ERGONOMIC ANALYSIS OF MATERIAL HANDLING AT COMPANY XYZ'S

RECEIVING DOCKS

by

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ABSTRACT

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Company XYZ is in the refrigeration manufacturing industry and provides warranties for its products. Supplies and defective warranty parts are transported to company XYZ's receiving docks, where employees segregate and then ship such materials to the appropriate departments. An evaluation of the workplace design as well as worker procedures indicates that the current material handling practices are placing employees at risk of developing work-related musculoskeletal disorders (WRMSDs).

The purpose of the study was to identify the presence of substandard practices/conditions during the unloading of materials and WRMSDs. Literature reviews included human physiology, WRMSDs, ergonomic losses, as well as the risk management process, methodologies, and instrumentation. The data collection process began with subject selection, obtaining each participant's consent, reviewing records, administering surveys, and video taping employees. Following are the results from this research: two back injuries resulted in a total loss of $30,576, employees experienced back, arm, and shoulder discomforts, no safety policies and training for the receiving docks, improper workplace design, RWL was 16.2 pounds and LI was 6.25, R.U.L.A score was 7, and force gauge measurement was 7.94 kg. In conclusion, the combined results from this research indicated that employees at the receiving docks are exposed to WRMSDs. The researcher recommends the implementation of engineering and administrative controls to alleviate the hazards.

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CHAPTER I: INTRODUCTION

Regardless of automation and mechanization, it appears that repetitive as well as excessive muscular exertions are still very common during many occupational tasks. Overuse of muscular loads has been found to develop musculoskeletal injuries, especially the back and upper extremity muscles. Through the study of ergonomics it has been found that a heavy emphasis should be placed on human factors to reduce these injuries. To clarify the meaning of ergonomics, Tayyari and Smith (1997) define it as the science that focuses on the relationships between laborers and their work place. It deals with the assessment of the human's capabilities/limitations in relation to work and environmental stresses, static and dynamic forces on the human body structure, vigilance, fatigue, design simulation and training, and design of workstations and tools (Tayyari & Smith, 1997). Such science fields as mathematics, biology, psychology, physics, chemistry, engineering, technology, and epidemiology all contributed to the field of ergonomics. The objectives of ergonomics are to protect workers from undue physical, biological, and psychological strain that may occur from performing the required duties. There are multiple occupational factors that can affect the workers. Some of these factors include environmental conditions (e.g., noise, vibration, temperature) of the work area, the physical and mental requirements of the job, the worker's exposure to hazardous materials, and the interaction between the worker and the work equipment (Tayyari & Smith, 1997).

Before World War II, there were no formal tests to fit humans to machines, but rather, it was performed on a trial and error process. If a worker was unable to operate a machine correctly, another person was selected until the right individual was found (Charlton & O'Brien, 2002). By the 20th century, many machines had been invented and consequently became much more complex. The demands for humans to operate these machines required more than just matching a person to the machine. Perhaps it was during this period that inventors gave serious thought to fully integrating humans into systems design (Charlton & O'Brien, 2002). During and immediately following WW II, most human factors research was sponsored by the military. It was not until the 1950s that private companies released the value of human factors expertise and began hiring their own human factors engineering staff (Charlton & O'Brien, 2002). In today's society it is probable that human-interface systems are more sophisticated than ever and require a human factors ergonomist to develop new techniques and measures to alleviate these issues.

Company XYZ manufactures and sells refrigeration, air-conditioning and heating units for rail cars, trucks, trailers, ocean-going containers, buses, trains, and urban mass transit worldwide. This company has 15 plants in ten countries and employs a total of 5,000 employees. To keep XYZ's costumers satisfied, it provides one of the most comprehensive standard warranty programs for its refrigeration units. This warranty extends coverage of major parts in XYZ's trailer refrigeration equipment. The warranty also includes parts and labor for the entire unit and major components for a limited time. With this program in place, XYZ created a Service Parts Warehouse along with receiving docks. These docks bring in parts from customers that need to be repaired or replaced as well as supplies for the company to use. At the receiving docks, employees were required to perform manual lifting of supplies and returned parts, push and pull carts, as well as use of manual forklifts to move pallets. To date, XYZ's employees at the receiving docks have reported two back injuries. One back injury required hospitalization while the other was still under investigation. These two incidences are indications that ergonomic risk factors may exist at the loading docks. If these risk factors are present at the docks and there are no corrective actions to remediate the problems, XYZ's employees would soon experience more frequent and severe work-related musculoskeletal disorders (WRMSDs). From this information, it is appropriate to suggest that the current practices of handling parts and materials on the receiving docks of XYZ, Inc. are placing associated employees at risk of developing back-related and upper extremity injuries.

Purpose of the Study

The purpose of the study will be to identify the extent that substandard practices/conditions are present during the unloading of parts/materials at XYZ's docks.

Goals of the Study

- Review medical and workers compensation records, OSHA Log 200, and symptom surveys to identify if employees are already experiencing musculoskeletal disorders
- Perform an analysis of procedures/practices to identify if such could contribute to employee injury
- Analyze the engineering aspects of the loading dock area to identify if deficiencies in machine design/setup could contribute to the occurrence of musculoskeletal disorders

Background and Significance

The National Institute of Occupational Safety and Health's (NIOSH) review of multiple studies in 1997 indicated there were strong evidences that low-back disorders were associated with work-related lifting, forceful movements, and/or exposure to whole-body vibration (WBV). Evidences also indicated that work-related awkward postures and/or heavy physical work are associated with low-back discomforts (NIOSH, 1997). Furthermore, the National Occupational Research Agenda (NORA) stated that back pain is one of the most common and significant musculoskeletal problems in the world. In 1990, the estimated total cost of low back pain to society was between $50 billion and $100 billion per year. About 30% of American workers are employed in jobs that routinely require them to perform activities that may increase risk of developing low back disorders (NORA, 1998). Thus, the high cost of injuries and the number of people being affected indicate that musculoskeletal disorders are major a concern to society.

If WRMSDs occur, company XYZ would incur direct and indirect losses. Direct losses include but are not limited to medical and worker compensation while indirect losses reflect the losts of production, decreased employee morale, and pay for overtime or temporary employees. Managers at company XYZ recognize the ergonomic hazards and want to take proactive steps toward the correction of these issues before more problems occur.

Assumptions of the Study

Assumptions made for this study include:

- The employees at company XYZ complete the survey with integrity and without bias.
- The employees' working methods and practices being analyzed were consistent with the ones they perform at a different time.

Definition of Terms

Below are the definitions for common terminologies used while conducting an ergonomic research:

1. *Ergonomics:* The science that concerns with the design of work environment, tools, tasks to match the physiological, anatomical, and psychological characteristic and capabilities of the worker (Putz-Anderson, 1988, Pg 86).
2. *Lumbar Sacral Syndrome:* Low back pain due to disease or trauma at these sites; the lumbar region refers to the part of the back and sides between the lowest ribs and the pelvis; sacral refers to the sacrum, a triangular bone made up of five fused vertebrae

and forming the posterious section of the pelvis; lumber sacral refers to both the lumbar region and sacrum (Peate & Lunda, 2002).

3. *Pronation:* A medial rotation (or inward rotation) of a body member. For example: medial rotation of the forearm brings the palm of the hand downward (facing the ground) (Tayyari & Smith, 1997).
4. *Supination:* A lateral (or outward) rotation of a body member. For example, lateral rotation of the forearm brings the palm of the hand upward (facing up) (Tayyari & Smith, 1997).
5. *Work-related Musculoskeletal Disorder (WRMSD)* is also known as Cumulative Trauma Disorder (CTD) or Repetitive Motion Injury (RMI). They are defined as illnesses that are cumulative over time or chronic injuries to the soft tissues caused by repetitious exertions (Peate & Lunda, 2002).

Limitations of This Study

The risks analyzed/assessed, processes, and recommendations from this study are specific to the receiving docks at XYZ facility for first shift employees only.

CHAPTER II: LITERATURE REVIEW

Introduction

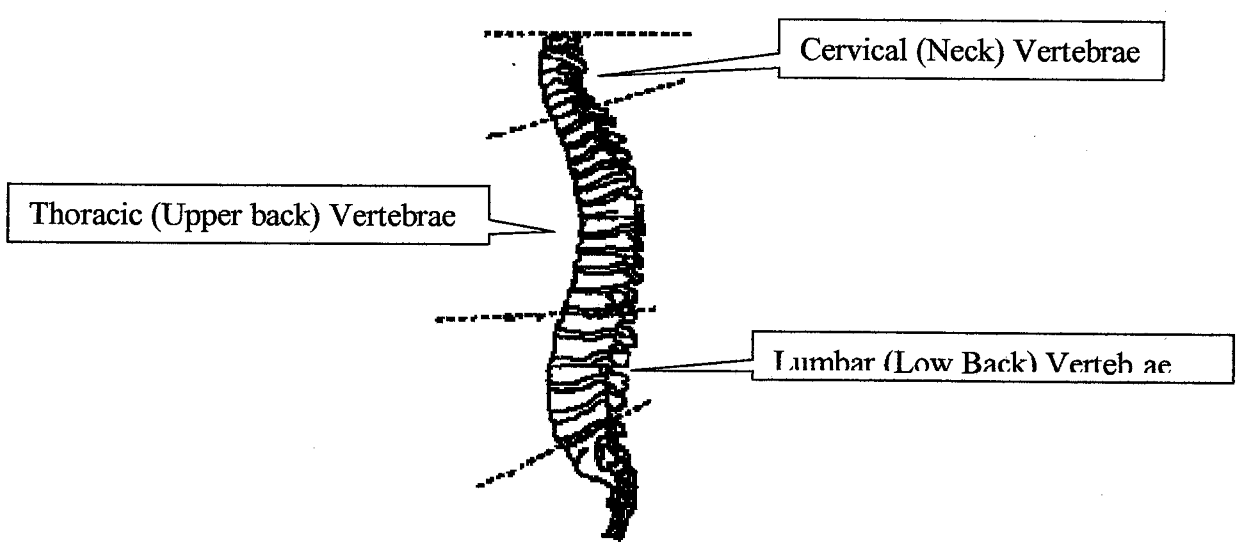
The purpose of this research was to determine the level that substandard practices and conditions are present during the unloading of materials at XYZ's docks. Major institutions such as NIOSH and universities are putting forth efforts to study work-related musculoskeletal disorders to find solutions to abate the hazards. To understand how these body parts get injured, the researcher will explain the human physiology of the upper extremities and back as well as the common musculoskeletal disorders of these body parts. Current ergonomic loss trends will also be discussed to show the impact of the losses to society. In addition, it is important to explain the significance of involving management and employees in the process of developing appropriate workplace designs. Furthermore, the investigator will present the risk management process as well as provide case studies to identify what has been researched.

Human Physiology: Upper Limbs and Back

In order to understand why and how back pains occurred, the anatomy of the spine needs to be reviewed. The spinal column is one of the most important parts of the human body because it provides support for the trunk and makes mobility possible. It is divided into three major regions as displayed in Figure 1; the cervical spine (neck), the thoracic spine (upper back), and the lumbar spine (lower back) (Spine-health.com, 2004). As indicated in Figure1, the cervical vertebrae (neck) consist of seven vertebral segments, but the first cervical segment is a ring that does not have a vertebral body. The right side is attached to the second vertebral body that behaves as a base for rotation. This rotation flexibility may allow the neck to be more susceptible to injuries because it is not well supported. Other vertebral segments are like the rest of the spine, with three joints at each segment, including one disc in the front and paired facet joints in the back. Since the disc is in the front of the vertebral body, bending and extending of the neck can compress or expand the disc that may lead to injuries.

