

Employee Risk Due To Ergonomic Exposure During
Adhesive Application Process

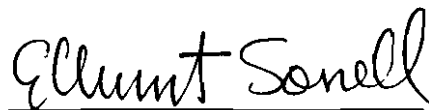
by

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ABSTRACT

The purpose of this study was to identify and assess specific areas of the adhesive application process that may increase the risk of developing musculoskeletal illnesses. Goals were developed in order to achieve the purpose of this study. Conduct quantitative surveys on employees to determine the extent of the problem. Conduct qualitative observations and survey employees to determine the extent of the problem. Analyze the adhesive application process workstation and cart design. Identify all injuries the organization has incurred within the past three years. Finally, develop a cost justification for improvements. The evaluation consisted of using several ergonomic assessments, surveys, and a workplace/cart design analysis to identify the specific body parts that are at-risk of developing injuries. The researcher identified that back injuries attribute for forty-four percent of all injuries/illnesses suffered by Company XYZ throughout the past three years. A cost justification followed to justify the reasoning for investing in changes so that Company XYZ is able to identify whether they will receive a return

on their investment. The study identified that workers' are exposed to the five risk factors: force, awkward postures, repetitive motions, mechanical stresses and vibration. The researcher identified a number of possible controls and procedure changes to improve the current adhesive application process to reduce or eliminate the risk of ergonomic injuries. The recommendations were justified and concluded that Company XYZ would receive a payback period of a year and six months by implementing the changes.

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Chapter I: Introduction

Company XYZ is a manufacturer of acoustical ceiling and wall panels for the commercial and industrial construction business. They are known for innovative customized solutions and are one of the leading design and manufacturing firms of acoustical interior ceiling and wall products. They meet the needs of various construction companies and architectural firms, custom cutting and laminating fiberglass insulation. The acoustical ceiling and wall panels are constructed in a wide variety of core materials, finishes, sizes, shapes, thicknesses and mounting options that are associated with each and every design.

The manufacturing process remains the same, although product design changes per customer's order. Computer Numerical Control (CNC) cutting equipment is first used for cutting the fiberglass board and fabric. Next, various different types of spray equipment are used to manually spray and apply adhesive to the boards, adhering the fabric to the boards. The adhesive application process requires extensive manual labor. Workers lift custom cut fiberglass boards of varying dimensions and weights off the CNC machine and stack them on carts. After loaded, workers push the carts to the next stage of the manufacturing process: the adhesive application process.

Maneuvering the carts requires the worker to manually stack the cut ceiling or wall panels on the cart platform. Then, the workers push or pull the cart to the adhesive application process area. The cart must then be aligned in front of a raising table to proceed with the manual application of adhesive. All of these procedures are physically demanding, causing significant flexing and extending of the shoulders and lower back. Moving the carts involves many variables consisting of different dimensions, weights and sizes of the fiberglass boards. The variables are associated with risk factors of extreme forces, awkward postures, repetitive motions, mechanical

stresses and vibration. The researcher will be analyzing the transportation of the carts between the CNC and adhesive application process. The variables and risk factors involved within the manufacturing process have a considerable potential of contributing to musculoskeletal illnesses.

Musculoskeletal illnesses are developed gradually over time through the implication of ergonomic stresses to the body. Ergonomics, also known as human engineering or human factors, is the study of workplace design and the physical and psychological impact it has on workers. It is directed towards the fit between people, their work activities, equipment, work systems and environment to ensure that the workplaces are safe, comfortable and efficient. Ergonomics continuously strives to gain a favorable relationship between the people conducting the work and the work environment in which they are working in. This may decrease the likelihood of injuries, increase employee comfort and total job satisfaction, reduce product or process errors/faults, decrease product downgrading, and in turn increase productivity and efficiency, all while increasing the organization's profitability. Ergonomics focuses fitting the job to the worker by adapting workstations, tools, equipment and processes to provide optimum comfort and efficiency to the worker. Every worker is characterized through attributes of size, strength, range of motion, expectations and physical or physiological capabilities.

The United States Bureau of Labor Statistics defines musculoskeletal disorders (MSD's) as "an injury or disorder of the muscles, nerves, tendons, joints, cartilage, or spinal discs" (U.S. Bureau of Labor Statistics, 2007, musculoskeletal disorders section, para. 1).

One common musculoskeletal illness is cumulative trauma disorder. A cumulative trauma disorder is "the term used for injuries that occur over a period because of repeated trauma or exposure to a specific body part, such as the back, hand, wrist or forearm" (Ergoweb, 2008, cumulative trauma disorders section, para. 1). Five risk factors can contribute to the emergence

of this disorder. They are as follows: extreme forces, awkward postures, repetitive motions, mechanical stresses and vibration. According to Chatterjee (1987) among occupational factors, repetitive motion and forceful exertions, static muscle load, unnatural body posture, mechanical stress, vibration, temperature, faulty work systems and untrained personnel services appear to be the most prevalent. Types of cumulative trauma disorders include trigger finger, tendonitis, tenosynovitis, ganglionic cyst, epicondylitis, carpal tunnel syndrome also known as CTS, thoracic outlet syndrome, neck tension syndrome, pronator teres syndrome, radial tunnel syndrome, rotator cuff syndrome, DeQuervain's syndrome ganglion, ulnar nerve entrapment, guyon tunnel syndrome, Raynaud's syndrome and vibration syndrome. These injuries occur gradually over time. Cumulative trauma disorder injuries occur because risk factors are present within the manufacturing process.

The occurrence of employee complaints of shoulder and lower back pain while maneuvering carts during the adhesive application process at Company XYZ is placing the employees at risk of developing musculoskeletal illnesses.

Purpose of this Study

The purpose of this study is to identify and assess specific areas of the adhesive application process where risk factors potentially increase the potential for ergonomic issues to workers. The evaluation will consist of using several ergonomic assessments, surveys, and a workplace/cart design analysis to identify the specific body parts that are at-risk of developing injuries. A cost justification will follow to justify the reasoning for investing in changes so that Company XYZ is able to identify whether they will receive a return on their investment. Through this process of evaluation the researcher will identify a number of possible controls and

procedure changes to improve the current adhesive application process in reducing or eliminating the risk of ergonomic injuries.

Goals of the Study

- Conduct quantitative surveys on employees to determine the extent of the problem.
- Conduct qualitative observations and survey employees to determine the extent of the problem.
- Analyze the adhesive application process workstation and cart design.
- Identify all injuries the organization has incurred within the past three years.
- Develop a cost justification for improvements.

Significance

While Company XYZ has not suffered any loss time injuries in recent years, the potential is threatening of cumulative trauma disorders gradually occurring over time. Substantial financial losses may develop because of the daily work practices and workplace design at Company XYZ. The likelihood of identifying the foremost major areas leading to musculoskeletal illnesses may be evident by identifying the risk factors of force, awkward postures, repetitive motions, mechanical stresses and vibration.

Assumptions of the Study

- The manufacturing process remains the same; however weight variables change due to the dimensions of the ceiling and wall panels.
- The adhesive application process is being completed by the same workers every day.
- Information provided through surveys and injury history is accurate.

Limitations of the Study

- The mass of each loaded cart is not consistent because of customer's orders ranging upon the size of each ceiling and wall panels.
- Employees completing symptoms survey may not be answering truthfully.
- Cost justification potential average of injury payment was an estimate based on averages.
- Cost justification cost of controls was an estimate.

Definition of Terms

Cumulative Trauma Disorders – “The term used for injuries that occur over a period because of repeated trauma or exposure to a specific body part, such as the back, hand, wrist or forearm. Muscles and joints are stressed, tendons are inflamed, nerves pinched or the flow of blood is restricted” (Ergoweb, 2008, cumulative trauma disorders section, para. 1).

Duration – “The length of exposure to a risk factor. It can be measured as the minutes or hours per day the worker is exposed to a risk” (Ergoweb, 2008, duration section, para. 1).

Force – “The amount of muscular effort required to perform a task” (Ergoweb, 2008, force section, para. 1).

Musculoskeletal Disorders – “Disorders of the muscles, tendons, peripheral nerves, or vascular system not directly resulting from an acute or instantaneous event” (Karwowski, Marras, 1999, p. 1256).

Repetition – “The number of similar exertions performed during a task” (Ergoweb, 2008, repetition section, para. 1).

Risk Factor – “Actions in the workplace, workplace conditions, or a combination thereof that may cause or aggravate a work related musculoskeletal disorders” (Ergoweb, 2008, risk factor section, para. 1).

Sprain – “A stretching or tearing of ligaments” (Mayo Clinic, 2008, sprain section, para. 1).

Strain – “A stretching or tearing of muscle or tendon” (Mayo Clinic, 2008, strain section, para. 1).

Chapter II: Literature Review

Company XYZ's employees performing the tasks of moving carts throughout the adhesive application process may be contributing to the exposure to ergonomic issues. Workers in this process encounter various factors that have been proven to develop into musculoskeletal illnesses. This chapter will present a review of literature that relates to the development of musculoskeletal illnesses with the purpose of describing and analyzing research that has already been done on this topic.

Purpose of the Review of Literature

The purpose of the review of literature is to inform readers of the research related to this research problem and the ergonomic exposures contributing to the development of musculoskeletal illnesses. The study will allow the researcher to focus on the major areas of concern associated with daily work practices and work conditions. Moreover, the potential for developing musculoskeletal illnesses will be identified. The study of ergonomics has recognized the relationship between five ergonomic risk factors and musculoskeletal illnesses. They are as follows: force, awkward postures, repetition, mechanical stresses, and vibration. Research has identified a number of tools used to analyze the five risk factors. The tools include: Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), Symptoms Surveys, and a Workstation Analysis. By not dealing with the five risk factors, a company may experience economic consequences. Economic consequences can be identified using a Loss Analysis to identify where losses are occurring and trends associated with the injuries or illnesses suffered. The implementation of controls to decrease those losses can be evaluated using a Cost Justification Analysis. The researcher will recommend improvements to the current process using administrative and engineering controls to reduce the risk of employee's exposure.

Overview Of Ergonomic Risk Factors

Risk factors are attributes within a job that increase the possibility of musculoskeletal disorders (MSD). MSD's are usually a result of the combination of a number of present risk factors. Although, it is difficult to measure how each factor contributes to the development of MSD's because they all affect each other.

Ergonomic Risk Factors

Ergonomic risk factors include extreme forces, awkward postures, repetitive motions, mechanical stresses and vibration. All risk factors contribute to the development of MSD's.

