to evaluate the potential of back injuries to workers while manually handling roll stock and to evaluate the effectiveness of an automated method of material handling to reduce the injuries while handling the roll stock.

Methods and Procedures

In this study, the following steps were followed to conduct this study:

7. Met with safety coordinator and reviewed accident records for the FY 98 to FY 99 periods.
8. Met with employees to discuss what methods were being used to lift roll stock and the accidents that were occurring.
9. Conducted testing of back movement and measurement of the lifting using the LMM and Wagner force gauge.
10. Met with employees to evaluate results and discuss suggested solutions to the problem.

11. Met with management to review the results and to bring in hoist on a trial basis.

12. Conducted testing of back movement using the hoist.

Major Findings

Loss Tab analysis

1. An increase in workers compensation costs of 45 percent occurred from FY 98 to FY 99.
2. Back strains accounted for 54 percent of the workers compensation costs in FY 99.
3. Manual material handling of roll stock accounted for 26.5 percent of the back strain costs.
4. The material handling of roll stock, pinched finger and material handling of barrels accounted for 25.28 percent of the total worker compensation costs, but only 14.7 percent of the recordable accidents.

NIOSH Lifting Equation

1. The average RWL calculated was 36.52. The average force required to lift the 120 pounds rolls is 65 pounds, almost double the RWL.
2. The average lifting index was 3.4. This amount is three times higher than the maximum that NIOSH suggests. According to NIOSH, any lift greater than three is deemed unsafe and requires modification.

Lumbar Motion Monitor

1. Thirteen of the eighteen measurements taken show an improvement of greater than 50% after the addition of the hoist. The biggest decrease in

movement was found to occur during the movement of the third layer, eight of the nine measurements indicated a greater than 87 percent reduction in movement of the back with the exception of sagittal motion velocity when the employees used the hoist. The results of the bottom layer were not as remarkable. Only side bending velocity and acceleration showed greater than 87 percent reduction in movement of the back. Rotational ROM, velocity, and acceleration and side bending ROM showed a greater than 50 percent decrease in movement. Sagittal motion for the bottom layer was worse than the third layer, the ROM, velocity and acceleration indicated less than a 25 percent reduction in back movement.

2. The hoist reduced the probability of loss (PL) by an average of 70 percent. This indicated that the hoist would make a positive impact on the reduction of injuries. The PL for the 3rd layer went from 55.5 percent to 1 percent with the use of the hoist. The reduction of PL was a bit smaller for the bottom layer. The PL for the bottom layer went from 63 percent to 26 percent. This correlated to the small change in sagittal movement for the bottom layer.

Conclusions

The data from the LMM-based monitoring indicate that a reduction movement was observed when the hoist was used. Except for sagittal movement on the bottom layer, significant reductions were seen in the actual movement of the back and in the probability of loss calculations, indicating that the hoist improved the lifting task by reducing the stress on the back. The minimal improvement of the sagittal motion can be attributed to the initial forward bend that occurs when the operator places the chuck of the hoist into the core of the roll stock. In the current set up of the packaging area, this motion can not be discontinued, however, the risk of this bending has been reduced by the use of the hoist. The reduction of the PL indicates the overall lift has improved even though the motion has not dramatically changed. While the hoist has reasonably eliminated the lifting problem, further studies could be done to examine if a scissors lift could reduce the forward bend by raising the pallet to knee height and decrease flex of the spine.

Recommendations

With the data presented, the addition of a hoist at all of the manual roll stock locations is recommended. Company XYZ would need eight hoists to completely eliminate the problem caused by the manual handling of the roll stock. The cost of the hoist installed is $8500 when compared to $6800 for the average back injuries, the hoists would be paid for in less than 2 years through the reduction of workers compensation-related losses. The potential saving over a 10 year period is over $340,000. These savings would be an increase in profits for the company, since the company is self-insured for workers compensation.

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Appendix A

Task analysis

The preparation of pouch paper for Used on the Cloud filler

Task Analysis

Handling of pouch paper used for the production of Grocery and Food service products.

Person responsible: Dry packaging Operator

Job: Preparing pouch paper for transfer to the Cloud filler

Pallet layout: 4 rolls of laminated pouch paper per layer
4 layers per pallet

Weight of rolls: Grocery - 140 lb.
Food service – 160 lb.