The second area of the spinal column, the thoracic region, has twelve vertebral bodies. These vertebral segments are well structured and supported because they firmly attach to the ribs and sternum (breastbone). Since there is little or no motion, this region of the spine is not usually a source of pain. Finally, the lumbar vertebrae have five vertebral bodies that extend from the lower thoracic spine (chest) to the sacrum (bottom of the spine). The vertebral bodies are piled on top of each other with a disc to separate each one. These vertebrae are most frequently injured or involved in back pain, due to carry the most amount of body weight and are subjected to the largest forces and stresses along the spine (Back.com, 2002). Unlike the well-supported vertebral bodies in the thoracic region, the location of the lumbar vertebrae (on the lower part of the spine) forces the vertebral bodies and discs to bear the most weight, making them more susceptible to injuries when carrying heavy objects.

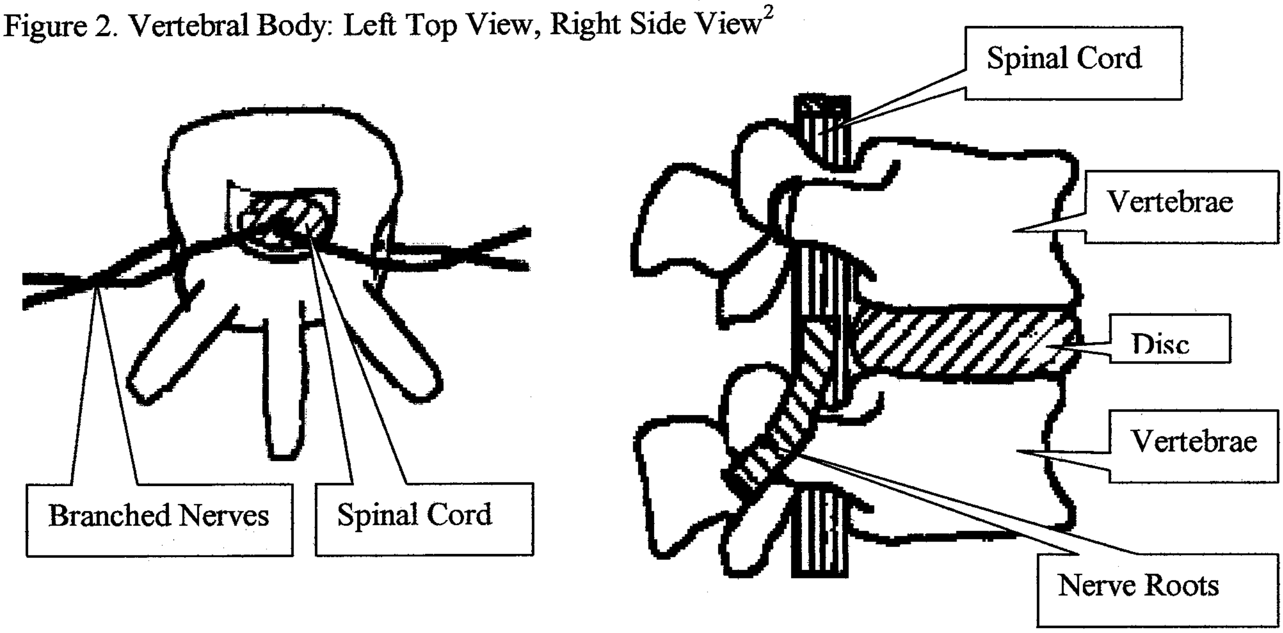
Figure1. The Human Spine[1]



[1] From "*Occupational Ergonomics*" *by* Fariborz Tayyari and James L. Smith, 1997, p. 20. Copyright 1997 by T.J. Press Ltd, Pasdstow, Cornwall.

Each region of the spinal column consists of vertebral bodies, nerves, cartilages, as well as discs. The vertebral bodies act as shock absorbers and support the columns to hold up the spine. This spinal column and the muscles work together to support the weight of the body; therefore, weak muscles can lead to back injuries. Attached to the vertebral bodies in the spinal column is a bony arch, where nerve roots run through as shown on Figure 2. The nerve root provides sensations; therefore, if the hernia disc pressed against it the individual will feel the pain. The arch comprises of the paired facet joints, and a disc which generates a three joint complex at each vertebral motion segment. The facet joints are surrounded by cartilages and a capsule. As a person ages, the cartilage can deteriorate and lead to degenerative arthritis. The three-joint complex at the vertebral segment allows for movement in flexion, extension, rotation, and lateral bending. Furthermore, about 50% of the bending forward takes place at the hips, and fifty percent happens at the lower (lumbar) spine. The flexion occurs along the five motion segments in the lumbar spine. There is an unequal amount of the motion at lumbar segment 3, 4, and 5. As a result, these segments are more susceptible to break down with degeneration. As these segments deteriorate they can become unstable with too much motion creating pain (Spine-health, 2004). Considering the various components such as the nerves, discs, and cartilages in the spinal structure, the function of spine, and the amount of movement in the lumbar region, it is no wonder why individuals experience back pain.

Figure 2. Vertebral Body: Left Top View, Right Side View[2]



Other body parts to review would be the shoulder, upper arm, lower arm, wrist and hands. The shoulder is designed to serve as a pivot that allows the arm to rotate as well as move up, down, forward and backward. Attached to the shoulder is the upper arm, which contains a long bone, called the humerus. This bone joins at the shoulder in a complex ball-and-socket joint arrangement. The lower arm contains the ulna and radius bones that are joined to the humerus at the elbow. This joint allows for flexion and extension of the elbow as well as supination and pronation of the forearm and hand. Attached to the lower arm is the wrist and hand. The wrist has small bones, named carpals, the palm contains bones, called metacarpals, and the fingers are comprised of phalanges (bones) forming the strong and flexible wrist and hand. As shown in Figure 3, muscles and tendons allow the wrist and hands the flexibility to move in any directions (Putz-Anderson, 1988). The shoulder, arms, wrist and hands consists of bones, muscles, and tendons that are all interconnected. These body parts can move in any direction to allow a person to perform a function but over-used of the flexible arms and hands can lead to injuries.

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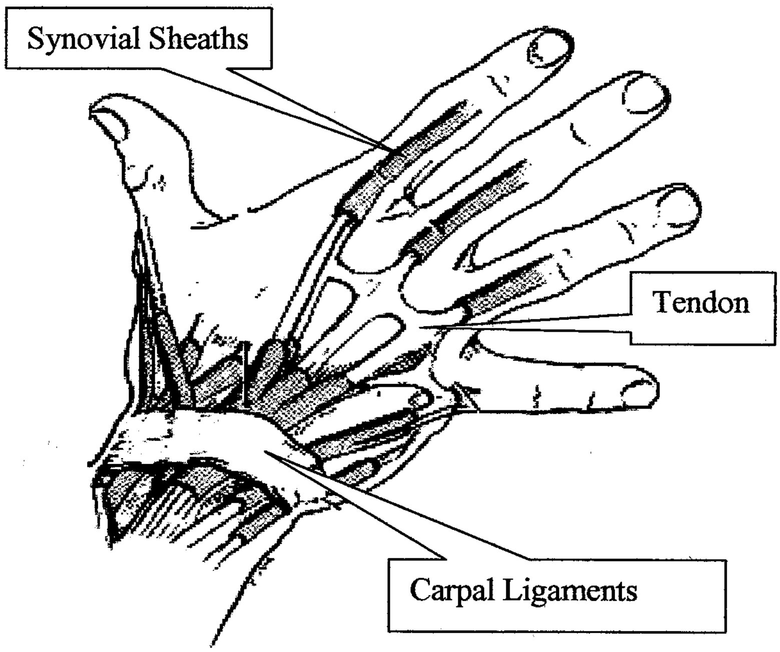
[2] From "*Occupational Ergonomics*" *by* Fariborz Tayyari and James L. Smith, 1997, p. 20. Copyright 1997 by T.J. Press Ltd, Pasdstow, Cornwall.

Figure 3. A View Of The Tendons, Sheaths And The Carpal Ligament In The Hand[3]



Common Musculoskeletal Disorders for Upper Extremities and Back

The tissues in the human body can handle stresses to a certain level, but when they are over-used for an extended period of time, musculoskeletal disorders are likely to occur. Musculoskeletal disorders (MSDs) are aggravated by repetitive motions, vibration, forceful exertions, mechanical compression, and awkward postures that occur overtime. Common signs of MSDs are a decrease of gripping strength and range of motion as well as loss of function. Some MSDs symptoms include pain in the joints and other body parts such as wrists and back, tingling, numbness in the hand or feet, inflammation, and stiffness (J.J. Keller & Associates, 2004). The above signs and symptoms are indications of the development of MSDs but if ignored may lead to serious injuries.

[3] From "Cumulative Trauma Disorders: A Manual for Musculoskeletal Diseases for the Upper Limbs," by Vern Putz-Anderson, 1988, p. 11. Copyright 1988 by Taylor & Francis, Ltd.

Some common musculoskeletal disorders (MSDs) include tendonitis, tenosynovitis, trigger finger, carpal tunnel syndrome, Raynaud's Syndrome, and back disorders. The first MSD, tendonitis, is inflammation of the tendon which results from overuse, vibration, or awkward posture of the wrist or shoulders. Without rest and sufficient time for the tendon to heal, it can become calcified and permanently weakened. The second MSD, tenosynovitis, is an injury or inflammation of the synovial shealth (see Figure 3) that surrounds the tendon. Lubricating synovial fluid is secreted by the sheaths to reduce friction during movement, but over-use of the hands and wrists cause excessive secretion of the liquid, and thus leading to swollen sheaths. The third MSD, trigger finger, is another tendon disorder which attributes to the formation of a groove in the flexing tendon of the finger. When the tendon becomes locked in the sheath, moving the finger causes spontaneous and jerking movements. The fourth MSD, carpal tunnel syndrome, is compression and entrapment of the median nerve in the carpal tunnel where it passes through the wrist into the hand. The median nerve provides the sense of touch in the thumb, index finger, middle finger, and half of the fourth or ring finger. When the tendons inside the carpal tunnel swell and press against the median nerve which causes tingling, numbness, or severe pain in the wrist and hand. If the pressure continues permanent loss of sensation or even partial paralysis can occur. The fifth MSD, Raynaud's Syndrome, also referred to as "white finger", results from damage to the blood vessels of the hand due to long-term exposure to vibration. Lack of necessary oxygen from the blood causes the skin and muscles to die. Common symptoms of the disease include numbness and tingling in the fingers, pale and cold skin, and loss of sensation and control of fingers and hands (Putz-Anderson, 1988). The last MSD, back disorder, usually results from pulled or strained muscles, ligaments, tendons, and discs. Most back disorders result from chronic or long-term injuries rather than one specific incident. Back disorders are usually caused by lifting loads that are too heavy or too large, staying in one position too long, poor physical condition, awkward posture, or repetitive motion. It should be noted that when the back is repeatedly injured, the muscles, discs, and ligaments can become weakened and scarred, thus loosing the ability to support the back, making additional injuries more likely to occur (J.J. Keller & Associates, 2004). The above injuries are common, but it is probable that such can be prevented if the appropriate intervention is provided.

Current Ergonomic Loss Trends

Information from multiple sources indicates that ergonomic injuries cost company production time as well as money. The Bureau of Labor Statistics (BLS) reported that in 1998, workers who were afflicted with carpal tunnel syndrome missed approximately 24 days of work. Women are more susceptible to carpal tunnel syndrome than men. According to the BLS, repetitive motion injuries cause the longest work absences from work, averaging roughly 15 days. Besides lost time, the Occupational of Safety and Health Administration (OSHA) can penalize a company under the General Duty clause of the OSH Act for ergonomic injuries (J.J. Keller & Associates, 2004). To provide more insight on the specific losses that are occurring, Dempsey & Hashemi (1999) stated that the lower back is the most frequently injured area followed by the upper extremity parts in manual material handling. Data from the BLS in 2001, displayed in Table 1, concurs with the Dempsey and Hashemi results on back and upper extremities injuries. Dempsey and Hashemi also found that low back disorders are responsible for a higher percentage of the manual material handling claim costs than the upper extremity injuries. Together, these two injuries account for over 70% of manual material handling claims costs. Lower back strains create the highest percentage of claims (27.2%), which justifies the injury for being the primary research topic in the area of work-related injuries. However, sprains and strains of other body parts such as the shoulder should be another area of concern to researchers and companies. In addition, intervertebral disc ruptures are few in claims but the costs are relatively high compared to other types of injuries in manual material handling (Dempsey, Hashemi, 1999). According to the information above, ergonomic related injuries continue to be a big concern for industries, the government, and the workers.