Force. Force refers to the physical effort that is required to complete a task. Force is used in almost any application involving lifting, reaching, pinching, pushing and pulling. In some cases the application of a high force is needed by placing a mechanical load on muscles, tendons, ligaments and joints. As muscles effort increases to the response of higher task loads, the circulation to the muscles decreases causing the muscles to fatigue more rapidly (Putz-Anderson, 1988). When force requirements are high or demanding on an individual and a suitable amount of recovery time is not available during the task, then soft tissue injuries will occur. Armstrong's (1986) study (as cited in Putz-Anderson, 1988) stated that acceptable limits of force on different parts of the body are conditioned by variables of age, sex, body build and general health, all of which determine the tolerable amount of force available.

Armstrong (1986) also stated that when more force, wrist deviation or pinch grip is used or required, then the higher the percentage of work capacity is on active muscles. There is more of an opportunity that fatigue and inflammation will occur in the muscles and joints when a higher percent of work capacity is needed (as cited in Putz-Anderson, 1988).

injuries. In the article “Toolbox Tray 6: Evaluating Job Risk Factors,” the National Institute for Occupational Safety and Health (NIOSH) quantifies repetition as being a task cycle time of less than thirty seconds (NIOSH, 1997). In the article “Repetitive work of the upper extremity: Part I- Guidelines for the practitioner,” Kilbom (2000) indicates, as illustrated in Table 1, repetition rates of different body parts:

Table 1: *Repetition Rates by Different Body Parts*

Body Region	Frequency of Movement or Contraction
Shoulder	More than 2.5/min
Upper Arm/Elbow	More than 10/min
Forearm/Wrist	More than 10/min
Finger	More than 200/min

Kaplan’s (1983) study notes that tasks with high repetition rates can still develop trauma even when the force of the task is minimal (as cited in Putz-Anderson, 1988).

Mechanical stresses. Mechanical stresses are considered injuries that are caused from hard, sharp edges, equipment and or instruments. The injuries generally occur while grasping, leaning, balancing, pushing or pulling. The muscles or tendons of the worker are impaired due to being pressed against the hard or sharp edges of the object. In the chapter “Biomechanical Risk Factors,” Warren and Sanders state that past studies have indicated that force, pressure and compression of tissues against structures do in fact increase internal pressure, resulting in swelling of tissues and increases in the development of MSD’s (Warren & Sanders, 2004). When employees are using tools, the grip forces are transmitted to the soft tissues that are underlying the tool. If the tool grip has a hard surface or is equipped with sharp edges, then the forces used

to operate the tool will concentrate to a smaller area, increasing the pain and tissue damage to the area.

Vibration. Exposure to vibration generally comes from machines, vehicles and equipment throughout the workplace. According to Warren and Sanders, when vibration is applied to the body, it causes oscillations in tissues and a bodily response will follow (Warren & Sanders, 2004). The response will generally depend on frequency, direction, intensity, acceleration, point of application and the posture of the body at the point of vibration contact. Generally, vibration is specified in two distinct categories: whole body vibration and segmental vibration. Whole body vibration consists of vibration that is transmitted through lower extremities, buttocks, back or the entire body depending upon whether the individual is sitting or standing (Warren & Sanders, 2004). Whole body vibration can result in low-back disorders. Whole body vibration is associated with the use of low frequency vibration found in trucks, buses or cars. Segmental vibration, on the other hand, is transmitted through the hands and fingers from direct contact with the vibrating source. Segmental vibration damages nerve fibers and small blood vessels in the fingers that result in vibration induced white finger (VWF) and vibratory neuropathy. Segmental vibration is associated with the use of high frequency vibration such as pneumatic drills, grinders and chain saws.

The most prevalent types of musculoskeletal illnesses that Company XYZ could potentially encounter are cumulative trauma disorders of: tendon disorders, nerve disorders and neurovascular disorders.

Tendon disorders are caused from tendons rubbing close ligaments and bones together (as cited in Putz-Anderson, 1988). Types of tendon disorders at Company XYZ may include: tendinitis, tenosynovitis, and rotator cuff tendinitis. Tendinitis is a form of tendon inflammation

that occurs because a muscle/tendon pairing is repeatedly tensed. Further use can damage fibers making up the tendon that can possibly calcify causing a permanently weakened tendon.

Tenosynovitis is due to extreme repetition where the synovial sheath of the tendon produces synovial fluid causing the sheath to swell and become very painful. Rotator cuff tendonitis is due to the four tendons of the shoulder rubbing against the bursa causing swelling in these two regions.

Nerve disorders are caused from nerves being exposed to hard objects which pinch the nerves during repetitious tasks (as cited in Putz-Anderson, 1988). One type of a nerve disorder at Company XYZ may be cumulative trauma disorder. This is caused if any of the tendon sheaths located in the carpal tunnel become swollen. Generally the median nerve being pinched causes the tendon sheaths to swell.

Neurovascular disorders are caused from compression of nerves and blood vessels (as cited in Putz-Anderson, 1988). One type of Neurovascular disorder that may be prevalent at Company XYZ is thoracic outlet syndrome. Thoracic outlet syndrome is due to the compression of nerves and blood vessels between the neck and shoulder. Work activities causing this syndrome may include pulling the shoulders back and down. This may cause numbness in the fingers, hand and arm.

Overview Of Analysis Tools And Methodology

Research shows identification of risk factors can be analyzed through the use of tools. The tools generally help evaluate the significance and role in which risk factors contribute to the development of MSD's.

Types of Ergonomic Analysis Tools

There are a number of assessment tools available for use in ergonomic investigations within a workplace. Survey analysis tools indicate different risk factors that are prevalent to several parts of the body. Survey tools being used in this study include: Rapid Upper Limb Survey (RULA), Rapid Entire Body Assessment (REBA), and a symptoms survey. The researcher will undergo a task analysis and workplace design analysis to identify current indicators that may develop musculoskeletal illnesses. Also, two instruments are used to identify joint angles and force stressors on the body: manual goniometer and force gauge.

RULA. The RULA survey stands for Rapid Upper Limb Assessment. The RULA survey was developed for use in ergonomic investigations where work related upper limb disorders are apparent. This survey is a screening tool to assess biomechanical and postural loading throughout the entire body through repetition, force and awkward postures. The survey specifically pays attention to the neck, trunk, shoulders and upper limbs.

The RULA assessment takes a short time to complete in which the scoring indicates the level of importance required to reduce the risks of an injury occurring (McAtamney & Corlett, 1993). Corlett (1999) also states in "The Occupational Ergonomics Handbook," the RULA was needed so an individual with little training could assess a workplace while a worker was performing a task. The researcher can recognize major areas contributing to risk and integrate actions against them. It provides a rapid assessment of the loads on the musculoskeletal system due to posture, muscle function and force (McAtamney & Corlett, 1993).

To perform a RULA assessment, the researcher will choose to observe limb and body postures for parts of the work cycle that are considered the most frequent use of joints and joint angles. For those chosen parts of the work cycle, the researcher will analyze the positions of the

upper, lower arm and wrist (Corlett, 1993). The positions will then be given a score in the appropriate box.

The RULA coding system for scoring has four levels indicating the level of involvement needed to reduce risk of injury to physical loading on the worker. The scoring system is as follows:

- Level 1: posture is acceptable.
- Level 2: further investigation is needed and changes may be needed.
- Level 3: investigation and changes are needed soon.
- Level 4: investigation and change immediately (McAtamney & Corlett, 1993).

Although the RULA is a widely used ergonomic assessment tool, Corlett has stated that past studies have failed to show a successful method of measuring the frequency of joint angles used, postures adopted by limbs, and forces exerted in the upper limbs (Corlett, 1999). Further in this literature review, the instruments: manual goniometer and force gauge will be discussed as methods used to address the problem identified by Corlett.

REBA. REBA survey stands for Rapid Entire Body Assessment. The REBA was developed by Hignett and McAtamney (1993) to assess and identify posture for risk of work-related musculoskeletal disorders. Before the development of the REBA, past studies could not grasp the unpredictable working postures being found in the health care and service industries. According to Hignett and McAtamney, in the article "Rapid Entire Body Assessment," the development of REBA was aimed to develop a postural analysis system that is sensitive to musculoskeletal risks (Hignett & McAtamney, 2000). This is done in a variety of tasks by separating the body into segments to be coded individually and providing a scoring system for

muscle activity output of the activity. The activity will then be given an action level for urgency of adjustments or additional considerations.

Coyle (2005) supports Hignett and McAtamney (2000) in the article “Comparison of the Rapid Entire Body Assessment and the New Zealand Manual Handling ‘Hazard Control Record’, for assessment of manual handling hazards in the supermarket industry,” that the REBA assesses working postures that involve the use of the whole body through a static, dynamic, rapid changing or unstable manner where a material handling is occurring. The REBA will score a specific posture throughout the task by assessing the trunk, neck, legs, upper arms, lower arms, and wrist postures. While scoring the posture, the researcher is taking into account the force, load, coupling, duration and repetition of the task.

Symptoms survey. A symptoms survey is a quick and inexpensive way to provide a quick way of identifying a worker’s perception of discomfort and the sources that are contributing to the discomfort. The survey is a good tool to identify areas or jobs where the potential for an injury may occur. Various workers can indicate symptoms they are experiencing from the demands in their work, and investigations can be based on the symptoms experienced through workstation design, equipment design, and work methods (Putz-Anderson, 1988). A symptoms survey is designed to disclose the nature of the injury whether pain, tingling, swelling and or stiffness is involved. The worker is able to provide a visual support of the discomfort by highlighting areas on the body-parts map (Putz-Anderson, 1988).

Surveys encounter limitations in that they rely on the workers recognition of discomfort and willingness to report their injury or health conditions (Putz-Anderson, 1988). Many workers interpret the tolerance of pain or discomfort at different levels which may be difficult for the researcher to establish a common ground. Some workers may be more prone to pain than others.

Although, a workers positive response to questions identifies that the worker is experiencing discomfort and understands the reasoning for conducting the symptoms survey. In the chapter “Musculoskeletal Discomfort Surveys Used at NIOSH,” Sauter, Swanson, Waters, Hales and Dunkin-Chadwick also identify limitations to discomfort surveys in that, the diversity of discomfort surveys raise the question about the best measures of discomfort because no one specific standard is in place (Sauter, et al., 2005). Few studies have been conducted to examine the relationship between the design of discomfort surveys and whether they can predict certain outcomes.