Equipment used: Roll stock cart used to move the pouch paper from pallet to the machine
Lever bar 48 in. long
Pallet of roll stock

Procedure:

***Top three layers* - -**This procedure is used for all 4 rolls on the layer.

1. Slide roll slightly off pallet so approximately 6 inches are hanging off the roll.
2. Bend knees in a semi-squat position.
3. Place heels of both hands on bottom of roll and arm and under edge of roll.
4. Straighten legs to standing position and at the same time straighten arms to bring roll into an upright position.
5. Maneuvre the roll to the edge of the pallet.
6. Remove plastic wrap and place a chock under the roll to prevent roll from shifting.
7. Position foil cart at the edge of the pallet and adjust mandrel to the height of the roll core.
8. Push the cart into the roll to position the foil on the mandrel.

Bottom layer

On the first roll of the layer only

1. Slide roll slightly off pallet so approximately 6 inches are hanging off the roll.

2. Bend knees in a semi-squat position.

3. Place heels of both hands on bottom of roll and arm and under edge of roll.

4. Straighten legs to standing position and at the same time straighten arms to bring roll into an upright position.

5. Remove plastic wrap and chock roll to prevent roll from shifting.

6. Position foil cart at the end of the pallet and adjust mandrel to the height of the roll core.

7. Push the cart into the roll to position the foil on the mandrel.

Remaining 3 rolls on the pallet

1. Standing in front of pallet, place lever bar in the core of the roll, being careful not to go farther in than the roll to be upended.

2. Place one foot ahead of the other, bending at the knees more deeply than before and pull lever bar towards you in a rocking motion to upend roll.

3. Remove plastic wrap and chock roll to prevent roll from shifting.

4. Position foil cart at the end of the pallet and adjust mandrel to the height of the roll core.

5. Push the cart into the roll to position the foil on the mandrel.

Appendix B

Agreement to Participate in a Research Study

Agreement to Participate in a Research Study

RESEARCH STUDY TITLE:
Evaluation of manual material handling of packaging material and associated injuries at Company XYZ

My name is Ellen Schieber. As part of my Graduate course work in the Risk Control Program, University of Wisconsin-Stout, I am conducting the above named research study.

I would like to ask for your consent to be interviewed and/or monitored as part of a research participation group that would: 1) provide information for workers compensation costs for fiscal 1998 to present, 2) aid in the development of a dry packaging operators task analysis, 3) give input regarding methods of handling packaging roll stock, 4) allow yourself to be monitored for shoulder and back movements while handling roll stock.

BENEFITS
The results of this research will allow employees and management to make informed decisions on material handling of roll stock. This could include modification of current methods, changes in procedures and a reduction of accidents and costs associated to manual handling of roll stock in the packaging areas.

RISKS
The information gathered will be kept strictly confidential and reports of this research will not contain your name, therefore there is no perceived association with this study.

CONFIDENTIALITY OF RESPONSES
Your responses to the questions during the interview will be strictly confidential. Any information that is collected during this study will be held in strict confidence. For this research to be effective, job position and/or roles (not names) of persons interviewed will be used to describe the makeup of the consult group who gave input for this study.

RIGHT TO WITHDRAW OR DECLINE TO PARTICIPATE
Your participation in this study is entirely voluntary. You may choose not to participate without any adverse consequences. Should you choose to participate and later wish to withdraw, you may discontinue your participation at any time without adverse consequences.

NOTE: Questions or concerns about participation in the research or subsequent complaints should be addressed first to me, Ellen Schieber, home phone 715-232-9642, work number 651-704-5464, Brian Finder, in the Risk Control office at UW-Stout, phone 715-232-1422 or to Dr. Ted Knous, Chair of the UW-Stout Institutional Review Board for the Protection of Human Subjects in Research, 11 HH, UW-Stout, Menomonie, WI, 54751, phone (715) 232-1126.

Once the study is completed, the analyzed findings would be available to you.

CONSENT

I attest that I have read and understood the above description, including potential risks, benefits, and any rights as a participant, and that all of my questions about the study have been answered to my satisfaction. I hereby give my informed consent to participate in this research study.