Table 1. Percentage Of Work-related Musculoskeletal Disorders, 2001[4]

Part of Body Affected	Percentage of WRMSDs	Musculoskeletal Disorders	All Cases
Back	71%	265,018	372,683
Shoulders	62%	55,119	88,484
Wrist	59%	46,567	78,857
Neck	41%	11,064	27,111
Knees	20%	23,477	119,670
Multiple	16%	21,737	139,675
Hands	7%	4,538	63,727
All other	6%	561	9,695
Fingers	3%	3,712	123,523
Feet, toes	3%	1,872	68,117

Management and Employee Involvement During Process Development

In order to reduce musculoskeletal disorders (MSDs), companies must establish internal standards as well as re-engineer workstations and tools. However, before any programs or procedures can be developed, the company's risks and hazards need to be assessed. Both management and line employees need to work together to identify the risks and develop the most effective safety and health management plans. Research performed by loss control management specialists indicates that 15% of a company's injuries can be controlled by individuals, but 85% or more is controlled by the system (Hodson & Covert, 2001). Based on the information Hodson

[4] From "Bureau Labor Statistic," by www.bls.gov/iif/oshwc/osh/case/ostb1154.pdf, 2004.

and Covert's (2001) provided, management leadership and organizational commitments are required to develop successful safety and health programs. Management needs to have a vision of the occupational health and safety procedure and serve as an inspiring force behind the methods. Leadership and commitment can be illustrated in various methods. The first strategy is by issuing policies with the manager's signature to show that he/she is serious about preventing accidents. The second method is to include safety responsibilities in all management job descriptions. The third technique is to involve management in actions that increase visibility in safety activities and create regular staff contacts (Bird and Germain, 1985). These activities are only a few examples of what management can do to show their leadership and commitment to safety and health.

In addition to management leadership and commitment, developing a corporate safety culture that encourages true employee involvement is important. Employees need to be motivated to get involved in safety as a method of self-ownership. Workers are more likely to perform safe practices and procedures in which they are involved in developing. The sense of ownership increases employees' rate of safe behaviors even when they are not being directly supervised (OR-OSHA, 2002). Employees are motivated to participate in voluntary activities which they believe create some real benefits. They can participate in policy development as well as the planning of objectives, risk assessment, procurement, design, problem solving, and operation of risk control systems. The workforce can also get involved in carrying out inspections, accident and near-hit investigation and hazard spotting as well as audit and review of the efficiency and effectiveness of the health and safety system (Bell, 2001). Employee involvement in such programs is important because they are experts in the operation, closest to the hazards, and have the most control over the occurrence of accidents.

Hazards Identification

To succeed in the reduction of work-related musculoskeletal disorders (WRMSDs), the first step is to determine the level of WRMSDs in the workplace. The objective can be achieved by reviewing existing records, surveying the workers, as well as medical screening, and identifying working conditions or practices that may lead to injuries.

Review of Existing Records

The first method of the identification process is to review existing medical, safety, and insurance records to identify past cases of WRMSDs. The information can be used to determine which current jobs would generate the highest risks to the employees and the nature of WRMSDs. The records to be reviewed include the Log and Summary of Occupational Injuries (OSHA Form 300), plant medical records, and worker compensation (WC) insurance. The OSHA Form 300 is a log, required by OSHA, on which most employers have to maintain records of injuries and illnesses. Occupational injuries include cuts, sprains, and amputations, which occur as a result of an accident or exposure in the workplace, whereas occupational illnesses are defined as any abnormal condition or disorders (not injury) associated with the working environment. The objective of the review would be to verify the company's concern regarding musculoskeletal disorders (MSDs) and identify the progression of the injuries (NIOSH, 1997). The usefulness of the log depends on the local practices of the recording of injuries and illnesses, because some plants only record cases that require visits to the hospital (Putz-Anderson, 1988). Reviewing existing OSHA logs are very useful in identifying past musculoskeletal disorders as well as identifying jobs that contribute the most to ergonomic related injuries.

Another type of loss-based documentation to review is the plant medical records, which are usually found in larger companies that have their own clinic staff, and trained medical personnel. A medical record is similar to OSHA Form 300, but in many cases every visit to the clinic is recorded in the workers' medical profile. The information may include the date of a visit, job title, department, and description of injuries and/or illnesses as well as treatment. A medical record provides more detail of the injury, treatment, and includes non-recordable harms that could be analyzed to forecast future cumulative trauma disorders (Putz-Anderson, 1988). The medical record may be similar to OSHA Form 300, but it does provide more information and could be used to identify future musculoskeletal disorders.

A third record is the workers' compensation insurance loss summaries, which provide information regarding medical and disability costs. Medical costs are paid to hospitals or medical personnel outside of the company as well as rehabilitation such as physical therapy. Disability costs include money paid to the injured worker for lost work time and lump sum payments to settle permanent disabilities. Worker compensation (WC) records can be used to estimate some costs associated with WRMSDs and identify department and jobs where the costs are high. However, WC describes more severe or existing problems only. The report may fail to identify existing cases that are still in the early developmental stage (Putz-Anderson, 1988). Similar to the OSHA Form 300, worker compensation records identify more severe and past cases only, but they also provide the cost of each case.

Surveying Workers

The safety profession generally assumes medical as well as other forms of records only reflect the past occurrences of cumulative trauma disorders (CTDs). Records do not give an accurate picture of the current problems, which may include frequency, severity, and possible causes of the injury. To correct the lack of current information, a survey should be administered to the workers. There are both advantages and some limitations for using surveys. One benefit is anonymity for individuals encouraging them to report more private opinions. Another benefit for using a survey is the standardized questions, which allow replication to detect changes over time. Also, a standardized survey can be administered at a low cost (Salvendy, 1987). The last advantage of the survey is the information, which can be used to identify areas or jobs where potential CTDs may exist. In addition, survey responses indicate the location and nature (swelling, tingling, stiffness, etc) of symptoms.

Although a survey provides many benefits, it does have limitations. First of all, the survey questions rely on the worker's acknowledgement of pain, willingness to report, and general health condition. For example, in most early stages of CTDs, many symptoms frequently occur more at night. The workers may not recall or recognize the importance of the symptoms on the day of the survey (Putz-Anderson, 1988). Lastly, the survey is incapable of diagnosing a specific disorder. Surveys are a great tool, but need to be interpreted with caution because tolerance of pain levels differs from one person to another; therefore, responses may vary. A positive response indicates that noticeable discomforts exist in the workers (Putz-Anderson, 1988). Symptom surveys provide current information regarding the frequency, severity, and possible causes of the ergonomic related injuries, but it does have limitations such as the reliance on workers acknowledgement of the problem.

When designing a survey, many important factors should be considered. The factors include the language and reading level of the workers, length of the questionnaire, wording of instructions, and time and method of administration. The workers need to be able to read and understand the language, and the questions should not overwhelm the subjects. The instruction should be clear and allow enough time for the workers to answer the questions. A general anatomy diagram should be included in the survey for the workers to circle the part of the body where the pain is located. The design of a survey plays an important role in collecting accurate data; therefore, consider the language, length of questions, and the time.

Medical Screening

After the survey suggests that disorders exist, a medical screening examination is particularly useful. To maintain objectivity, physicians who have no knowledge of the workers' health conditions should perform the examinations. Trained medical personnel use simple testing maneuvers to determine a more accurate picture of the nature and severity of the symptoms that may exist. For example, evaluation of shoulder problems would include asking the workers to touch the top of their heads and scratching their backs. The workers would then rate the level of pain experienced doing the maneuvers (NIOSH, 1997). If the workers cannot perform the motions without pain or limitations, they need to see a physician for further evaluation and treatments (Putz-Anderson, 1988). Symptom surveys determine the existence of MSDs but medical screening can identify the severity of the injuries.

Hazard Analysis

Hazard analysis could be considered the heart of a successful ergonomic program. According to Bird and Germain (1985), good analysis of the hazards or risks in the workplace will identify the critical areas that produce the highest exposure. One of the most effective methods is to analyze the job. Job tasks where cumulative trauma disorders (CTDs) exist or high-risk profile jobs should be subject to a systematic job analysis. Evaluation includes work methods, workstation design, and tools. The goal is to identify the biomechanical stressors or sources that may contribute to the occurrence of CTDs. The analysis evaluates improvements needed in job and tool redesign. Ideally, job analysis measures worker exposures such as force, posture, and repetition. These exposures can be compared to known human capabilities to compute an injury probability. Documenting jobs that illustrate safe levels of task factors and effective work design can be used for benchmark comparison. Task analysis is complex and time-consuming, but is an essential part of a comprehensive safety-management scheme. When performing a task analysis the following steps should be followed:

1) Establish a list of tasks performed by employees

2) Determine the tasks to be analyzed by evaluating the level of risk

3) Select one of the critical few tasks to be investigated

4) Divide the tasks into individual steps

5) Identify potential problems involving health, safety, quality, and production within each step

6) Verify the task cannot be changed; then write a safety standard to control the hazards (Bird and Germain, 1985). If performed correctly, a job analysis can identify the risk factors that contribute to the occurrence of musculoskeletal disorders and can be used to develop control systems.

Having a task analysis procedure is advantageous, but each job is different; therefore, different analytical methods may have to be used. Putz-Anderson (1988) created two ergonomic methods to analyze jobs: checklist and work-method technique. An ergonomic checklist is a more direct approach where it itemizes undesirable workplace conditions or work activities that may cause soft tissue injury. A checklist needs to be customized to include a list of the biomechanical risk factors. For example, the risk factor of force includes holding, assembling, and pinching while the risk factor for posture includes reaching, inspecting, assembling. Before one would customize a new checklist, a walk-through survey should be conducted to ensure the list covers that correct risk factors and job attributes. Most checklists cover crowding or cramping of the workers in a work area. Additionally, the location of tools and supplies may force workers to twist the spine to see or reach. Such repeated reaching motions force the workers to stretch and lean to reach and grasp and leads to misalignment of body parts. Inappropriate arrangement of workstations may cause workers to have one shoulder higher than the other or have painful spine or neck bending to one side (Putz-Anderson, 1988). For a simple job, an ergonomic checklist can be used to document undesirable workplace conditions, but it is likely that the work-method analysis is better for a complex job.

The other technique, work-method analysis, is effective for new or unusually complex jobs. For this method, a complete task description is needed to categorize work content including production records and a videotape of the worker on the job. Once the job components are documented, awkward postures, high repetitions, excessive forces and stresses can be identified. The most difficult task in the method is to decide if the risk factors pose demands that exceed acceptable ranges of human capacity (Putz-Anderson, 1988). However, some ergonomic guidelines such as National Institute for Occupational Safety and Health (NIOSH) lifting equation and Rapid Upper Limb Assessment (RULA) survey, and/or instruments such as a force gauge can be used to assist in the judgment. The work-method analysis may be complex and time consuming, but there are guidelines to assist in deciding the risk factors.