In an article “Assessing work-related body-part discomfort: Current strategies and a behaviorally oriented assessment tool,” by Cameron, the study concluded that a body map and discomfort scales within a symptoms survey allow ergonomists to distinguish and diminish sources of discomfort and behaviors based on work techniques (Cameron, 1996).

Manual goniometer. A manual goniometer is an instrument used to measure joint angles and range of motion. Range of motion is measured in degrees for either active or passive joint range. Its use is relevant to indicating workplace design features and the worker’s functional reach within the workplace. A goniometer device is comprised of a fulcrum and extending arms. A still shot will be captured using a camera or digital video recorder. The researcher will measure joint angles and range of motion by holding the stationary arms in place and marking the end points of the joint being moved.

Force gauge. A force gauge is an instrument used to measure tensile and compression tests of force. The tensile force test is used to identify the force required to pull an object, and a compression force test is used to identify force used to push an object. There are a few different accepted types of force gauges used in industry today. One type is a spring mechanism

instrument in which the spring is either pulled or compressed. In the chapter “Force Dynamometers and Accelerometers,” Radwin and Yen (1999) state that spring force devices have a precision of 1 percent full scale. Another type of force gauge is a hydraulic system device ensuring accurate readings and a dial that continuously shows instantaneous force and holds the maximum force reading. These instruments objectively measure push, pull and lift forces for manual tests, functional capacity evaluation and job task evaluation.

Task analysis. Task Analysis is a means of identifying the areas of a workplace or workstation placing stressors on a worker and is the basis for any human factors design attempt. A task analysis is completed prior to redesigning a workplace or workstation. In the chapter “Task analysis: Part I-Guidelines for the practitioner,” Landau, Rohmert and Brauchler state that a task analysis provides information on peak stress situations that may be occurring, and then indicates how these stressors can be eliminated or reduced by job redesign (Landau, et al., 2000). Gramopadhye and Thaker’s opinion of a task analysis is similar to Landau, Rohmert and Brauchler in the chapter “Task Analysis”: the goal of a task analysis is to examine the existing human/machines systems to provide a way of designing more efficient and effective systems that are based on human capabilities (Gramopadhye & Thaker, 1999). When redesigning an existing system, a task analysis can be used to analyze all or part of the system to identify any modifications or any complete changes the system. A task analysis can be used for the following applications:

- System function – deciding on human and machine function issues
- Organizational issues – selection, qualification and skill requirements of personnel

- Task design – identify what skills, procedures and knowledge is needed to perform task
- Human-machine interface – workplace design, equipment and tool design
- Human supporting requirements – training or job aids
- System reliability analysis – data and human error to determine reliability of system

A task analysis being conducted on the worker actually doing the work should be completed by a person who is competent in doing an ergonomic assessment of the job or task situation (Landau, et al., 2000). Task analyses conducted by outside evaluators have been criticized as being one-sided and incomplete.

Workplace design. An inadequate workstation design is a major contributor to the development of musculoskeletal illnesses. An ergonomics approach to an industrial workstation design attempts to achieve a balance between the worker's capabilities and the work requirements that enable the worker to optimize productivity (Das & Sengupta, 1996). The design of a workstation will also provide the worker physical and mental well being, job satisfaction and safety. In the chapter "Job Design," Sanders states, that a well-designed workplace will reduce wasted effort and enable the workers to establish a rhythm with themselves and the sequence for the task (Sanders, 2004). The design objective is to promote the worker's interface with individual components of the workplace. These components are relative to controls, instrument panels, materials, products and people throughout the process. The process must take into account what the system output performance is and whether it is in-line with the production objective of the organization. The workplace design criteria will include the use of anthropometric data in order to evaluate its implementation and/or change.

Anthropometrics, the study of human dimensions and body size, must be established in order to accommodate most of the workers in the workstation. Human dimension may include height, arm length, arm thickness, lifting and carrying capacities. Sanders (2004) states that anthropometric criteria used in ergonomic design should include clearance, reach, posture and strength that accommodate ninety-five percent of workers' human dimensions. Ninety-five percent of the workers' human dimensions relates to a ninety-five percent confidence interval, accommodating the largest user and smallest user throughout the population. This means that the largest 2.5% and smallest 2.5% of the population will be excluded from the workplace design consideration. This is not to be confused with accommodating the average user (50%) within the population, but simply accommodating most workers as the largest and smallest user. Clearances should always be designed for the largest user, and reach should always be designed for the smallest user. Preferably a workstation should be designed to fit each individual worker, but turnover and the changing workforce make it difficult for companies that cannot afford the cost of change. Anthropometrics is critical in ergonomics because it applies the workers body dimensions to the design of jobs, workstations, equipment, tools, and personal protective equipment (PPE). As mentioned earlier, ergonomics is directed towards the fit between people, their work activities, equipment, work systems and environment to ensure that the workplaces are safe, comfortable and efficient.

According to Boussenna, Corlett and Pheasant (1982) in the article "The relation between discomfort and postural loading at the joints," inadequate posture from an improperly designed workstation causes static muscle efforts, eventually resulting in acute muscle fatigue. The presence of inadequate postures causing acute muscle fatigue will ultimately decrease worker productivity and increase the chance of worker's health hazards (Boussenna, et al., 1982).

Das and Segupta (1996), state that before redesigning a workstation a worker survey should be conducted to determine the effect of existing equipment or workstation design in relation to comfort, health and ease of equipment use. The survey should entail:

1. Operator rating of various equipment/system design and environmental factors.
2. Current level of physical, mental and visual fatigue of the job to the operators.
3. The changes in postural discomfort in specific anatomical regions throughout the day (Das & Segupta, 1996).

Chengalur et al., stated, “from an ergonomics perspective, a well-defined job is one that most of the potential workforce can perform well without excessive stress” (Chengalur, et al., 1996, p. 435). Some of the characteristics are:

- Physical dimensions in relation to reaches, clearances, and work heights that accommodate the capabilities and characteristics of at least 90 percent of the workforce.
- Peak load capacities accommodate at least 90 percent of the workforce.
- Environmental factors do not accommodate risk or performance limits on healthy workers.
- Perceptual, cognitive, and visual demands are within the capacities of most workers.
- Job repetition rates are not excessive, and the workers have control over their work patterns.

The height of a work surface can play a vital role in job performance and musculoskeletal problems. A surface which is too high can cause painful cramps in the shoulders and neck (Putz-

Anderson, 1988). If the work surface is too low, then the worker must bend over and flex the back. This can cause pain in the neck and lower back.

Overview Of The Economics Of Loss

A company may suffer economic consequences due to injuries and/or illnesses. These losses may be a direct result of not dealing with the five risk factors in the workplace. Losses from injury and/or illness play a vital role in the economic structure, reputation and growth of the company. Losses drain and hinder a company's ability to generate profit.

Loss Analysis

Wiening, in the book "Foundations of Risk Management and Insurance," states that a loss analysis is the process of examining records of past losses and missed opportunities that the company has sustained (Wiening, 2002). Looking at a company's past injury losses enables the researcher to identify the major areas that need attention and evaluation. An analysis demonstrates the present value of losses due to injury and subsequent losses to earning capacity. This analysis contributes to management information by revealing trends. A loss analysis will categorize the reported injuries into trends indicating the more frequent or severe injuries that have been occurring. If conditions continue to stay the same within work processes, then it is fair to say that there is a high probability of the identified injuries occurring again in the future. The analysis provides an evaluation of problems and procedures as a guide for risk management. The problems and procedures will help risk managers make decisions that relate to the organization's future operations.

The Occupational Safety and Health Administration (OSHA) require employers to maintain records of their work-related injuries and illnesses (OSHA, 2004). The OSHA 300 Log of Work-Related Injuries and Illnesses is the document that employers will maintain for their

work-related injuries and illness. The log is used to classify work-related injuries and illnesses and the severity of each. If an injury or illness occurs, the company will record the specifics of what happened and how it happened. The log consists of records of work-related injuries and illnesses that result in death, loss of consciousness, days away from work, restricted work activity, job transfer or medical treatment beyond first aid. The log also records work-related injuries and illnesses: those diagnosed by a physician or another licensed health professional, a case involving cancer, chronic irreversible disease, fractured or cracked bone, or a punctured ear drum. Additional criteria an employer must record pertinent to work-related injuries and illnesses are: a needlestick injury or cut from a sharp object contaminated with another person's blood or potential of an infectious material and any case where an employee must be removed under the OSHA health standard requirements and tuberculosis.

An incident rate can be calculated to determine the number of recordable injuries and illnesses a company is sustaining among a given number of employees over a period of time (OSHA, 2004). The incident rate involves calculating the total amount of recordable injuries and illnesses that occurred in their establishment during that year by the number of hours worked by all employees. This number is then multiplied by a given factor of two hundred thousand equaling the company's incident rate. The incident rate will allow a company to evaluate their incident rate to industry statistics and help them identify problems in the workplace.

Worker's Compensation insurance records are another means of evaluating a company's losses associated with injuries and illnesses. According to Putz-Anderson (1988) the costs can be broken down into two categories: medical costs and disability costs. Medical costs are those of any payments for diagnosing and/or treating the injuries and illnesses made to outside hospitals, clinics, physicians, and other licensed medical professionals. Disability costs are those payments

made directly to the injured worker for missing or losing work time if unable to work and settlement payments in the case of a permanent disability. The worker's compensation records entries will include the description of the injuries and illnesses suffered. This enables departments and jobs to be identified which have high injuries and illnesses and are a higher cost to the organization. Putz-Anderson also states that worker's compensation records can be limited, in that they only consider injuries and illnesses that are more severe and not the injuries and illnesses that are in the development stage (Putz-Anderson, 1988). A company's direct costs may be identified through worker's compensation records, but this does not take into consideration the indirect costs a company may be suffering. These costs could include but are not limited to: production loss, increased overtime due to production loss, and replacement training.

Overview of a Cost Justification for Improvements

Organization shareholders and management place a considerable amount of attention to the bottom line: money. When injuries and/or illnesses are contributing to loss, changes have to be made in order to reduce the exposure to loss. In order to make changes, a plan must be in place to justify why specific controls are suggested. The plan will consist of an explanation for the controls, and the overall cost of its implementation to the organization.