Signature ______________________________________ Date _______

Appendix C

Information Survey

Survey information from employees:

Subject #

Height _______________

Weight _______________

Sex _______________

Age _______________

Length of time at current job _______________

Lumbar Motion Monitor results:	**Bottom layer**	**Third layer**
Sagital motion (degrees)		
Side bending velocity (degrees /second)		
Rotational velocity(degrees /second)		

Wagner force gage results

Pulling roll 6" off pallet ______________________________

Bottom lift pounds ______________________________

Survey of Company records

Records review

Cost in dollars

Total workers compensation __________________________

Top three accidents

____

____

____

Top three areas

____

____

____

Appendix D

NIOSH Lifting Equations

NIOSH Lifting Guide, 1981 calculation

(Keyserling and Chaffin, 1986)

Action Limit

AL = 90(HF)(VF)(DF)(FF) pounds

90 = acceptable weight for occasional lifts, close to the body and standing erect

Horizontal factor HF See graph 1

Horizontal location at the beginning of the lift

H = horizontal location in inches

Vertical factor VF See graph 2

Vertical location of the load at the beginning of the lift

V = vertical location in inches

Distance factor DF See graph 3

Distance the load is lifted from the
D = (distance at the destination) **–** (distance at the origin) in inches

Frequency factor FF See graph 4

F = average lifts per min,

Maximum Permissible Level

MPL = 3AL

Graph 1. Horizontal Factor

Graph 2. Vertical Factor

Graph 3. Distance Factor

Graph 4. Frequency Factor

NIOSH Lifting Equation, 1991 calculation:

(Revised NIOSH Lifting Equation, 1993)

Recommended Weight Limit

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

<table>
<tr><th>Variable</th><th></th><th>English</th><th>Metric</th></tr>
<tr><td>Load constant</td><td>LC</td><td>51 pounds</td><td>23 kg</td></tr>
<tr><td>Horizontal Multiplier</td><td>HM</td><td>10/H</td><td>25/H</td></tr>
<tr><td colspan="4">H = measured in inches/centimeters from the mid- point of the line joining the inner ankle bones to the point projected on the floor directly below the mid-point of the hand grasps.

If H<10 inches (25 centimeters) then H = 10 (25)</td></tr>
<tr><td>Vertical Multiplier</td><td>VM</td><td>1 - (0.0075 |V-30|)</td><td>1-(0.003 |V-75|)</td></tr>
<tr><td colspan="4">V = the vertical height of the hands above the floor. Measured vertically from the floor to the mid-point between he hand grasps.</td></tr>
<tr><td>Distance Multiplier</td><td>DM</td><td>0.82 + (1.8 / D)</td><td>0.82 + (4.5 / D)</td></tr>
<tr><td colspan="4">D = the vertical travel distance of the hands from the origin and destination of the lift.

If the task is lifting an object D = V (destination height) - V (origin height)
If the task is lowering an object D = V (origin height) - V (destination height)
If D < 10 inches (25 cm) then D = 10 (25)

Note: D must be between 10 and 70 inches (25 – 175 cm)</td></tr>
<tr><td>Asymmetrical Multiplier</td><td>AM</td><td>1 – (0.0032A)</td><td>1 – (0.0032A)</td></tr>
<tr><td colspan="4">A = angle between the sagittal mid point and the asymmetry line.

Asymmetry line = the horizontal line that joins the mid-point between the ankle bones and the point projected on the floor directly below the mid-point of the hand grasps.

If AM > 135o AM = 0</td></tr>
<tr><td>Frequency multiplier</td><td>FM</td><td>See Table 1 in App. D</td><td>See Table 1 in App. D</td></tr>
<tr><td colspan="4">Frequency multiplier = the number of lifts per min, the amount time engaged in the lifting activity and the vertical height of the lift from the floor.

F = the average number of lifts made per minute over a 15 minute period.</td></tr>
<tr><td>Coupling Multiplier</td><td>CM</td><td>See Table 1 in App. D</td><td>See Table 2 in App. D</td></tr>
<tr><td colspan="4">This is dependent on the hand grasp and the force needed to hold onto the item.</td></tr>
</table>

Table 1. Frequency Multiplier (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	1.0	1.0	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.5	.5	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.6	.6	.35	.35	.18	.18
9	.52	.52	.3	.3	0	.15
10	.45	.45	.26	.26	0	.13
11	.41	.41	0	.23	0	0
12	.37	.37	0	.21	0	0
13	0	.34	0	0	0	0
14	0	.31	0	0	0	0
15	0	.28	0	0	0	0
>15	0	0	0	0	0	0