NIOSH Lifting Equation

One of the guidelines that can be used to analyze the risks of a task is the NIOSH Lifting Equation. In 1994, the NIOSH issued a revised formula for the evaluation of manual lifting tasks. The equation provides techniques for evaluating the unbalanced lifting and handling of objects that do not have optimal grip. The formula (see Table 2) also provides a recommended weight limit (RWL) for a specific set of task conditions. The RWL is the weight of the load that nearly all healthy workers could perform over a substantial period of time without an increased risk of developing lift-related lower back pain. Healthy workers are defined as those who do not have adverse health effects that could increase their susceptibility to musculoskeletal injuries (J.J. Keller & Associates, 2004).

Table 2. Recommended Weight Limit Equation[5]

Recommended Weight Limit equation: RWL = *LC* x *HM* x *VM* x *DM* x *AM* x *FM* x *CM*

Load Constant (LC)	51 lb
Horizontal Multiplier (HM)	(10 / *H*)
Vertical Multiplier (VM)	1–(.0075 | *V*–30 |)
Distance Multiplier (DM)	.82 + (1.8 / *D*)
Asymmetric Multiplier (AM)	1–(.0032*A*)
Frequency Multiplier (FM)	From Table 4
Coupling Multiplier (CM)	From Table 3

Where:
H = horizontal distance of hands from midpoint between the ankles (cm or in).
V = vertical distance of the hands from the floor (cm or in).
D = vertical travel distance between the origin and the destination of the lift (cm or in).
A = angle of asymmetry—angular displacement of the load from the sagittal plane. Measure at the origin and destination of the lift (degrees).
F = average frequency rate of lifting measured in lifts/minute. Duration is defined to be: £ 1 hour (short); £ 2 hours (moderate); or £8 hours (long) depending on the work pattern.

The hand-to-object gripping method affects the force a worker must exert on the object as well as the vertical location of the hand during the lift. A poor coupling (see coupling multiplier in Table 3) will require higher grasp forces and frequent lifts per min (refer to frequency multiplier in Table 4) reduce the acceptable weight for lifting.

[5] From "www.jjkelleronline.com/topics/TopicInfo.aspx?topickey=1066&doctype=1&pagekey=513907," by J.J. Keller and Associates, Inc. Retrieved February 19, 2004. Copyright by J.J. Keller & Associates, Inc.

Table 3. Coupling Multiplier[6]

	V **t 75 cm (30 in)**	***V*** **w 75 cm (30 in)**
Couplings	**Coupling multipliers**	
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

Table 4. Frequency Multiplier[7]

# of lifts/min	**Task duration**					
	≤1h		**≤2h**		**≤8h**	
	V<75 cm	*V*≥75 cm	*V*<75 cm	*V*≥75 cm	*V*<75 cm	*V*≥75 cm
0.2	1.00	1.00	0.95	0.95	0.85	0.85
0.5	0.97	0.97	0.92	0.92	0.81	0.81
1	0.94	0.94	0.88	0.88	0.75	0.75
2	0.91	0.91	0.84	0.84	0.65	0.65
3	0.88	0.88	0.79	0.79	0.55	0.55
4	0.84	0.84	0.72	0.72	0.45	0.45
5	0.80	0.80	0.60	0.60	0.35	0.35
6	0.75	0.75	0.50	0.50	0.27	0.27
7	0.70	0.70	0.42	0.42	0.22	0.22
8	0.60	0.60	0.35	0.35	0.18	0.18
9	0.52	0.52	0.30	0.30	0.00	0.15
10	0.45	0.45	0.26	0.26	0.00	0.13
11	0.41	0.41	0.00	0.23	0.00	0.00
12	0.37	0.37	0.00	0.21	0.00	0.00
13	0.00	0.34	0.00	0.00	0.00	0.00
14	0.00	0.31	0.00	0.00	0.00	0.00
15	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

The Lifting Index (LI) provides a relative estimate of the physical stress associated with a manual lifting job. The LI is calculated using the formula below:

$$LI = \frac{\text{Load Weight*}}{\text{Recommended Weight Limit}} = \frac{L}{RWL}$$

* Where Load Weight (L) = weight of the object lifted (1 lb. or kg.)

[6] From "www.jjkelleronline.com/topics/TopicInfo.aspx?topickey=1066&doctype=1&pagekey=513907," by J.J. Keller and Associates, Inc. Retrieved February 19, 2004. Copyright by J.J. Keller & Associates, Inc.
[7] From "www.jjkelleronline.com/topics/TopicInfo.aspx?topickey=1066&doctype=1&pagekey=513907," by J.J. Keller and Associates, Inc. Retrieved February 19, 2004. Copyright by J.J. Keller & Associates, Inc.

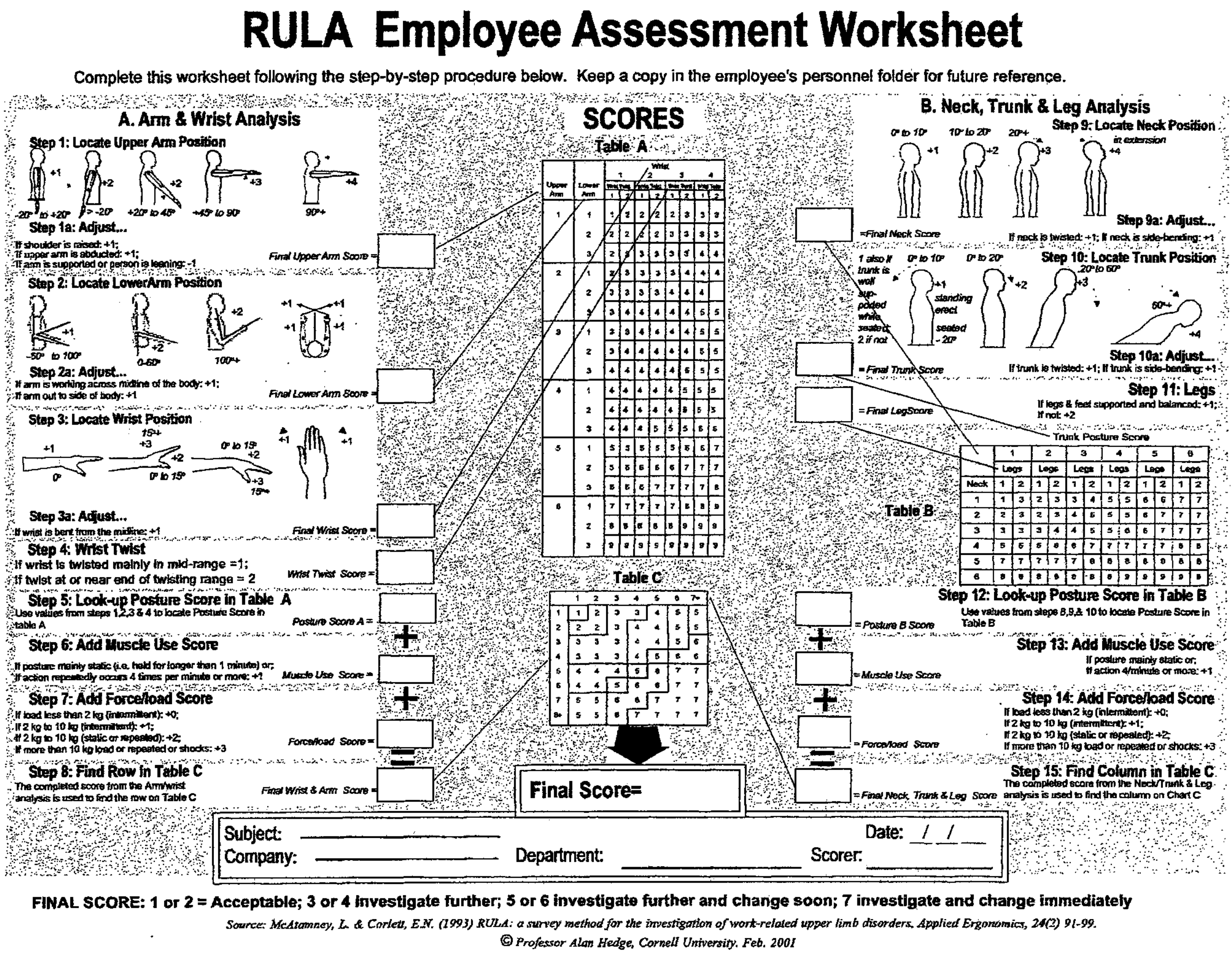
The above RWL and LI calculations combined can be used to guide ergonomic design in various methods. Each multiplier can be used to determine specific job-related issues and the RWL can be used to guide the design of manual lifting jobs. The LI can be used to estimate the relative magnitude of physical stress for a task or job. A greater LI number indicates that a smaller fraction of workers are capable of safely sustaining the level of work. The LI can also be used to prioritize ergonomic redesign and evaluation efforts. Lifting tasks with a LI greater than one pose an increased risk for lifting-related low back injury for a percentage of the workforce (J.J. Keller & Associates, 2004). Overall, the recommended weight limit equation calculates the maximum safe weight of a load, while the lifting index estimates the physical stress associated with a job.

An ergonomist can use the NIOSH equation to help with ergonomic design or redesign to a certain extent, but, it does have limitations. The formula is not intended to apply to such situations as one-handed lifting, lifting in extreme temperatures, or the presence of risk factors that may increase slip, trips or falls. Moreover, the equation does not take into consideration the horizontal distance that the object must travel from its origin to the destination. Other limitations of the equation include an assumption that manual material handling such as holding, carrying, pushing, and pulling to be minimal, and the worker is assumed to be at rest when not lifting. The worker is also presumed to be physically fit and accustomed to the rigorous labor (Tayyari and Smith, 1997). The NIOSH equation can be used to assist in ergonomic design, but it is not applicable to certain situations such as one-handed lifting, horizontal traveling distance, and temperature extremes.

R.U.L.A.

In addition to the NIOSH Lifting equation, the Rapid Upper Limb Assessment (RULA) survey in another methodology that can be used to analyze a task. Drs. Lynn McAthamney and Nigel Corlett from the University of Nottingham's Institute of Occupational Ergonomics developed this method in 1993. The technique evaluates the worker's exposure to postures, forces and muscle activities that have been shown to contribute to repetitive strain injuries (RSIs), which focused on the neck, trunk and upper limbs (see Figure 4). The first step in performing this survey is to observe and select the posture to assess. The assessment represents a moment in the work cycle; therefore, it is important to select the worst posture or the longest held posture. The next step is to score and record the posture. This evaluation gives a quantity result ranging from one to seven, where a higher score signifies a greater level of risk. However, a low score does not mean the workplace is free from hazards and a higher number does not assure severe problems exist, because the assessment only focuses on one moment in the work cycle and on the worst posture. The last step is the action level, which is using the score to detect work postures, or risk factors that require further investigation (McAtamney and Corlett, 1993). The survey should be used in conjunction with verified results. The outcome should be confirmed with data from other measuring techniques and evaluated against work practices. For this reason, the force gauge will be discussed in the next section.

Figure 4. Rapid Upper Limb Assessment Survey[8]



[8] From "RULA: A Survey Method For The Investigation of Worker-Related Upper Limb Disorders," by L. McAtamney and E.N. Corlett, 1993, *Applied Ergonomic, 24(2)*, p. 91-99. Copyright 2001 by Professor Alan Hedge, Cornell University. Reprinted with permission.

Force Measuring Instrumentation

A force gauge is a device used to measure the amount of force required to move an object. According to CheckLine By Electromatic (2004), their ESH/PSH series mechanical force gauge is manufactured to allow high capacity measurements. As shown in Figure 5, the strong metal cover and heavy duty springs will withstand the adverse atmosphere of a manufacturing facility, yet the highly precise, matched springs will ensure dependable outcomes and maintain their precision over long periods. A button, tare ring, permits the researcher to zero the measurement and alter measuring positions. The real time/peak hold selector button allows the researcher to monitor transients or detain peaks. This force gauge can be used to measure the pushing, lifting, pulling, or carrying force, and it is available in pounds, kilograms and Newtons. The researcher will provide a summary of the instruction to use the device in the following paragraph.