Cost Justification for Improvements

In the article "Ergonomics ROI: Impacting Workers' Compensation Costs, Productivity, Quality, and Revenue," Wynn describes cost justification as being based on one simple concept: "the benefit of an improvement should outweigh the cost" (Wynn, 2004, p. 2). Benefits will provide the organization with a return on their investment by reducing injuries and illnesses. Based on Wynn's research (2004) and Putz-Anderson's cost benefit prevention of CTD's

justification (Putz-Anderson, 1988), financial benefits of improvements generally come in five different categories:

- Productivity
- Workers' Compensation Costs
- Quality
- Absenteeism
- Employee Turnover

A control proposal must always be justified when brought forth to upper management.

Putz-Anderson states that the justification could include: the extent of the problem, the number and severity of cases, and the time, expense and disruption that may be involved within implementing the program (Putz-Anderson, 1988). Oxenburgh's opinion is similar to one of Wynn (2004), and Putz-Anderson's (1988) points that a cost-benefit analysis assumes that productivity is not optimal and any changes that are implemented are done so for productivity improvement (Oxenburgh, 2000). When a cost-benefit analysis is conducted it is centered on the employees who produce the products and not the products themselves.

In the article, "More Liberty Mutual Data on Workplace Safety," Michael explains an executive survey performed by Liberty Mutual in 2001 following the release of their safety index (Michael, 2001). The survey reported that seventy percent of executives believe that protecting employees is a leading benefit of workplace safety (as cited in Ergoweb, 2001). The survey indicates that ninety-five percent of business executives feel safety has a positive financial impact on a company's performance and sixty one percent of those executives also believe their companies receive at least a three dollar return on investment for every one dollar they invest on improving workplace safety.

The Liberty Savings Equation is one technique available to evaluate the cost effectiveness of loss through a company's capital investment. Although the Liberty Savings Equation is a trademark name, it is simply a double discount equation provided from an accounting perspective. Shareholders are simply interested in the bottom line: profit. This being said, the double discount equation provides shareholders and corporate executives the ability to accurately predict a return on investments through loss controls efforts. The technique reveals that a capital investment for designed equipment or processes will reduce worker injuries. It supports the fact that the investment will have a return on cost by saving money that would usually be spent on medical and worker's compensation costs.

Overview of Ergonomic Controls

The development of ergonomic controls must be carefully planned before implementing in the workplace. Management will justify the reasoning and cost of controls by prioritizing their implementation.

Types of Ergonomic Controls

A hierarchy of controls has been established to provide companies a way to effectively eliminate or reduce hazards in the workplace. This hierarchy of controls places techniques in a sequential order for a company to follow in a step by step process when risks or exposure is evident. This hierarchy will greatly increase the possibility of achieving reduced or eliminated exposure to the specific hazard. This process may be used when determining controls, or considering changes to existing controls. According to the British Standards Occupational Health and Safety Management Systems - Requirements, the order of the hierarchy is in descending order beginning with elimination, substitution, engineering controls, administrative controls, and

lastly personal protective equipment as a last resort mechanism (British Standards Institution, 2007).

Elimination. According to Merriam-Webster's Dictionary, elimination is defined as "the act, process, or an instance of eliminating or discharging" (Merriam-Webster, 2008, elimination section, para. 1). When the risk of injury is apparent, the company must try and eliminate the risk if possible. Eliminating hazards throughout the workplace, work processes and entering the workplace, is the most effective method of control. It is easier and more efficient to eliminate hazards in the design stage because the exposure is not yet present.

Substitution. In the case that elimination is not practical or sufficient, appropriate steps must then be performed in order to reduce the risk through the control method of substitution. Substitution can be used with workplace hazardous materials and work processes. The substitution of work processes can include changing process procedures to provide workers with a safer workplace and a reduced exposure to hazards. An example of this could include using pneumatic tools rather than using manual tools in a manufacturing process to reduce the demanding manual work involved.

Engineering controls. Engineering controls are physical changes to jobs that control employee exposure to risk without depending on the employee to protect themselves against potential risks. Successful ergonomic projects are achieved primarily through implementing engineering controls which consist of changing tools, controls, piece presentation, workstations, and workflow to reduce or eliminate risk factors (Wynn, 2004). According to Putz-Anderson (1998), engineering controls try to achieve control over the job risk factors that are associated with the development of Cumulative Trauma Disorders (CTD's). In the chapter "Reducing Injuries, Claims, and Costs," Clark states that the goal of engineering controls is to "design out"

ergonomic hazards (Clark, 2004). This is done by adjusting the demands of the job with an engineered improvement instead of expecting the worker to adjust their human capacity to the job demands. Implementing engineering controls will not only limit the apparent hazards to workers in the workstation, but optimize comfort, efficiency and total job satisfaction. In the article “Musculoskeletal disorders in a handmade brick manufacturing plant,” it is reported that a recent study indicated that the introduction of a conveyor system running alongside each moulder, providing workers with individual clots of clay, eliminated the workers from a strenuous reaching task previously being performed (Trevelyan & Haslam, 2001).

Administrative controls. Administrative controls are the fourth tier or step in the hierarchy of hazard control. These controls refer to actions taken by management or medical staff to limit the potential health effects on workers (Putz-Anderson, 1988). This is done by modifying personnel functions. The article “Prevention Through Design: Addressing occupational risks in the design and redesign process,” Manuele (2008) signifies that administrative controls include: selecting personnel, applying or changing work methods and procedures, training, supervising, motivating workers, modifying behaviors, scheduling, rotating jobs and breaks, maintaining equipment, managing change and investigating, and inspecting.

In the article “Workplace Hazards: A Threat To Workers’ Senses,” Stromme states that administrative controls can be affected by human error and should not be relied upon to reduce exposure every time (Stromme, 2004). Manuele’s point of view is similar to Stromme’s in that achieving a level of effectiveness in all areas of administrative controls is very difficult and not often accomplished (Manuele, 2008). For example, if a company implemented an administrative control in a manufacturing setting for workers to use two people to push carts into place, and the

workers chose to only move the carts with one person. Then the administrative control is not effective because the exposure may not be reduced due to human error.

Personal protective equipment. In the event that no engineering or administrative control has been making a significant effect on reducing or eliminating hazards, then PPE should be used to ultimately protect the worker from potential hazards and risks. PPE is a last resort mechanism in the hierarchy of hazard controls. PPE may include but is not limited to safety glasses, hearing protection, breathing apparatuses, face shields, safety shoes or boots, gloves, and helmets. PPE may be utilized when engineering controls are not feasible or are in the process of being developed, when safe work practices do not provide sufficient protection, and in the case of an emergency (Stromme, 2004). Depending on the type of equipment a company wishes to use or implement, it is important that the equipment is being used properly, appropriate training has been completed and the upkeep or maintenance of the equipment is frequently completed to maintain its correct operation and protection. Proper PPE requires supervisory and personnel actions by identifying and selecting the type of equipment needed, proper fitting for correct use, training, inspections and maintenance (Manuele, 2008).

PPE can also increase hazards for the workers in different conditions when being used excessively. According to Stromme (2004), there is a greater risk of problems developing with using PPE improperly or in a manner unsuited to its design and purpose. This can be worse than using no protection at all. Manuele (2008) has a similar view to Stromme (2004) in that PPE may be necessary in many different occupational settings but is the least effective way to reduce the exposure of hazards and risks in the workplace.

Summary

A review of literature has indicated that risk factors of force, awkward postures, repetition, mechanical stresses and vibration contribute to the development of musculoskeletal illnesses. The development of MSD's is usually a result of a number of risk factors. Although these risk factors are present, they adjust to each other's level of presence within the work process. A number of recognized ergonomic tools can be used to identify and analyze risk factors in the workplace. These tools establish the urgency for adjustments or additional considerations. A company can analyze injuries and identify trends associated with those injuries by conducting a loss analysis. The analysis will allow shareholders to understand the importance of loss occurring from these injuries. Companies have established the hierarchy of controls to eliminate or reduce the presence of risk factors. The hierarchy consists of engineering controls, administrative controls, and PPE. In order to implement these controls, companies must develop a cost justification to define the appropriate approach and benefits gained through their implementation.

Chapter III: Methodology

Method of Study

The purpose of this study was to identify and assess specific areas of the adhesive application process that may increase the risk of developing musculoskeletal illnesses. The evaluation consists of using several ergonomic assessments, surveys, and a workplace/cart design analysis to identify the specific body parts that are at-risk of developing injuries. A cost justification will follow to justify the reasoning for investing in changes so that Company XYZ is able to identify whether they will receive a return on their investment. Also, it will depict how long it will take Company XYZ to get a return on their investment. Through this process of evaluation, the researcher identified a number of possible controls and procedure changes to improve the current adhesive application process to reduce or eliminate the risk of ergonomic injuries. Goals were developed in order to achieve the purpose of this study; they are as follows:

- Conduct quantitative surveys on employees to determine the extent of the problem.
- Conduct qualitative observations and survey employees to determine the extent of the problem.
- Analyze the adhesive application process workstation and cart design.
- Identify all injuries the organization has incurred within the past three years.
- Develop a cost justification for improvements.

Subject Selection and Description

The subjects were chosen based on their job duties throughout the adhesive application process at Company XYZ. The focus of the observations, assessments and surveys were based on the employees manually pushing and pulling the carts in the adhesive application process.

The carts are used to transport ceiling and wall panels from the CNC machine to the adhesive application process. The Safety Director and Maintenance Director selected the subjects in the adhesive application process. The extensive manual labor required in the process is of ergonomic concern that potentially expose employees to ergonomic risk factors.

Prior to conducting any research, all subjects were clearly notified about the purpose of the study. The researcher explained all the necessary documents that were needed to inform all subjects within the study. The researcher and subjects reviewed the consent form, confidentiality information, observation schedule, assessments, and the symptoms survey. The participants were able to ask any questions before agreeing to participate in the study. Upon their agreement, the subjects followed by signing the consent form.

Instrumentation

The researcher used three different analysis tools to collect data. The analysis tools were used to evaluate workers pushing and/or pulling the carts. The three analysis tools are as follows:

- Rapid Upper Limb Assessment (RULA) Survey

The RULA survey was developed by McAtamney and Corlett (1993) for use in ergonomic investigations where work related upper limb disorders are apparent. This survey is a screening tool to assess biomechanical and postural loading throughout the entire body through repetition, force and awkward postures. The survey specifically focuses on the neck, trunk, shoulders and upper limbs.