Table 2. Hand to table coupling classification (CM)

Good	Fair	Poor
1. For containers of optimal design, such as some boxes, creates etc. a "GOOD" hand-to-object coupling would be defined as handles or handhold cut-outs of optimal design (see notes 1 to 3 below)	1. For containers of optimal design, "FAIR" hand-to-object coupling would be defined as handles or handhold cut-outs of less than optimal design (see notes 1 to 4 below)	1. Containers of less than optimal design or loose parts of irregular objects that are bulky, hard to handle or have sharp edges (se note 5 below)
2. For loose parts of irregular objects, which are not usually containerized, such as castings, stock, and supply materials, A "GOOD" coupling would be defined as a comfortable grip in which the hand can easily be wrapped around the object. (See note 6 below)	2. For containers of optimal design with no handles or hand hold cut-outs or for loose parts of irregular objects, a "FAIR" hand-to-object coupling is defined as a grip in which the hand can be flexed about 90 degrees (See note 4 Below	3. Lifting non-rigid bags (i.e. bags that sag in the middle)

Notes:

An optimal handle design has .75 – 1.5 inches (1.9 to 3.8 cm) diameter, ≥ 4.5 inches (11.5 cm) length, 2 inches (5cm) clearance, cylindrical shape, and smooth, non-slip surface.

1. An optimal hand-hold cut-out has the following approximate characteristics: ≥ 1.5 inch (3.8 cm) height, 4.5 inch (11.5 cm) length semi-oval shape, ≥ 2 inch (5cm) clearance, smooth non-slip surface, and > 0.25 inches (0.60 cm) container thickness (e.g., double thickness cardboard)

2. An optimal container design has ≤ 16 inches (40 cm) frontal length, ≤ 12 inches (30 cm) height, and smooth non-slip surface.

3. A worker should be capable of clamping the fingers at nearly 90o under the container, such as required when lifting a cardboard box from the floor.

4. A container is considered less than optimal if it has a frontal length > 16 inches (40 cm), height > 12 inches (30 cm), rough or slippery surfaces, sharp edges, asymmetric center of mass, unstable contents or requires the use of gloves. A loose object is considered bulky if the load cannot easily be balanced between the hand-grips.

5. A worker should be able to comfortably wrap the hand around the object without causing excessive wrist deviations or awkward postures, and the grip should not require excessive force.

Lifting Index

LI = weight of the actual lift / RWL

If the LI:

< 1 the lift is acceptable, no modification needed.

> 1 but < 3 modification is recommended

> 3 the task is high risk for injury and requires modification.

Appendix E

NIOSH Lifting Calculation for Company XYZ

Company XYZ Job Analysis Worksheet

Date: ______________________
Job Title: ______________________
Analyst's Name: ______________________
Department: ______________________

Part # and Name: ______________________
Job Description: ______________________

____
Control at destination:

STEP 1. Measure and Record Task Variable Data

Object Weight (lbs)		Hand Location				Vertical Distance (inches)	Asymm Angle (deg)		Freq Rate lifts/min	Duration	Origin Coupling	Dest. Coupling
		Origin		Dest			Origin	Dest		Hours performing job tasks		
L (Avg)	L (Max)	H	V	H	V	D	A	A	F		C	C
						0						

STEP 2. Determine the multlipiers and compute the RWL's

	LC x	HM x	VM x	DM x	AM x	CM	FM =	RWL	(Recommended Weight Limit)
Origin RWL=	51	1.00	0.78	1.00	1.00	0.00		**0.0**	**lbs.**
Dest. RWL=	51	1.00	0.78	1.00	1.00	0.00		**0.0**	**lbs.**

STEP 3. Compute the LIFTING INDEX

ORIGIN LIFTING INDEX = Object Weight (L) / RWL = 0.0 / 0.0 = **0.0**

DESTINATION LIFTING INDEX = Object Weight (L) / RWL = 0.0 / 0.0 = **0.0**

Optimal Lifting Task Variables:
(V) Vertical Height = 30 inches
(H) Horizontal Reach <= 10 inches
(A) Assymetric Angle = 0 degrees

(C) Coupling = Good (1.0)
(L max) = 51 pounds if all variables optimal