Figure 5. ESH High Capacity Mechanical Force Gauge[9]

Using the force gauge requires two processes. The first step is to calibrate the force gauge by pressing the tare button to zero it. If the pin is not at the zero, one would manually turn

[9]From "www.checkline2.com/product.php/Mechanical%20Force%20Gauges/ESH/id/125845/1ang/en/buy/yes," by Check.Line By Electromatic. Retrieved April 24, 2004.

the pin slowly to such point on the dial. The operator would need to attach the appropriate hook to the device and then place the hook on the object needed to be measured. Placing both hands on the force gauge handles and pulling the object should move the pin to a number, and indicate the amount of force required to move the material. The second procedure is to determine the maximum acceptable force for the task condition using the appropriate Snook table (see Table 5), and determine if the measured force is within the safe range. The Snook table is different for each situation; therefore, Table 5 only pertains to initial pulling force for females and is provided as an example. The first step is to locate the vertical distance (cm) from the floor to the hands, and then identify the desired percentage of industrial population that can handle the force (preferably 90 percent). Next, determine the frequency (seconds, minutes, or hour) and distance (meter) of the pull. After locating the above information, the initial force required to move an object can be determined. If the measured energy is lower than the maximum acceptable force, then it is within the safe range.

Table 5. Maximum Acceptable Forces of Pull for Females (kg)[10]

		2.1 m pull							7.6 m pull						
		One Pull Every							One Pull Every						
		6	12	1	2	5	30	8	15	22	1	2	5	30	8
		s		min				h	s		min				h
Vertical distance from floor to hands (cm)	% of industrial population	Initial Forces							Initial Forces						
135	90	13	16	17	18	20	21	22	13	14	16	16	18	19	20
	75	16	19	20	21	24	25	26	13	17	19	19	21	22	24
	50	19	22	24	25	28	29	31	19	20	22	23	25	26	28
	25	21	25	28	29	32	33	35	21	23	25	26	29	30	32
	10	24	28	31	32	36	37	39	24	26	28	29	32	34	36
89	90	14	16	18	19	21	22	23	14	15	16	17	19	20	21
	75	16	19	21	22	25	26	27	17	18	19	20	22	23	25
	50	19	23	25	26	29	30	32	19	21	23	24	26	27	29
	25	22	26	29	30	33	35	37	22	24	26	27	30	31	33
	10	25	29	32	33	37	39	41	25	27	29	30	33	35	37
57	90	15	17	19	20	22	23	24	15	16	17	18	20	21	22
	75	27	20	22	23	26	27	28	17	19	20	21	23	24	26
	50	20	24	26	27	30	32	33	20	22	24	25	28	29	30
	25	23	27	30	31	35	36	38	23	25	27	29	32	33	35
	10	26	31	34	35	39	40	43	26	28	31	32	35	37	39

Control Systems

Administrative and engineering controls are two strategies used for controlling and preventing work-related musculoskeletal disorders (WRMSDs) in the workplace. Administrative control focuses on personnel solutions, while engineering deals with the job or work place. Before beginning any changes, support from key personnel is necessary. The involved personnel should include upper management, engineers, safety, personnel staff who implement the changes, and the workers. During the process, justification for the proposed plan is required to gain approval from upper management. After getting approval, developing a plan to engage the support of others in the firm is important (Putz-Anderson, 1988). Administrative and engineering control systems will be discussed in more detail in the following sections.

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[10] From "www.rehab.queensu.ca/mclean/snooktables.pdf." Retrieved April 20, 2004.

Administrative Control of Hazards

Administrative controls are actions performed by management and medical staff to reduce potential harmful stress that can affect the workers. The control actions focus on the workers and can be achieved by modifying existing personnel functions through job matching, worker training, and job rotation (Putz-Anderson, 1988). Methods of selecting workers to fit specific jobs would include performing screening tests, assigning jobs, or bidding-for-jobs. Screening potential employees though the use of wrist X-rays and physical tests is one method that can be used. It is imperative that screening tests are relevant to the job otherwise the company can run into legal issues. Another technique is assigning jobs to employees according to their physical build-up. For example, place a tall worker to work on areas above the machine and assign a shorter worker on a lower bench. The last method, bidding for jobs, allows workers to sign-up for an available job. The job is awarded to the worker with the highest seniority (Putz-Anderson, 1988). Selecting the right person for the job is a critical step in reducing injuries, but it is likely that the process must be performed with care to avoid discrimination and legal issues.

Training Workers To Work Safely

Workers are often trained in business and industry to work efficiently in a safe and healthful manner. The goals of the training are to reduce the number of awkward postures, mechanical forces, and repetitive motion patterns that may exist for given processes. When training employees, an important factor to keep in mind is that the workers may not be able to perform the recommended practices because they have habits of working in certain ways, production requirements pressure them to take short cuts, or the new method is time consuming or difficult (Putz-Anderson, 1988). Before starting a training course, the following need to be accomplished: pin-point training requirements; set reasonable training objectives; find the best strategy to reach the objectives; develop a program; perform the training; and evaluate the training to determine if objectives are being met and how the program can be improved (Bird & Germain, 1985). To identify accurate objectives, the job should be analyzed by watching a video of the work practices. After determining the problem, the trainer should perform the job himself/herself. When the trainer teaches, he/she needs to tell and demonstrate the practices. Visual aids allow trainees to internalize and practice the new skills on the job. Before teaching a course that requires a specific work behavior, the trainer should assure there are no work pressures to meet a production quota and the behavior is supported by the environment (Putz-Anderson, 1988). In summary, when instructing employees to work safely it is critical to identify the teaching requirements, set objectives, develop and perform trainings to reach the goals, and evaluate the program.

There appears to be a belief that behavioral change provides awareness, which makes training seem to be the best option, but the success in reducing cumulative trauma disorders (CTDs) is mixed. Also, some may think that training costs less than ergonomic interventions, but experience has shown that the on-going training of new and existing employees may be more expensive than changing the job or tools, which is mostly likely to be a one time cost (Putz-Anderson, 1988). Training may not be considered the best practice to reduce musculoskeletal disorders (MSDs), but it is still a good strategy to use. It therefore seems apparent that every employee in the workplace needs to be trained on how to perform his/her job safely.

Job Rotation of Employees

Work rotation allows workers to experience a variety of jobs. The purpose of work rotation is used as a control to reduce physical fatigue and stress by systemically alternating job demands. The practice attempts to reduce the employees' exposure to an awkward posture, stressful forces, and highly repetitive activities by limiting the time a worker spends at a particular task. Job rotation is most often used with other techniques such as employing enclosures, containment, personal protective equipment, or lifting devices. The technique is a loss reduction method because the worker has already been exposed to harmful hazards or is expect to be exposed (Head, 1995). Job rotation is a complicated method because the acceptable level of exposure to a cumulative trauma disorder (CTD) risk factor is not documented. The potential of injury can be increased because the employee may lack experience in the rotated job. In addition, work rotation may violate certain employment agreements between the employee and employer, or the worker may dislike the process. Some supervisors may have issues regarding production levels because the rotated employee may not have the skills to produce as much as the experienced person. Before implementing a job rotation system, gaining supervisors' cooperation is essential. If a worker is assigned to a different job that poses the same physical demands as the previous one, the goal of job rotation has failed (Putz-Anderson, 1988). The success of a job rotation requires cooperation from the employees and supervisors as well as careful analysis of the job to avoid placing a worker in jobs that required the same physical demands.

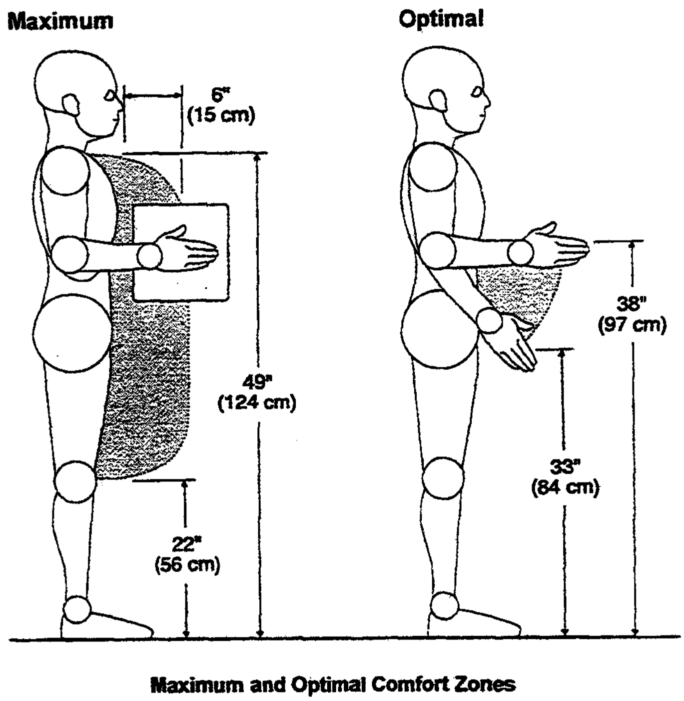
Engineering Control of Hazards

Administrative procedure should only be considered as a temporary hazard control measure until a more permanent solution, from an engineering standpoint, is implemented. Engineering controls alleviate potential risks from the workplace by altering the work environment or production processes (WHSCC, 2004). The process of redesigning tools, workstations, and jobs to fit the workers can alleviate physical stresses such as high force, repetition, and awkward postures. By improving the fit between the workers and their job/tools, a company can reduce injuries as well as increase productivity. With any job redesign, there are numerous obstacles with which to overcome. Implementing an ergonomic solution normally involves numerous overlapping of problems including high production demands, faulty workstation layout, and ill-fitting tools. Also, effective ergonomic designs may have to be customized to each location, thus making the changes costly. In addition, the side-effects may outweigh the proposed benefits. To avoid severe adverse effects, ergonomic solutions should be implemented with caution. One should perform a thorough job analysis, evaluate and select the most appropriate intervention, use conservative treatments, monitor the progress, and then continue to adjust the scope of the intervention (Putz-Anderson, 1988). When altering the workplace to eliminate potential risks, various designing principles should be considered to reduce high costs and increase the benefits of the intervention.

Designing Principles Based On Ergonomics

The objectives to control cumulative trauma disorders (CTDs) include reduction of extreme joint movement, excessive force levels, and highly repetitive movements. Reduction of extreme joint movement can be achieved by keeping performed motions within the joint range. Ideally, work activities should be performed within the joints at about the midpoint of range of movement. A worker operates more efficiently in the area directly in front of the torso called the comfort zone as displayed in Figure 6. The comfort zone extends from the knee to the shoulder in front of the body and no more than 20 degrees to the side of the body. However, the optimal comfort zone is located a few inches below and above the elbow, within six inches and directly in-front of the body (Smagacz, 2004). Consequently, it appears that extreme joint movement can be controlled by keeping the work within the comfort zone, from the knee to the shoulder.

Figure 6: Maximum and Optimal Comfort Zones[11]



In addition to reducing extreme joint movement, another important factor is to lessen excessive force. Prolong muscle contractions to maintain a posture can lead to cumulative trauma disorders (CTDs). A worker should not exert more than 30% of his or her maximum force for a specific job in a prolonged or repetitive manner. Also, muscular contractions in excess of 50% of the maximum should be avoided. Job forces can be controlled by reducing the strength required, spreading the energy, and using stronger muscle groups and tools with longer handles (Putz-Anderson, 1988). Given that force is another risk factor that contributes to the occurrence of CTDs, it also can be minimized by using better and sharper tools or assisting devices.

[11] From "Better, Faster and Cheaper Ergonomics," by Jeffrey Smagacz, 2004. Copyright, 2004 by Humantech. Reprinted with permission.