- Rapid Entire Body Assessment (REBA) Survey

The REBA was developed by Hignett and McAtamney (2000) to assess and identify posture for risk of work-related musculoskeletal disorders.

The REBA assesses working postures of the entire body when a manual material handling task is taking place.

- Symptoms Survey

The symptoms survey used in this study was developed by the researcher to identify possible symptoms or discomfort workers may be presently experiencing or have experienced. A copy of the survey can be found in Appendix A.

Two instruments were used to generate joint angles, range of motion, and force used to push and pull carts. They are as follows: manual goniometer and force gauge. A manual goniometer is a protractor which measures body joint angles. This instrument analyzes postural demands of a job. A force gauge measures push, pull or lifting demands of an activity. This device is performed on a single axial (single direction) basis.

Also, three other additional analyses were conducted to gather more information to signify results. The three analyses are as follows:

- Workstation/Cart Design Analysis

Establishes dimensions and sizes of workstation which include the work area from CNC machine to adhesive application process and the cart design.

- Loss Analysis

A loss analysis of the past three years categorizes the reported injuries into trends intended to indicate the more frequent or severe injuries occurring within Company XYZ.

- **Cost Justification**

A cost justification allows the researcher to evaluate any costs to justify the changes or controls that may be implemented to eliminate or reduce exposure of the development of musculoskeletal illnesses. This will allow company XYZ to see if they will receive a return on their investment for changes made to reduce or eliminate exposures. A double discount method will be used to accurately predict a return on investments. The equation involves: average cost of injuries, life expectancy of control, prevention efforts of injuries, cost of capital, inflation rate and payback period. The technique reveals that a capital investment for designed equipment or processes will reduce worker injuries. It supports the fact that the investment will have a return on cost by saving money.

Data Collection Procedures

RULA Survey

1. The entire work cycle is observed to familiarize the postures adopted during the full work cycle.
2. A moment in the work cycle is identified that presents postures to assess.
3. The RULA assessment diagrams are used to score the postures for each body part, forces/loads and the muscles use for the specific posture.
4. Posture scores for group A and B are tabulated by following the scoring sheet.
5. The grand scores are compared with the list of action levels to determine what type of investigation or procedure is needed.

REBA Survey

1. The task is observed to formulate the workplace layout, use of equipment, and risk factors present.
2. Select postures to analyze by the criteria of repetitious postures, longest maintained postures, most muscular activity or force involved, awkward postures, and postures needing control measures.
3. The postures are scored based on the scoring sheet and body parts scores for groups A and B.
4. The scores are processed to equal a single score.
5. The REBA score is then calculated to the activity score to give the final REBA score.
6. The score is evaluated against the action levels that correspond to the levels for the urgency needed to make changes.

Manual Goniometer

1. Align the fulcrum of the device with the fulcrum or joint to be measured.
2. Align the stationary arm of the goniometer with the limb being measured.
3. Hold the arms of the goniometer in place while the joint is moved through its range of motion.

Force Gauge

1. Hook force gauge onto cart and pull the cart to get force reading.
2. Push cart with force gauge to get force reading.

Symptoms Survey

1. Nine employees complete the survey and express if they have or are currently experiencing any discomfort.
2. Allows workers to identify limbs that have or are experiencing discomfort.
3. Expresses whether the discomfort is hindering daily work activities.
4. The last section of the survey allows the worker to highlight the area(s) and limbs that are experiencing discomfort on a body diagram.

Workstation/Cart Design Analysis

1. Cart's size and height are measured.
2. Force gauge is used to indicate pounds of force used to push and pull empty carts.

Loss Analysis

1. Evaluate areas where the company is having losses due to injuries.
2. Identify the percentage of different injuries the company is sustaining in relation to the total injury loss.

Cost Justification

1. Company XYZ is able to see if there is a return on their investment.

Data Analysis

The joint angles identified through the RULA and REBA as well as the manual goniometer will be assessed and compared to anthropometric data. This is done by identifying the limits and joint angles that are acceptable for the ninety-fifth percentile and compare measurements of this study to that data. The force gauge data is analyzed and compared to acceptable and unacceptable industry standards and limitations. Industry standards and limitations indicate what the acceptable amount of force is, and how it is to be used in different

applications. The symptoms survey data collected simply identifies qualitative data showing specific areas of concern for the development of musculoskeletal illnesses. The workstation and cart design analysis measurements are compared and analyzed to anthropometric data with respect to confidence intervals. The ninety-fifth percentile will benchmark the measurements of the workstation and cart design against acceptable limits of anthropometric data for the ninety-fifth percentile. The loss analysis allows the researcher to identify what percent of injury and illness losses Company XYZ is sustaining. This is done by reviewing Company XYZ's OSHA 300 log and incident analyses to signify injuries and illnesses reported in the past three years. A cost justification indicates costs and benefits of re-engineering the carts and implementing controls throughout the facility.

Limitations of the study

The limitations to this study were:

- The mass of each loaded cart is not consistent because of customer's orders ranging upon the size of each ceiling and wall panels.
- Employees completing symptoms survey may not be answering truthfully.
- Cost justification potential average of injury payment was an estimate based on averages.
- Cost justification cost of controls was an estimate.
- The data is limited due to short collection time.

Chapter IV: Results

The purpose of this study was to identify and evaluate specific areas of the adhesive application process that may increase the risk of developing musculoskeletal illnesses. The researcher established goals in order to identify and evaluate the risk and/or development of musculoskeletal illnesses as well as the opportunity to recommend controls and changes. The goals developed in order to achieve the purpose of this study are as follows:

- Conduct quantitative surveys on employees to determine the extent of the problem.
- Conduct qualitative observations and survey employees to determine the extent of the problem.
- Analyze the adhesive application process workstation and cart design.
- Identify all injuries the organization has incurred within the past three years.
- Develop a cost justification for improvements.

Presentation of Data

Goal #1

The first goal of this study was to collect quantitative data about employees to determine the extent of the potential problem. To achieve the first goal of this study, RULA and REBA surveys, manual goniometer and force gauge were used to generate quantitative data on the workers moving carts throughout the adhesive application process.

RULA. The researcher used the RULA assessment as a screening tool to assess biomechanical and postural loading throughout the entire body through repetition, force and awkward postures. The researcher first examined the pushing and pulling of the carts in the adhesive application process using a digital video recorder. By using a digital video recorder, the

researcher was able to evaluate the repetition involved in the task and the push and pull postures being used. The RULA assessed repetition, force and postures from the still shots that were taken from the recording. The RULA survey was appropriate in this application because it specifically pays attention to the neck, trunk, shoulders and upper limbs.

Table 2 below identifies the RULA scores generated from the worker pushing and pulling the cart:

Table 2: *RULA Scores For Worker Pushing and Pulling Cart*

RULA	Arm & Wrist	Neck, Trunk & Leg	Final
	Score	Score	Score
Push	8	7	7
Pull	7	8	7

Table 2 above tabulated a final score of seven for the worker pushing and pulling a cart during the adhesive application process. The score of seven indicates that the process must be investigated and redesigned. The completed RULA surveys can be located in Appendix B and Appendix C.

REBA. The researcher used the REBA survey to assess working postures of the entire body when a worker was manually pushing and pulling a cart. The REBA survey was used for the snap shots taken from the digital recording during the adhesive application process. Table 3 below indicates the scores generated from the REBA surveys:

Table 3: *REBA Scores For Worker Pushing and Pulling Cart*

REBA	Score A	Score B	Score C	REBA Score
Push	7	6	9	9
Pull	8	8	10	10

Table 3 above indicates REBA score of nine and ten for the worker pushing and pulling the cart. These REBA scores indicate that the activity is high risk. The completed REBA surveys can be located in Appendix D and Appendix E.

Manual goniometer. The manual goniometer was used in the same application as the RULA and REBA, using still pictures from the digital video recorder. The manual goniometer measured joint angles of the workers pushing and pulling the carts.

Joint angles measured with the manual goniometer for workers pushing the cart:

- Upper arm position used at a 105° angle.
- Lower arm position used to the side of the body at an angle of 100°.
- The wrists were extended at a position of 19°.
- Neck position had flexion at 3°.
- Trunk position had flexion at 48°.
- Legs were bilateral with stable weight bearing and the knees had flexion of 30°.

The manual goniometer measured joint angles of the workers pulling the cart:

- Upper arm position at a 98° angle.
- Lower arm position being used at the side of the body at an angle of 110°.
- Wrists were extended at a position of 17° and were bent from the midline.
- Neck position was at 6° and twisted.

- Trunk position had flexion in the back of 120°.

The joint angle measurements listed above were used in the RULA and REBA surveys to generate a final RULA and REBA score.

Force gauge. A force gauge was used to measure push and pull demands of moving a cart. This device is performed on a single axial (single direction) basis. The researcher performed multiple tests on the carts that ranged from testing an empty cart and a weight bearing cart. Three tests were performed on each movement to get an average amount of static force required to move the carts. Table 4 below indicates the amount of static force it took to begin moving the empty cart before the cart began moving on its own momentum:

Table 4: *Static Force Required to Move Empty Cart*

Movement	Test 1	Test 2	Test 3	Average
Push	28 lbs	30 lbs	31 lbs	29.7 lbs
Pull	16.5 lbs	17 lbs	25 lbs	19.5 lbs

As indicated in Table 4, the average static force required to push an empty cart was 27.9 pounds and the average static force required to pull an empty cart was 19.5 pounds.

Table 5 below indicates the amount of static force it took to begin moving the weight bearing cart before the cart began to move on its own momentum:

Table 5: *Static Force Required to Move Weight Bearing Cart*

Movement	Test 1	Test 2	Test 3	Average
Push	40 lbs	44 lbs	45 lbs	43 lbs
Pull	30 lbs	33 lbs	29 lbs	30.7 lbs

Table 5 shows that the average required force to push the weight bearing cart was 43 pounds and the average amount of static force required to pull the weight bearing cart was 30.7 pounds.

The static force measurements in Table 4 and Table 5 above were used in the RULA and REBA surveys to generate a final RULA and REBA score.

Goal #2

Symptoms survey. The second goal of this study was to gather qualitative information from observations and surveys about employees to determine the extent of the potential problem. To achieve this goal, a symptoms survey was used to identify possible symptoms or discomfort workers may experience or have experienced. Nine employees completed the survey, allowing them to identify limbs that are experiencing or have experienced discomfort as well as whether the discomfort is hindering daily work activities.

The first symptoms survey question asked if the workers' present job involves arm, hand, shoulder or finger actions to be repeated many times throughout an hour. One hundred percent of the workers answered yes to the question that there is repetition involved within their daily work activities.

The second survey question asked whether the workers have experienced any pain, discomfort or tingling in their shoulders, arms, wrists or back within the past two months. The question asked for the responder to check all that apply from a list of body locations. Figure 1 below provides the responses:

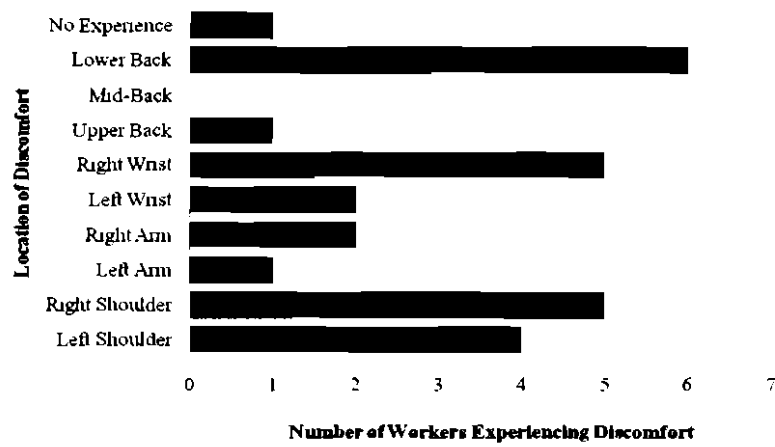


Figure 1. Workers Experiencing Discomfort

Figure 1 indicates that the top three locations of discomfort for the workers are: sixty-seven percent in their lower back, fifty-six percent in the right wrist, and fifty-six percent in the right shoulder.

The third survey question asked the workers whether they have experienced any frequent feelings of soreness or pain in any of the locations selected in question two. The workers' responses are located in Figure 2 below:

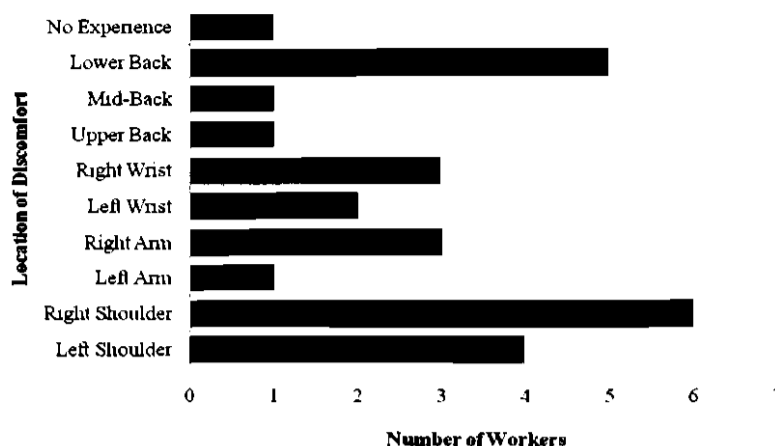


Figure 2. Workers Experiencing Frequent Feelings of Soreness or Pain

Figure 2 indicates that the top three most common locations of discomfort and/or frequent feelings of soreness or pain are: sixty-seven percent in the right shoulder, fifty-six percent in the lower back and forty-four percent in the left shoulder.

Survey question four asked the workers what time of day their discomfort tends to occur.

Figure 3 illustrates their responses:

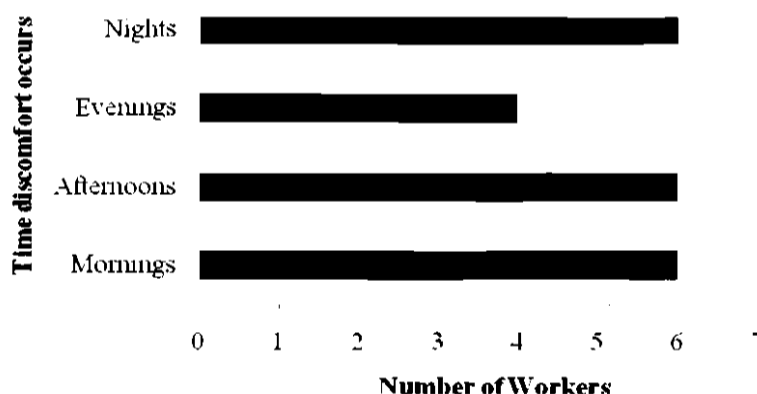


Figure 3. Time Discomfort Regularly Occurs

As indicated in Figure 3 above, sixty-seven percent of the workers are experiencing discomfort throughout the entire day.

Survey question five asked the workers to most accurately describe their discomfort from a list provided. Figure 4 illustrates the responses:



Figure 4. Description Which Most Accurately Describes Discomfort

The responses above in Figure 4 indicate that the top three forms of discomfort are: sixty-seven percent aching, fifty-six percent tingling and forty-four percent of workers are experiencing numbness.

Survey question six asked the workers whether the discomfort they are feeling hinders their daily work activities. Forty-four percent of the workers responded that the discomfort they are experiencing does in fact hinder their daily work activities.

The seventh survey question asked the workers to what extent the discomfort hinders their daily work activities. Figure 5 provides the responses:

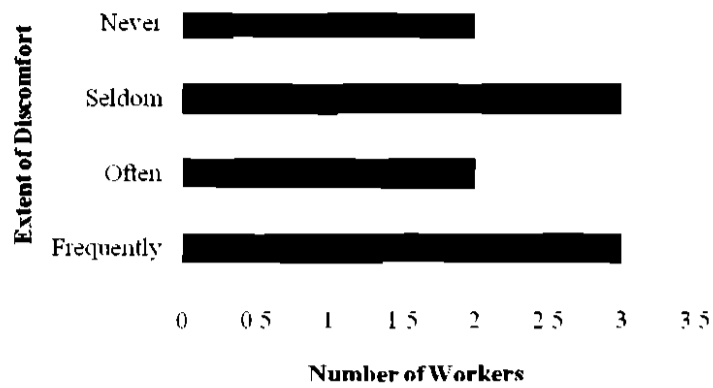


Figure 5. Extent of Discomfort Hindering Daily Work Activities

As indicated in Figure 5, the responses indicate that thirty-three percent of the workers are frequently feeling discomfort that does hinder daily work activities.

The eighth question in the survey asks the workers to indicate whether they have received any medical treatment for the discomfort or pain. Fifty-six percent of the workers answered that they have received medical treatment for the discomfort.

Survey question nine asked if any of the symptoms experienced have caused problems with sleeping. Sixty-seven percent of the workers indicated that they have had problems with sleeping due to the experienced symptoms.

The last question in the survey asked whether the workers complete any tasks or duties away from work that give them discomfort. Fifty-six percent of the workers indicated that they do complete tasks or duties away from work that give them discomfort.

Goal #3

Workplace design/cart design. The third goal of this study was to analyze the adhesive application process workstation and cart design. The researcher achieved this goal by measuring the dimensions and sizes of workstation and cart design. The dimensions are as follows:

- Distance from CNC machine to staging area is twenty-five feet.
- Width of opening to move cart inside adhesive application process booth is sixteen feet.
- Distance from the front of the staging area to the scissor lift in booth is twelve feet.
- Distance from adhesive application process booth to next process is forty-seven feet.
- Cart is four feet in width.
- Cart is eight feet in length.
- Cart wheel radius of six inches.
- Cart wheel thickness of two inches.
- Carts stand nine and one-quarter inches off the ground.

The dimensions of the workplace and cart design listed above were used in conjunction with joint angle measurements in the RULA and REBA surveys to develop the final RULA and REBA score.

Goal #4

Loss analysis. The fourth goal of this study was to identify all injuries the organization has incurred within the past three years. The researcher did this by analyzing all injury/illness losses that Company XYZ has suffered throughout the past three years. Figure 6 below illustrates the injuries/illnesses suffered:

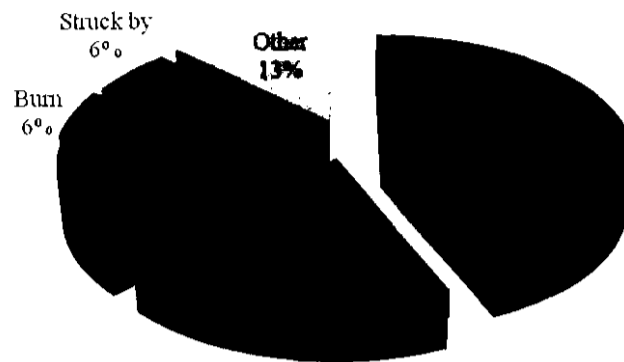


Figure 6. Injuries and Illnesses Occurred at Company XYZ

As indicated in Figure 6, the back accounts for forty-four percent of all injuries/illnesses suffered at Company XYZ throughout the past three years. The remaining injuries followed in order: nineteen percent cuts, thirteen percent other, twelve percent were eye injuries, six percent were burns and another six percent were struck by injuries.