Controlling joint movement and force is a good beginning point, but repetition also needs to be reduced. In general, a job should be considered to pose a risk for developing CTDs if the cycle time is less than 30 seconds, with a fundamental cycle greater than 50% of the total cycle time. A fundamental cycle is a task cycle that has a sequence of steps, which repeat themselves within the cycle. A reduction of highly repetitive movements can be achieved through task enlargement, mechanization, or automation. Task enlargement allows the worker to have larger and different tasks to perform. Mechanization includes usage of special tools with ratchet devices or power drivers to decrease repetition. Automation is the use of machines to perform repetitive tasks (Putz-Anderson, 1988). It is likely that repetitive motion can cause as much injuries as force and joint movement, but it can be controlled through task enlargement, mechanization, or automation.

Design of Workstations, Work Methods, and Tool Handles

It would seem favorable that employees be allowed to customize their work area to enhance efficiency and reduce some pain or discomfort. However, customized work space would be difficult to accomplish if various workers share a workstation and as such, a guideline based on ergonomic principles for laying out a workstation to minimize the stress from repetitive and static work should be utilized. Data for workstation design can come from anthropometric tables, fitting trials, and fatigue measurements. Anthropometric tables provide a list of human body sizes and proportions of the adult population, which can be very helpful at the drawing stage of a workstation design (Putz-Anderson, 1988). In addition, employees should use the correct methods to perform their jobs. Jobs should be analyzed to identify long static contractions and frequent repetition. The elements of the sequence should be re-arranged to reduce repetition or break up static contraction. Moreover, tasks could be recombined to enlarge the job and thus reduce repetition. Studies showed that job design allows the workers to feel more in control and responsible to finish their job. Due to the nature of the job and the cost and difficulty of redesigning the job, the task may be automated or semi-automated to reduce highly repetitive operations. Machines can perform high-risk jobs or a portion of the tasks with the operator to finish the remaining tasks (Putz-Anderson, 1988). A well designed workstation will most likely reduce injuries and can be achieved by using anthropometric tables, fitting trials, and measuring fatigues.

When redesigning workstations or work methods for manual material handling tasks, the activities should be within the employees' capabilities. The redesign would be attained by reducing physical force required to move the object, minimizing or eliminating reaching and lifting, and allowing more time to complete the job (Head, 1995). Devices such as a vacuum lift, lifting table, and conveyor can be installed to alleviate lifting and reaching. Allowing employees to self-pace their work provides them with more control over the work methods. New employees should start at a slower rate than existing employees and be allowed to warm up a few hours prior to assuming full-work capacity. In addition, an injured employee who returns to work should be given a few weeks to get themselves back to the full work routine (Putz-Anderson, 1988). Breaks should be scheduled to allow frequent rest and consequently provide relief for the most active muscles. In addition, effective tools are important to promote productivity as well as reducing the risk of cumulative trauma disorders (CTDs). The right tools are judged on effectiveness, balance, weight, shape, and handle. Tools and handle designs to prevent CTDs should be based on four fundamentals; avoidance of high contact forces and static loading, extreme or awkward joint positions, repetitious finger actions, and tool vibration (Putz-

Anderson, 1988). In addition to the above methodology, it is probable that work methods such as warm-ups as well as adequate breaks can minimize the risk factors that contribute to CTDs.

Past Case Studies

Many case studies have focused on musculoskeletal disorders (MSDs) and evaluate the effectiveness of the tools used. Marras and other researchers found that compression and shear forces are significantly affected by the weight of the boxes and position on the pallet. Spine loading increases about 15% per box weight increase of 4.5 kg, leading to the risk of lower back disorders. The researchers found significant increase of spine compression in the front-bottom and back-bottom areas of the pallet. While proper handles on the boxes reduced the compression forces on the spinal area, lifting boxes from the bottom layer of the pallet generated more risk to the lower back than lifting from the middle and upper pallet layers (Marras, Granata, Davis, Allread, Jorgensen, 1999). The research confirms that the weight of boxes, a lack of box handles, and the lifting location of the boxes can adversely affect the lower back. However, other studies show that load knowledge can also reduce the risk of injuries. Commissaris and Toussaint's (1997) research indicated that lack of load knowledge can lead to loss of balance when load mass was overestimated. Expected load mass determines the peak of low-back loading rather than actual mass. Load knowledge is important for workers to prepare themselves to avoid loss of balance, which may result in a fall leading to back injuries (Commissaris & Toussaint, 1997). According to the above information, risk factors could be controlled through mental (knowledge of the load) or physical (lighter boxes).

Since weight and position of objects can increase the risk of MSDs, other researchers have focused their studies on the effectiveness of interventions. Marras and other researchers studied the effectiveness and efficiency of lift tables, lift aids, and workstation designs. They found the use of lift tables and lift aids significantly reduced incident rates. Lift tables brought the loads upward and closer to the employee, and reduced the mean incidence rate by 7.42 low back disorders per 100 full-time employees. Lift aids sustained the weight of the load itself and reduced the mean low back disorder incidence rate by over 6 injuries per 100 full-time employees. Other job interventions (workstation redesign and installed equipment) did not provide significant improvements in the incidence rate. However, it should be noted that the companies implemented the changes themselves without full analysis of the tasks performed. Employee job satisfaction with the lift aids was significant, but not for other interventions (Marras, Allread, Burr, Fathallah, 2000). The results of this research show that lift tables and aids reduce injuries, but workstation design did not provide a significant improvement. However, the proper design for a workstation is questionable because the companies did not performed job analysis.

In addition to the back, researchers have been studying upper extremities to identify the causes of musculoskeletal disorders (MSDs). Amell and other researchers found that the upper extremities produce the most energy when the hands are in front of and closest to the body; therefore, trunk rotation reduced lifting capacity because the hands are on the side of the body. When the trunk axially rotated, risk of injury may be transferred to the lower back as loads are lifted (Amell, Kumar, Narayan, Coury, Gil, 2000). The results of this research indicate the importance of proper work station design to minimize trunk rotation, and consequently reduce MSDs. In addition, Hoozeman and other researchers (1998) found that features of pushing and pulling activities influence the exerted forces and are likely to impact the employee's health. Pushing is preferred over pulling because pushing provides maximum acceptable forces compare to pulling (Hoozemans, Van Deer Beek, Frings Dresent, Duk, Van Der Woude, 1998).

According to these case studies, it appears that improper practices, tools, or workstation designs can increase the risk of developing MSDs.

Summary

In summary, when abating risk factors that contribute to musculoskeletal disorders, both employees and management need to understand potential injuries and the development of each. The next step is to explain the loss trends to show management how the costs increase and teach employees that they can get hurt too. Before any programs can be developed to control the risk factors, both management and employees need to become involved in the processes. Management needs to provide leadership and show its commitment and promote employees to volunteer to research the root causes, be willing to work safely, and follow the new standards. After everyone agrees to cooperate, the researchers can use the risk management process to identify the problems, analyze injuries to determine the root causes then control the hazards through administrative or engineering processes. Administrative control includes developing standards and procedures, job matching, employee training, and job rotation. Engineering control focuses on reducing the hazard by physically altering the workplace or processes. These actions include redesign of tools, workstations, and job processes to fit the job to the worker to reduce physical stresses.

CHAPTER III: METHODOLOGY

The objective of this chapter is to provide the reader a review of the purpose of this research, a description of how the subjects were selected, instrumentations used, data collection procedure, and how the data was analyzed.

Purpose and Goals

The purpose of the research was to identify the degree that substandard practices/conditions could contribute to employee injury during the unloading of parts/materials at the XYZ loading docks. Current practices of handling parts and materials at the loading docks of XYZ, Inc. are placing associated employees at risk of developing back-related injuries and WRMSDs. There have been two back injuries that required hospitalization and various complaints of discomforts. The goals of this study include reviewing existing loss records, administering symptom surveys, performing an analysis of procedures/practices, and analyzing the engineering aspects of the loading dock area.

Review of Literature

Relevant ergonomics literature was reviewed to obtain information regarding manual material handling. General knowledge of current loss trends in ergonomic identification, analysis, and control strategies were also reviewed. This information provided the adequate steps to identify the problems and providing practical solutions.

Subject Selection and Description

The researcher hosted a meeting with four regular full-time employees (100% of the population) who rotated to work at the loading dock on a monthly basis. These workers were between the ages of 40-55, weight between 115-250 pounds, and the average duration of employment is 30 years. At this meeting, the investigator explained the purpose, objectives of this research, and methods used to collect the data. In addition, the researcher explained the content of the consent form and subsequently asked if they would like to participate in the study. After they signed the consent forms, all volunteered participants filled out the symptoms survey. Two subjects were studied in depth while they performed their normal job at the loading dock.

Instrumentation

The instruments required to perform this research included a Super-8 video recorder, which was placed on a tri-pod and positioned at a 90° angle of the worker lifting, carrying, opening, and palletizing the boxes. The viewing angle at the video recorder captured the employee's full range of motion while performing the job. Other instrumentation required for this study included a jog-shuttle VCR for frame-by-frame view, T.V., water-based felt tip marker to assist on the analysis, and a manual goniometer to measure the angles of the joints at different postures. In addition, the distances the workers carried the boxes were measured using a 30' tape measure. A force gauge was used to measure the forces required to push or pull the boxes.

Data Collection Procedures

The medical, OSHA Log 300, and workers compensation records were reviewed for past injuries and claims. Medical records provided the type and severity of illness or injuries. OSHA Log 300 identified the types of incidents that related to ergonomic losses. Workers compensation records assisted in determining the costs associated with claims involving cumulative trauma disorders. Furthermore, the researcher reviewed policies/procedures as well as training records applicable to the receiving docks. Symptoms surveys were administered to the subjects to indicate their pains or discomforts. During this survey period, the subjects' age, height, weight, gender, duration of employment was recorded. The researcher video-taped two workers at two different time periods because only one person was scheduled to perform the duties at the receiving docks, and the goal was to analysis two workers' work practices. The workers were video-taped during their regular work activities at the receiving docks. Various data was collected on-site to complete the NIOSH Lifting Equation. This included the weights of the boxes from their shipping labels and dimensions of packages. Measurements of the horizontal, vertical, and distance multipliers were made using a tape measure, and the asymmetric value was estimated using a manual goniometer. The handle of the boxes was rated according to NIOSH Lifting Equation criteria and the lift per minute was timed during the data analysis from the video recorded. During the pushing and pulling of a cart full with boxes, a force gauge was used to measure the force required to move the cart. Data was collected from two employees, so work practices could be compared between the two.

Data Analysis

Data analysis was completed using various steps. The researcher began this procedure by reviewing the symptoms survey. These surveys identified the location of the pains or discomforts and level of stress experienced by the employees. The survey result was compared to the data of the review of records to determine if they were consistent with the records. The main areas of focus were the low back, wrists, shoulders, and elbows.

The next step was to use NIOSH Lifting Equation to calculate the Recommended Weight Limit (RWL) using the data collected on-site and NIOSH criteria. Moreover, the RWL was incorporated in the Lifting Index (LI) formula to calculate the LI. The LI was eventually used to determine the severity of the risk factors contributing to the onset of WRMSD's.

The third step was to complete a RULA Survey by using the jog shuttle VCR, goniometer, water-based marker, and TV. The jog shuttle VCR allowed the researcher to view the activities frame-by-frame. The researcher used the marker to draw lines on the television screen and assist in using a goniometer to measure the body posture and angles of the joints. During this analysis, the researcher focused on wrists/hands deviations, arm flexions/extensions, shoulder abduction/adduction, trunk twisting, bending, and feet support and location. Specific observations were made during lifting of boxes, opening of boxes, placing materials/parts on the pallet or in the box because these instances had more severe postures and joint angles.

The last step was to use the data from the force gauge to compare to standardized data to determine if the force was within a safe range.

Limitations of the Study

The video analysis is more of a qualitative technique. It would be more effective to use a combination of qualitative and quantitative (Lumbar Motion Detection) methods to compliment each other.