Goal #5

Cost justification. The fifth goal of this study was to develop a cost justification for improvements. A double discount cost effectiveness comparison was used to accurately predict a return on investments. The double discount cost effectiveness comparison is listed in Table 6 below:

Table 6: *Double Discount Cost Effectiveness Comparison*
Cost Effectiveness Comparison

	1	2	3	4	5	6	7
			(1 x 2)		(3 x 4)		(5 / 6)
Year	Potential Average Payment for One Injury	Goal - # of Injuries Being Eliminated	Total Cost Savings In Current Dollars	Average Inflation Factor (1+Infl. Rate) n-1	Actual Savings In Future Dollars	Discount Factor (1 + Minimum Desired Rate of Return on Investment) n-1	Present Value of Future Savings
1st	\$6,500	2	\$13,000	(1.10) ⁰ = 1	\$13,000	(1.11) ⁰ = 1	\$13,000
2nd	\$6,500	2	\$13,000	(1.10) ¹ = 1.10	\$14,300	(1.11) ¹ = 1.11	\$12,883
3rd	\$6,500	2	\$13,000	(1.10) ² = 1.21	\$15,730	(1.11) ² = 1.23	\$12,789
4th	\$6,500	2	\$13,000	(1.10) ³ = 1.33	\$17,290	(1.11) ³ = 1.37	\$12,620
5th	\$6,500	2	\$13,000	(1.10) ⁴ = 1.46	\$18,980	(1.11) ⁴ = 1.52	\$12,487
6th	\$6,500	2	\$13,000	(1.10) ⁵ = 1.61	\$20,930	(1.11) ⁵ = 1.69	\$12,385
7th	\$6,500	2	\$13,000	(1.10) ⁶ = 1.77	\$23,010	(1.11) ⁶ = 1.87	\$12,305
8th	\$6,500	2	\$13,000	(1.10) ⁷ = 1.95	\$25,350	(1.11) ⁷ = 2.07	\$12,246
9th	\$6,500	2	\$13,000	(1.10) ⁸ = 2.13	\$27,690	(1.11) ⁸ = 2.30	\$12,039
10th	\$6,500	2	\$13,000	(1.10) ⁹ = 2.36	\$30,680	(1.11) ⁹ = 2.56	\$11,984
11th	\$6,500	2	\$13,000	(1.10) ¹⁰ = 2.59	\$33,670	(1.11) ¹⁰ = 2.84	\$11,856
12th	\$6,500	2	\$13,000	(1.10) ¹¹ = 2.85	\$37,050	(1.11) ¹¹ = 3.15	\$11,762
13th	\$6,500	2	\$13,000	(1.10) ¹² = 3.13	\$40,690	(1.11) ¹² = 3.50	\$11,626
14th	\$6,500	2	\$13,000	(1.10) ¹³ = 3.45	\$44,850	(1.11) ¹³ = 3.88	\$11,559
15th	\$6,500	2	\$13,000	(1.10) ¹⁴ = 3.80	\$49,400	(1.11) ¹⁴ = 4.31	\$11,462
							8. (Sum Col. #7) Total Present Value of Injury Payments
							\$183,003
							9. (Subtract) Cost of Controls
							-
							10. Present Value of Savings for Program
							\$15,000
							\$168,003

Required Data

Average Cost of <u>MSD</u> Injury	\$6,500	(1)	
Life Expectancy of Control (write off period in years)	20	-	Payback Period <u>1 Year 2 months</u>
Goal: # of <u>2</u> (2) Injuries to be Prevented/Year	13,000	(3)	(Determine from Column 7)
Cost of Controls	\$15,000	(9)	The payback period is the time period needed for total savings realized to equal the original investment.
Company's Opportunity Cost of Capital			
Minimum Desired Rate of Return on Investment	11%	(6)	
Average Inflation Rate Over Write-Off Period	10%	(4)	

Table 6 indicates that Company XYZ will receive a payback period of one year and six months by investing on the controls to reduce the cost of injuries. The technique reveals that a capital investment for designed equipment or processes will reduce worker injury costs of \$168,003. Company XYZ would like a desired rate of thirteen percent return on investments. It will cost \$15,000 to implement changes to the cart design and processes. Also, they have an average inflation rate of ten percent.

Discussion

According to the results of the methodology used in this study, there are various risks involved when workers move carts throughout the adhesive application process. As identified in the assessments conducted on the digital stills, flexion of the back and trunk as well as reaching above shoulder height is prevalent to the development of MSD's. Workers must reach down to the ground to handle the carts and move them throughout the process. This requires flexion of the back and trunk, causing the worker to reach at or above shoulder height to maneuver the carts to the desired destination. A study indicated in the literature review that pulling and pushing tasks are associated with lower back pain and are considered risk factors for musculoskeletal problems in the manual handling tasks (Hoozemans, et al., 1998).

The cost justification will total up the monetary value of the benefits and costs to the implementation allowing Company XYZ to evaluate whether the implementation of controls will result in a return on investment for the company. The cost justification will allow the company to predict what rate of return and length of time it will take for payback from the implementation. Shareholders and management will pay attention to these numbers because they are concerned with the bottom line: profit. In the literature review the author indicates that when justifying the cost, one simple concept should be applied: "the benefits of an improvement should outweigh the cost" (Wynn, 2004, p. 2).

Chapter V: Conclusions and Recommendations

The purpose of this study was to identify and evaluate specific areas of the adhesive application process that may increase the risk and/or contribute to the development of musculoskeletal illnesses. The goals of this study were to identify and evaluate the risk associated with musculoskeletal illnesses. The goals are as follows:

- Conduct quantitative surveys on employees to determine the extent of the problem.
- Conduct qualitative observations and survey employees to determine the extent of the problem.
- Analyze the adhesive application process workstation and cart design.
- Identify all injuries the organization has incurred within the past three years.
- Develop a cost justification for improvements.

Summary

Restatement of the Problem

The occurrence of employee complaints of shoulder and lower back pain while maneuvering carts during the adhesive application process at Company XYZ is placing the employees at risk of developing musculoskeletal illnesses.

Methods used

The researcher used three different analysis tools to collect data in this study. The RULA and REBA analysis tools were used to evaluate workers pushing and/or pulling the carts. The symptoms survey was used to identify possible symptoms or discomfort workers may be experiencing or have experienced. Two instruments were also used to generate joint angles, range of motion, and force used to push and pull carts. They are as follows: manual goniometer

and force gauge. Also, three other additional analyses: a workstation/cart design analysis, loss analysis and a cost justification were used.

Major Findings

The RULA survey tool used in the study generated final scores of seven, which indicate that the process should be investigated and redesigned to minimize overexertion exposures. The REBA survey tool generated scores of nine and ten which indicate the process is high risk. The symptoms survey indicated workers moving carts throughout the adhesive application process have and/or are experiencing discomfort. Company XYZ's past loss experience indicated that back injuries are the leading injury suffered at Company XYZ throughout the past three years. The cost effectiveness comparison justified potential cost savings for Company XYZ.

Conclusions

Based on the data collected throughout the study, the following conclusions can be made from the results found on workers moving carts throughout the adhesive application process. The conclusions are as follows:

- The survey tools used throughout the study identified that the process should be investigated and redesigned to better accommodate the workers. This was concluded due to workers reaching down low to the ground to handle carts and move them throughout the process. This requires flexion of the back and trunk, causing the worker to reach at or above shoulder height to maneuver the carts to the desired destination.
- Based on the symptoms survey conducted, most workers have and/or are currently experiencing discomfort. The back and upper limbs are the most prevalent area of discomfort experienced, having frequent feelings of soreness and/or pain. Most

workers are experiencing discomfort throughout the day, and this hinders their daily work activities.

- Symptoms survey findings concluded that workers experiencing discomfort could potentially lead to financial loss to Company XYZ. Workers discomfort can develop into musculoskeletal illnesses causing direct and indirect costs to Company XYZ.
- The task analysis conducted identified that workers are routinely exposed to flexion and extension of the neck, flexion of the back, reaching below and above shoulder height, flexion of the trunk, static force, and flexion and extension of the wrists.
- Workstation design and cart design in the adhesive application process seems to be exposing workers to risk factors: extreme force, awkward postures, repetitive motions, and mechanical stresses with the possibility of vibration. The risk factors were found throughout the study, so it can be concluded that they could be the main contributors to the development of musculoskeletal illness.
- Looking at the loss analysis, back injuries are occurring more frequently than any other injury, increasing the possibility of higher worker's compensation costs.
- The cost justification indicated that a capital investment for designed equipment or processes could significantly reduce worker injury costs.

Recommendations

Based on the conclusions, the following controls are recommended to reduce the exposure of risk factors and the development of musculoskeletal illnesses from moving carts throughout the adhesive application process.

Engineering Controls

- Work with the engineering department to develop handles for the cart. The handles can be accessible for both ends and sides of the cart depending on the size of ceiling and wall panels being stacked on the cart. This will allow workers to push the cart without severe flexion of the back and trunk.
- Provide workers with padded gloves to prevent mechanical stressors when pushing or pulling carts. The exposure of workers' tendons is reduced from pressing on hard and/or sharp objects. As indicated in the literature review, mechanical stressors generally occur while grasping, leaning, balancing, pushing and pulling.
- Consider using swivel offset casters to help turn and pivot cart wheels to reduce static force needed to initiate movement of the carts.
- Use large diameter wheels within casters to help rollover irregulars and foreign substances such as cracks, debris, and adhesive application material.
- Reevaluate the workstation after the process improvements have been implemented.

Administrative Controls

- Train workers on the use of the cart handles and the importance of always using them.
- Train and encourage workers to push carts instead of pulling them. Pulling carts involves flexion of the neck, twisting of the neck and severe flexion of the back and trunk.

- Train workers to evenly load carts which will distribute weight throughout the entire cart.
- Develop a stretching program immediately at the beginning of a shift and during shift hours.
- Establish a rotation schedule that rotates workers in and out of the adhesive application process for the task of moving carts.
- Consider using two people to move carts in tandem which will decrease the amount of static force required to move the carts and alleviate routine stress on the body.
- Have a process in place to conduct preventative maintenance of the carts to identify whether the casters are working correctly and up to their operational potential.
- Implement a scheduled floor cleaning within the adhesive application booth to reduce the added friction that impedes the progress of the cart wheels.
- Reevaluate the process if and when improvements are made to assess the effectiveness of implementations.

Areas of Further Research

To more thoroughly investigate the possible development of musculoskeletal illnesses at Company XYZ, a researcher could conduct the following analysis in order to identify the risk factors that are apparent:

- A force gauge was used to quantify the amount of static force required to initially begin manually moving the carts. The wheels used on these carts to move throughout the process may be inhibiting the consistent movement of the cart. An

analysis could be conducted to determine whether the appropriate wheels are used on the facility's flooring and whether the excess material from the adhesive application is causing the wheels to stick to the floor.

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Appendix A: Symptoms Survey

Symptoms Survey: Ergonomics

This statement has been approved by the IUPUI Institutional Review Board of Human Subjects Title 45 Part 46.

1. Does your present job involve arm, hand, shoulder or finger actions to be repeated many times throughout an hour?
 - Yes
 - No

2. Have you experienced any pain discomfort or tingling in your shoulders, arms, wrists or back within the past 2 months? (check all that apply)
 - Left Shoulder
 - Right Shoulder
 - Left Arm
 - Right Arm
 - Left Wrist
 - Right Wrist
 - Upper Back
 - Mid-Back
 - Lower Back
 - No, I have not experienced any pain. Please skip to question 10.

3. Have you experienced any frequent feelings of soreness or pain in any of the selected above in question 1, within the past 2 months? (check all that apply)
 - Left Shoulder
 - Right Shoulder
 - Left Arm
 - Right Arm
 - Left Wrist
 - Right Wrist
 - Upper Back
 - Mid-Back
 - Lower Back
 - No, I have not experienced any frequent feelings.

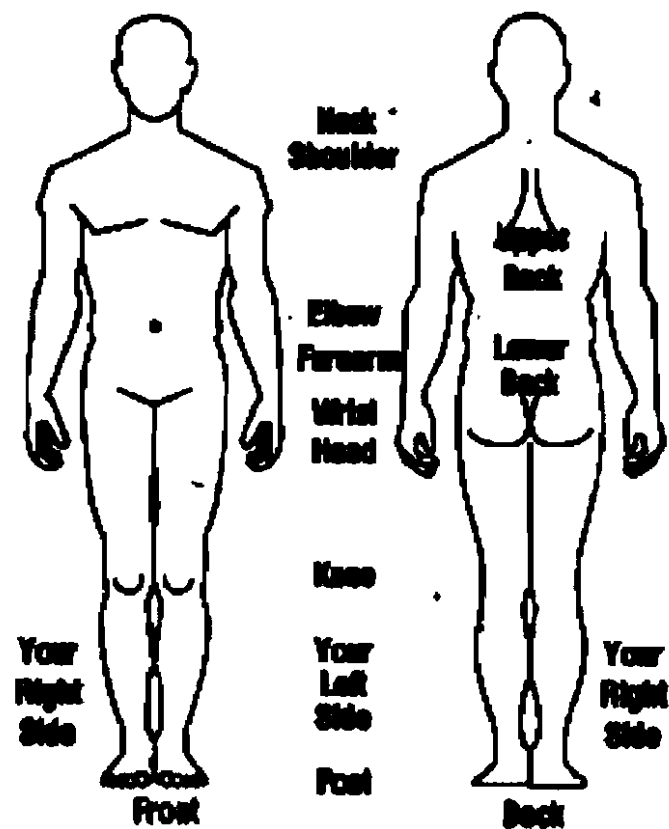
4. What time does your discomfort tend to regularly occur?
 - Mornings
 - Afternoons
 - Evenings
 - Night

5. Please put a check by the word(s) that most accurately describes your discomfort.
 - Aching
 - Numbness
 - Tingling
 - Burning
 - Weakness
 - Cramping
 - Swelling
 - Stiffness
 - Other

***Please Turn Over For Further Questions.**

6. Does your discomfort (ie. Shoulders, arms, wrists or back) hinder your daily work activities?
 Yes
 No
7. To what extent does your discomfort hinder your daily work activities?
 Frequently
 Often
 Seldom
 Never
8. Have you ever received medical treatment for the discomfort or pain?
 Yes
 No
9. Have any of the symptoms described above caused problems with sleeping?
 Yes
 No
10. Do you complete any tasks or duties away from work that give you pain or discomfort?
 Yes
 No

Please Shade in the areas that bothers you most.



Appendix B: RULA Survey Pushing Cart

PUSHING LOADED CART THAT IS STACKED HIGH.

RULA Employee Assessment Worksheet

Complete this worksheet following the step-by-step procedure below. Keep a copy in the employer's personnel folder for future reference.

A. Arm & Wrist Analysis

Step 1: Assign a score to the posture shown in the diagram. The score is based on the frequency of the posture and the range of motion.

Step 2: Look-up Posture Score in Table A.

Step 3: Assign a score to the posture shown in the diagram. The score is based on the frequency of the posture and the range of motion.

Step 4: Assign a score to the posture shown in the diagram. The score is based on the frequency of the posture and the range of motion.

Step 5: Assign a score to the posture shown in the diagram. The score is based on the frequency of the posture and the range of motion.

B. Neck, Trunk & Leg Analysis

Step 6: Assign a score to the posture shown in the diagram. The score is based on the frequency of the posture and the range of motion.

Step 7: Assign a score to the posture shown in the diagram. The score is based on the frequency of the posture and the range of motion.

Step 8: Assign a score to the posture shown in the diagram. The score is based on the frequency of the posture and the range of motion.

Step 9: Assign a score to the posture shown in the diagram. The score is based on the frequency of the posture and the range of motion.

SCORES

Posture	Frequency	Score
1	1	1
2	1	2
3	1	3
4	1	4
5	1	5
6	1	6
7	1	7
8	1	8
9	1	9
10	1	10
11	1	11
12	1	12
13	1	13
14	1	14
15	1	15
16	1	16
17	1	17
18	1	18
19	1	19
20	1	20
21	1	21
22	1	22
23	1	23
24	1	24
25	1	25
26	1	26
27	1	27
28	1	28
29	1	29
30	1	30
31	1	31
32	1	32
33	1	33
34	1	34
35	1	35
36	1	36
37	1	37
38	1	38
39	1	39
40	1	40
41	1	41
42	1	42
43	1	43
44	1	44
45	1	45
46	1	46
47	1	47
48	1	48
49	1	49
50	1	50

Final Score 7

Subject: IBC PIA/DUL Adverse Application Date: 11/11/08
 Company: XNZ Department: Process Scorer: TV

FINAL SCORE: 1 or 2 = Acceptable; 3 or 4 Investigate further and change score; 5 or 6 Investigate further and change score; 7 Investigate and change immediately

© Professor Alan Hedge, Cornell University, New York

Appendix C: RULA Survey Pulling Cart

PULLING CART #1

RULA Employee Assessment Worksheet

Complete this worksheet following the step-by-step procedure below. Keep a copy in the employer's personnel folder for future reference.

Step 1: Arm & Wrist Analysis

Posture 1: 4
Posture 2: 2
Posture 3: 3
Posture 4: 1
Posture 5: 4

Step 2: Neck, Trunk & Leg Analysis

Posture 1: 2
Posture 2: 4
Posture 3: 4
Posture 4: 1
Posture 5: 5

SCORES

Posture	1	2	3	4	5
1	1	2	3	4	5
2	2	3	4	5	6
3	3	4	5	6	7
4	4	5	6	7	8
5	5	6	7	8	9

Final Score: 7

Subject: ONE KARL PAUL **Department:** ALTERN APPLICATION **Date:** 11/11/08
Company: XYZ **Boiler:** TR **Scorer:** TR

Step 16: Final Overall Rating
 1 Investigate and change immediately
 2 Investigate and change soon
 3 or 4 Investigate further
 5 or 6 Investigate further
 7 Investigate and change soon
 8 or 9 Investigate further

FINAL SCORE: 1 or 2 = Acceptable; 3 or 4 Investigate further; 5 or 6 Investigate further and change soon; 7 Investigate and change immediately

Appendix D: REBA Survey Pushing Cart

REBA

Rapid Entire Body Assessment (REBA)

Date: 11 / 11 / 08

Task: CART PUSH	Analyst: TK
-----------------	-------------

Group A		Group B		Total: Left and Right	
Feature/Range	Score	Feature/Range	Score		
Trunk		Upper Arms (Shoulders)			
Upright	1	Flexion: 0-20° Extension: 0-20°	1	Arm Abducted / Rotated: +1	
Flexion: 0-20° Extension: 0-20°	2	Flexion: 20-45° Extension: >20°	2	Shoulder Raised: +1	
Flexion: 20-60° Extension: >20°	3	Flexion: 45-90°	3	Arm Supported: -1	
Flexion: >60°	4	Flexion: >90°	4		
Neck		Lower Arms (Elbows)			
Flexion: 0-20°	1	Flexion: 60-100°	1	No Adjustments	
Flexion: >20° Extension: >20°	2	Flexion: <60° Flexion: >100°	2		
Legs		Wrists			
Bilateral W/ Bearing: Walk; Sit	1	Flexion: 0-15° Extension: 0-15°	1	Wrist Deviated / Twisted: +1	
Unilateral W/ Bearing: Unstable	2	Flexion: >15° Extension: >15°	2		
Score from Table A	5	Score from Table B	5		
Load / Force		Coupling			
< 5 kg < 11 lb	0	Good	0	No Adjustments	
5 - 10 kg 11 - 22 lb	1	Fair	1		
> 10 kg > 22 lb	2	Poor	2		
Score A [Table A + Load/Force Score]	7	Unacceptable	3		
Activity	0	Score B [Table B + Coupling Score]	3		
One or more body parts are static for longer than 1 minute	+1	Score C (from Table C)	3		
Repeat small range motions, more than 4 per minute	+1	Activity Score	0		
Rapid large changes in posture or unstable base	+1	REBA Score [Score C + Activity Score]	3		

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(HIGH RISK)

Appendix E: REBA Survey Pulling Cart

REBA

Rapid Entire Body Assessment (REBA)

Date: 11/11/08

Task: CART PULL #1		Analyst: TK	
Group A		Group B	
Trunk		Upper Arms (Shoulder)	
Upright	1	Flexion: 0-30° Extension: 0-30°	1
Flexion: 0-30° Extension: 0-30°	2	Flexion: 30-45° Extension: >30°	2
Flexion: 30-60° Extension: >30°	3	Flexion: 45-90°	3
Flexion: >60°	4	Flexion: >90°	4
If neck is twisted or tilted to side: +1		Arm Abducted / Rotated: +1	
		Shoulder Bolster: +1	
		Arm Supported: -1	
Neck		Lower Arms (Elbow)	
Flexion: 0-30°	1	Flexion: 60-100°	1
Flexion: >30° Extension: >30°	2	Flexion: <60° Flexion: >100°	2
If neck is twisted or tilted to side: +1		No Adjustments	
Leg		Wrist	
Bilateral Wt Bearing: Walk; Sit	1	Flexion: 0-15° Extension: 0-15°	1
Unilateral Wt Bearing: Unstable	2	Flexion: >15° Extension: >15°	2
Knee(s) Flexion 30-60°: +1		Wrist Deviated / Twisted: +1	
Knee(s) Flexion >60°: +2			
Score from Table A		Score from Table B	
Load / Force		Coupling	
< 5 kg < 11 lb	0	Good	0
5 - 10 kg 11 - 22 lb	1	Fair	1
> 10 kg > 22 lb	2	Poor	2
Shock or Rapid Buildup: +1		Unacceptable	
Score A [Table A + Load/Force Score]		Score B [Table B + Coupling Score]	
Activity		Score C (from Table C)	
One or more body parts are static for longer than 1 minute	+1	Activity Score	
Repeat small range motions, more than 4 per minute	+1	REBA Score [Score C + Activity Score]	
Rapid large changes in posture or unstable base	+1		

(HIGH RISK.)