CHAPTER IV: RESULTS

Introduction

The purpose of this research was to evaluate the degree that substandard practices/conditions were present during the unloading of parts/materials at XYZ's receiving docks. The goals of the study were to review existing records, administer symptom surveys, analyze procedures and practices, and study the engineering aspect of the receiving dock area to determine the presence (MSDs) and contribution of the control systems to the occurrence of musculoskeletal disorders. To accomplish the above goals, the researcher reviewed relevant literature before determining the proper methodology to collect the data. Before beginning the data collection process, the researcher gave consent forms to the volunteer participants to obtain their permission to gather the information. After obtain the subjects' permission, the researcher reviewed OSHA log, medical records, workers' compensation cost, training records, as well as policies/procedures. Following that, the researcher administered symptom surveys to 100% of the work population. Fifty percent of the work population was selected to be videotaped and participate in further analysis. One of the instruments used to collect the data was a Super-8 video recorder to tape the workers, so the researcher could analyze the employee's work practices and engineering of the receiving docks. The researcher used a jog-shuttle VCR to view the video tape and analyze the workers' postures via a Rapid Upper Limb Assessment worksheet. In addition, a force gauge was used to measure the force required to move a cart. The weights of the boxes were collected on-site to complete the NIOSH Lifting Equation.

This chapter will provide the results from the data collection and examination process summarized in Chapter III. The researcher will begin by providing a description of the materials the employees handled manually, demographic information regarding the subjects in this study, results from the symptom surveys, and conclude with a discussion of the video analysis. All of the information will be used to determine the extent that employees at company XYZ are being exposed to WMSDs risk factors.

Process and Material Description

UPS and other carriers deliver packages to company XYZ's receiving docks. This study only focuses on packages delivered by UPS because this carrier delivered the most and the heaviest parcels. UPS delivers between one hundred to one hundred thirty boxes per day, and during this study, the average number of boxes delivered was 101. The packages were unloaded from UPS's truck onto a cart and then one of company XYZ's employee manually segregated them onto pallets (see Figure 7). As indicated in Figure 8, these packages weighed between one to one hundred fifty pounds and were shipped in bags or cardboard boxes. Some parcels were sturdy but others were torn, making them difficult to handle. Clearly labeled packages or returned parts did not require the worker to open them, but he/she needed to check the shipping list to ensure they were in the proper location. Unlabelled packages required an employee to check the shipping list against the materials received, sort the items inside, and then placed them on pallets to be shipped to different departments. The boxes on each pallet were stacked up as high as 38 inches and they were wrapped with a sheet of plastic to prevent them from falling. In addition, the worker located the department on a computer, printed a ticket, and posted the tickets on the wrapped boxes to identify their destinations.

Figure 7. UPS Unloaded Packages from Truck and Employee Segregated Boxes

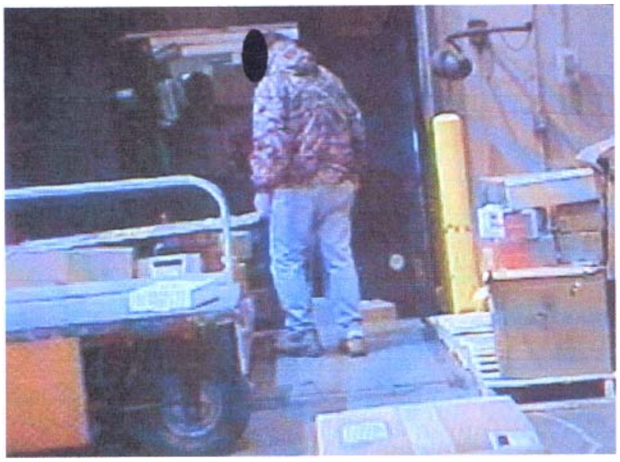
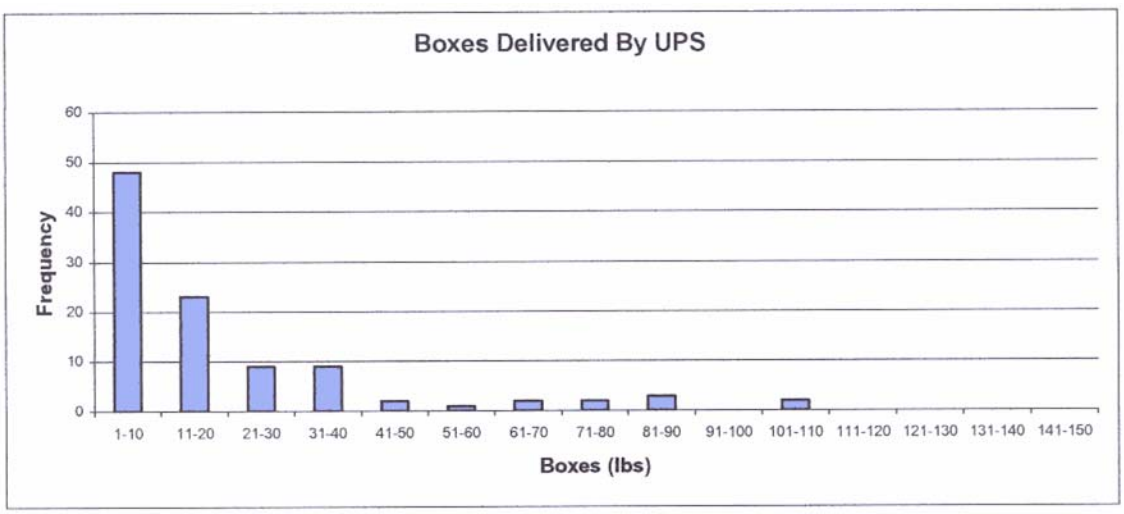


Figure 8. Boxes Delivered by UPS



Demographic Information

Only one employee worked at company XYZ's receiving docks, but five workers rotated monthly in and out of this location. All workers agreed to participate in this study, but only four participants completed the symptoms survey and two were further analyzed. Of the five, three (60%) were female and the remaining two (40%) were male. Three of the employees had been working at company XYZ for more than 26 years, while the remaining did not provide information regarding to the duration of their employment. These employees were all above 5 feet and 4 inches tall and the ages ranged between forty to sixty years. The results of the symptoms survey these employees completed are discussed in the next section.

Record Review and Symptom Surveys Analysis

One of the objectives of this research was to review medical and workers compensation records, OSHA Log 300, and symptom surveys to identify if employees are already experiencing musculoskeletal disorders. The company did not have any medical records, but an examination of the OSHA Log 300 showed two back injuries in 2002 and 2003. However, it is important to realize the employees rotate to other work areas, so the injuries may be classified under another department. An assessment of the workers compensation indicated the two back injuries resulted in lost and restricted workdays. One injury required hospitalization that cost the company $26,625, including administration fees for a lost time claim service. This person lost 49 workdays and had 39 restricted days. The second injury is still open but the accrued cost is $3,951 at the time of the research. This worker has lost 9 workdays and had 21 restricted days. Review of the symptoms survey indicated that all participants experienced some type of discomfort. The specific areas of concern include the lower back, elbow/forearm, and shoulder problems as indicated in Table 6. All participants experienced distress in the lower back and twenty-five percent of these employees also felt elbow/forearm and shoulder pains. On average, these episodes lasted about 54 days. Twenty-five percent of this workforce had ten lost and thirty restricted workdays. Most of the employees have attributed their discomfort from the repetitive lifting of heavy packages at the receiving docks. They all believe lifting/loading devices would reduce these ergonomic issues.

Table 6: Results of Ergonomic Symptom Surveys

Questions	Answers
Body Part	100% low back, 25% elbow/forearm, 25% shoulder
Problem	100% aching/stiffness, 50% pain/weaknesses
Duration of episode	54 days (average)
# of episodes this past year	3 (average)
Caused of problem	Lifting objects in the wrong way or heavy materials
Problem rating	50% bearable, 50% unbearable
Medical treatment	50% seek treatments, 50% did not seek treatments
Why no medical treatment?	Can still work or hope it go away
Lost workdays	25% worker 10 lost workdays
Restricted workdays	25% worker 30 lost workdays
How to improve	Lifting/loading aids

The signs and locations of discomfort the workers indicated in the symptoms survey are similar to the work-related musculoskeletal disorders (WMSDs) that the researcher discussed in Chapter II. All workers at the receiving docks claimed they experienced aching and stiffness. Of these employees, 50% felt unbearable pain and weaknesses in the lower back while the remaining suffered bearable pain. The employees whose pains were tolerable did not seek medical treatment with the hope that they will go away. Evidence from the symptom surveys disclosed that the activities at the receiving docks are exposing the workers to potential risk factors that may lead to the onset of WMSDs. In the next section, the investigator will assess the results of the ergonomic analysis to better identify the root causes of the distress.

Analysis of Control Systems

In conjunction with the symptoms survey and review of records, the researcher will use results from the review of the department's internal standards and ergonomic methodologies to better identify the extent of the problems that exist at company XYZ's receiving docks.

Analysis of Administrative Control

The second goal of this study was to perform an analysis of procedures/practices to identify if such could contribute to an employee injury. A review of the policies/procedures for the Receiving Department indicated there was no internal safety standard, and no ongoing training; only trained new employees to the skills needed to perform the job. Safety training consisted mostly of videos a couple times per year for the whole warehouse, but did not provide specialized training for each department. In addition to the standard, an observation of work practices indicated some of the employees lifted boxes that were over 70 pounds, while others rolled and pushed the heavier boxes.

Analysis of Engineering Controls

The last activity was to analyze the engineering aspects of the loading dock area to identify deficiencies in tools and to determine if workstation design could contribute to the occurrence of musculoskeletal disorders. During the analysis of the engineering aspects, the researcher was not able to locate lifting devices, conveyors, or other equipment to assist the workers in lifting the heavier boxes. However, the employees did have a cart to transport the parcels from the receiving docks to the sorting location. The empty cart weighed 146 pounds, but the loaded cart weighed on an average of 531 pounds. The force required to move the empty cart was 8 pounds but to move the loaded cart required an average of 17 pounds. Furthermore, the workers lifted boxes from the floor or a cart at 5 inches from the floor and manually carried these packages to their destinations.

Methodology and Instrumentation Analysis

The data extracted from the National Institute Of Safety and Health (NIOSH) Lifting Equation and Rapid Upper Limb Assessment (R.U.L.A.) will help the researcher determine the severity and amount of intervention required to alleviate the risk factors that lead to the onset of WMSDs.

NIOSH Lifting Equation

The NIOSH Lifting Equation is a technique the researcher used in this investigation to determine the extent that these employees are being exposed to work-related musculoskeletal disorder (WMSD) risk factors. As mentioned in Chapter II, the NIOSH Lifting Equation is comprised of two parts, the Recommend Weight Limit (RWL) and Lifting Index (LI). The first component RWL is expressed as: RWL=LC*HM*VM*DM*AM*FM*CM. During the on-site visit, the measurements required for this calculation were collected as discussed in Chapter III and are documented in Table 7.

Table 7: NIOSH Lifting Equation Components

Components	**Measurements**	**Calculations**
Load Constant (LC)	51 lb	51 lb
Horizontal Multiplier (HM)	H=16"	0.63
Vertical Multiplier (VM)	V=11.75"	0.86
Distance Multiplier (DM)	D=6.75"	1.09
Asymmetric Multiplier (AM)	A=45 degrees	0.86
Frequency Multiplier (FM)	Less than 1 hour	0.70
*Coupling Multiplier (CM)	Poor	0.90

*Since the boxes had no handles or were ripped, the employees had to use a pinch or press style grip.

The RWL was calculated using the equation and numbers in Table 7:

RWL = 51*0.63*0.86*1.09*0.86*0.70*0.90

RWL = 16.32 pounds

As elucidated in Chapter II, the RWL for a particular set of task conditions is the weight of the load that most healthy workers could lift over a period of time without increasing the risk of developing lift-related lower back pain, and is required to complete the LI equation. The researcher can utilize the LI to estimate the relative degree of physical stress for a lifting assignment. As the LI score increases, the fraction of employees who are capable of sustaining that particular level of physical exertion decreases. A LI score of one or greater signifies a need for immediate intervention because the lifting task has an increasing potential for WMSDs, particularly lower back injuries.

To calculate the LI score, the researcher used the formula: LI = Load Weight (L) / RWL. The weight (102 pounds) of the load was measured during the data collection process and the RWL (16.32 pounds) was calculated in the previous section. Below is the calculation of the LI score: LI = 102 pounds / 16.32 pounds; LI = 6.25. The Lifting Index for the receiving docks is 6.25, which indicates there is immediate need to intervene with the workstation design and practices. This result is consistent with the symptom surveys and record reviews, but to verify the accuracy of this calculation the researcher will complete the R.U.L.A. methodology and determine the maximum acceptable force.

Rapid Upper Limb Assessment

The Rapid Upper Limb Assessment worksheet is a method used to examine the stress that workplace practices can place on the upper extremities, trunk, and legs. This worksheet is used to capture the angles of the upper extremities as an employee placed the package on a pallet. The following section will explain the results step-by-step and the overall score.

R.U.L.A. is divided into groups A and B, and the grand score table. The result for each section is presented in Table 8.

Table 8. R.U.L.A. Score Sheet

Group A: Arm & Wrist Analysis	**Score**
Step 1: Locate Upper Arm Position	3
Step 2: Locate Lower Arm Position	2
Step 3: Locate Wrist Position	2
Step 4: Wrist Twist	1
Step 5: Posture Score A	*4*
Step 6: Add Muscle Use Score	*1*
Step 7: Add Force/load Score	*3*
Step 8: Final Wrist & Arm Score	**8**

Group B: Neck, Trunk & Leg Analysis	**Score**
Step 9: Locate Neck Position	1
Step 10: Locate Trunk Position	4
Step 11: Legs	1
Step 12: Posture B Score	*5*
Step 13: Add Muscle Use Score	*4*
Step 14: Add Force/Load Score	*3*
Step 15: Final Neck, Trunk & Leg Score	**12**

Grand Score Table

	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	**7**

Final Neck, Trunk & Leg Score = 12

Final Wrist & Arm Score = 8

Grand Score = 7

Group A of the R.U.L.A worksheet analyzes the postures of the arms and wrists. The angle measured for each of the steps was attained according to the participant's postures on the television screen. Steps one and two discovered the upper and lower arm's degrees of extensions, while steps four and five determined the wrist flexion and wrist twist. The scores from steps one through four were utilized to yield a posture score of four from R.U.L.A's table A. The muscle and force load numbers were added to the posture A score to give a final wrist and arm score of 8 as indicated in Table 8. This number (8) is inputted into the grand score table to find the grand score.

Group B of the R.U.L.A worksheet examines the positions of the neck, trunk, and legs. As indicated in Table 8, steps nine, ten, and eleven measured the degrees of neck extension, trunk twisting and bending, and leg supports, which resulted in a posture B score of five. Muscle use and force/load scored were added to the five, which resulted in a final neck, trunk, and leg score of twelve. The number twelve is incorporated into the grand score table to identify a final overall score of seven. According to McAtamney and Corlett (1993), a score of seven suggests further investigation and immediate intervention at the workplace. The results are significant because seven is the highest score allotted for this assessment.

Force Gauge Instrumentation

In addition, the NIOSH Lifting Equation and R.U.L.A methodologies, the researcher used a force gauge to determine the contribution of force to work-related musculoskeletal disorders. The force gauge was used to measure the force required to move the cart and a tape measure was used to determine other components needed for the calculation. The data is documented in Table 8.

Table 9. Measurements Associated With Force Calculation

Components	**On-site Measurement**
Weight of loaded cart	244.49 kg
Force required to move loaded cart	7.94 kg
Vertical distance from floor to hand	109 cm
Pull distance	1.82 m
Frequency of pull/hour	1
Preferred industrial population	90%

The measurements in Table 9 were used to identify the maximum acceptable forces of pull from Table 5 in Chapter 2. The pull distance of 1.82 m is closest to 2.1m, 109 cm is between 89 cm and 135 cm, and the targeted industrial population is 90%; therefore, the maximum acceptable force of pull is determined to be 22 kilograms. This result will be discussed in the following section.

Discussion

Currently, company XYZ is utilizing a job rotation system, which is an administrative control that was explained in Chapter 2. The workers who performed this job task alternated in and out of this position on a monthly basis. Consequently, the employees involved in this rotation worked at the receiving docks eight hours a day, five days a week. Although the company has such an administrative control in place, the technique is insufficient to protect the employees from feeling distress in the lower back, elbow/forearm, and shoulder, as indicated by the symptom surveys. Furthermore, a review of standards and practices indicated that company XYZ did not have any written safety policies and provide trainings specific to the receiving docks. The lack of standards and trainings could play a roll in the employees' experience of distress. The information from the symptom surveys guided the researcher in quantifying the results of the Rapid Upper Limb Assessment (R.U.L.A.) and National Institute of Safety and Health (NIOSH) Lifting Equation, which are explained in the next section.

The outcome of the R.U.L.A. and NIOSH Lifting Equation coincide with the complaints reported on the symptom surveys as well as results from the review of workers compensation records and internal standards and practices. The R.U.L.A. presents an overall score of 7, which is the highest number allotted for the assessment. This result indicated the need for further investigation and immediate intervention at the receiving docks. Furthermore, the Recommended Weight Limit for the lifting task at the receiving dock was 16.32 pounds, but the operators sometimes had to lift packages that were as heavy as 150 pounds. The Lifting Index of the NIOSH Lifting Equation was 6.25, which suggests the need to immediately change the workplace design and work practices to prevent further back injuries. The workers at the receiving docks suffered discomfort repeatedly from repetitive lifting of heavy packages and awkward bending throughout the segregating process. However, results from the force gauge measurement do not show the need for immediate intervention. The measured force required for the initial movement of the loaded cart was 7.9 kilograms (kg), which is less than the intervention benchmark of 22 kg. This data is irrelevant for the pulling action because the employee used an assisting device (i.e. a cart that had wheels on), rather than pulling cardboard boxes alone. The conclusion of this research will be discussed in Chapter V.

CHAPTER V: CONCLUSIONS AND RECOMMENDATIONS

Introduction

In this chapter, the researcher will discuss the results presented in Chapter 4 and relate the conclusions made. In addition, this chapter will supply recommendations and conclude with errors the researcher recognized during this research.

Purpose Statement and Goals

The purpose of this research was to evaluate the degree that substandard practices/conditions are present during the unloading of parts and/or materials at XYZ's receiving docks. One of the goals for this study was to review medical and workers compensation records, OSHA Log 300, and administer symptom surveys to identify the level of work-related musculoskeletal disorders (WMSDs) that the employees are experiencing. The second goal was to perform an analysis of procedures/practices and engineering aspects of the receiving dock area to identify if they contribute to the occurrence of musculoskeletal disorders.

Conclusions

The combined results from the R.U.L.A., NIOSH Lifting Equation, symptom surveys, and review of records, standards and practices, and engineering aspects reveal that employees working at the receiving docks are exposed to risk factors that could lead to the onset of work-related musculoskeletal disorders.

- The grand score (7) for R.U.L.A. was as high as the method would allow. For example, a final score of 1- 2 is acceptable, 3-4 means further study more, 5-6 indicates the need for further investigation and to change soon, and 7 signifies further examination and change immediately.

- The actual weight of a package the employee had to lift was 102 pounds, which was 6.25 times greater than the recommended weight limit.
- Symptom surveys reported that all participants experience some type of back pain and 25% of the subjects suffered from elbow or forearm and shoulder discomfort.
- A review of records indicated that two workers already suffered back injuries that cost the company a total of $30,576.
- There are no safety policies and training records specific to the receiving docks, and lift aids to assist the employees with lifting.
- The lifting origin is from the floor or a cart (5 inches above the floor); therefore, employees had to bend down to pick-up the boxes.

These results are a clear indication for the need to intervene immediately. As discussed in Chapter 4, the result from the force gauge is irrelevant because it is not consistent with other outcomes and the workers already used an assisting device. The researcher has concluded the best way to alleviate these risk factors would be to utilize some type of engineering controls. The current workplace is inadequately designed, compared to the engineering control discussed in Chapter 2. Consequently, the best practice to eliminate repetitive lifting of heavy packages is to engineer the risk factors out of the receiving docks. The researcher will present some feasible controls to reduce or remove the risk factors that may lead to the employee's discomfort in the next section.

Recommendations

The first recommendation from the researcher is to provide assisting devices and/or redesign the workstation in the following ways:

- Provide a portable and adjustable conveyor with rolling balls, at the end of the conveyor, to help with loading and carrying. The benefit of using a conveyor is that the employees will not have to manually carry the packages from the dock to the sorting location.
- To reduce the lifting risk factor, utilize an overhead lifting device such as Scmalz's JUMBOERGO (see Figure 7), to assist in transporting heavy parcels from a conveyor onto the pallets.
- The current pallet jack could be used to bring the pallets up to the height of the conveyor to prevent the employees from having to bend forward and/or down when stacking the packages.
- Provide a large basket that has a spring to allow the bottom to rise up when there is no load, or lower when the load is heavy. This piece of equipment is another tool to prevent bending and awkward stretching.
- If employees have to lift from the cart, it should be jacked up with a lifting device to the comfort zone indicated in Chapter 2.

Figure 8. Scmalz's JUMBOERGO For Handling Cardboard Boxes[12]

[12]From "vistamation.com/images/Vistamation%20Vacuum%20Liftingl%20Applications.pdf," by Scmalz. Retrieved April 25, 2004.

If the above recommendation is not possible due to space limitations, cost, or employee resistance, the researcher has provided a second set of options.

- Ask top management to establish written agreements with vendors or contractors to stop sending compressors, or other heavy warranty parts via UPS to XYZ. This action should eliminate or reduce the number of heavier packages delivered to XYZ's receiving docks. In order for the agreements to be effective, management must hold the vendors accountable for their activities.
- Train employees on the use of proper lifting techniques.
- Management along with the line employees should establish internal safety standards to prevent employees from lifting packages over the recommended weight of 16.2 pounds, or what the company determines to be the appropriate weight.
- Line supervisors should be held accountable for enforcing the policies and disciplining employees for violations.

In general, the objective of employing engineering controls is to reduce or eliminate the repetitive lifting of heavy packages and bending associated with the current manual handling of boxes. The workers are currently and will continue to suffer distress in the lower back and upper extremities if the workplace design does not change. The end result of the above recommendations would be to relieve the employees from risk factors that may lead to the onset of work-related musculoskeletal disorder, which is a big problem in industries today.

Summary

Two of company XYZ's employees already experience back disorders, which resulted in a total workers compensation cost of $30,576. The symptom surveys identified musculoskeletal disorder pre-cursors that have the potential to cause more back and shoulder injuries, which may result in further financial loss. Use of the proposed engineering controls will considerably decrease the probability of losses taking place in the future. Taking into account the insurance market and the current condition of the employees, the avoidance of occupational injuries at the receiving docks may be a key factor to ensure the company's future profitability.

Opportunities to Improve Analysis Process

- Use a force gauge to measure the amount of force required to lift the packages. This quantitative result could be used to compare to the outcomes from the NIOSH Lifting Equation and R.U.L.A. to validate the consistency of the data.
- Provide a more comfortable environment for the participants who filled out the symptom surveys. This type of atmosphere would allow the subjects to feel relax, so they provide more personal and thoughtful opinions.

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