An Ergonomic Analysis of the Seat-Sewing Line at Company XYZ.

by

Joshua Check

A Research Paper
Submitted in Partial Fulfillment of the
Requirements for the
Master of Science Degree
in

Risk Control

Approved: 2 Semester Credits

Dr. Brian Finder, C.I.H.

The Graduate School

University of Wisconsin-Stout

May, 2010

The Graduate School
University of Wisconsin-Stout
Menomonie, WI

Author: **Check, Joshua**

Title: ***An Ergonomic Analysis of the Seat-Sewing Line at Company XYZ.***

Graduate Degree/ Major: MS Risk Control

Research Adviser: **Dr. Brian Finder, CIH**

Month/Year: **May, 2010**

Number of Pages: **87**

Style Manual Used: **American Psychological Association, 6th edition**

Abstract

The continued presence of arm and wrist-oriented musculoskeletal disorder risk factors on the seat-sewing line at Company XYZ is placing the organization at risk of incurring continued employee illness and other production/financial forms of loss. The past four years of OSHA recordable injuries, the results of the ergonomic-based risk factor assessment methods of the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment(REBA), and an employee symptom survey were compared to recognition and remediation measures for musculoskeletal disorders (MSDs) that have been identified in professional literature on the topic. The research results indicate that awkward postures, high repetition, and small-range motions are all present in the top-stitch sewing process. Upper extremity injuries relating to MSDs were the only causes of lost time away from work in the sewing line for the past four years. The seat-sewing line currently has several administrative and engineering controls in place to prevent the occurrence of cumulative trauma disorders (CTDs), but the system is new and has an absence of enforcement and education. The conclusions of this research are that a

selection of administrative and engineering controls that educate the workers and physically remove the risk factors from the seat-sewing process can be implemented to reduce the ergonomic-related risk factors that are present while workers perform the top-stitch activity.

The Graduate School
University of Wisconsin Stout
Menomonie, WI

Acknowledgments

My journey through the Risk Control program has been made possible through the assistance of many people that I would like to thank. First, I would like to thank my advisor Dr. Brian Finder for his patience, expertise, understanding, and guidance through the completion of my thesis. I would also like to thank my family, close friends, and classmates for all the assistance and support they have provided to me over the past two years of my graduate studies. Without their support, I would not have been able to accomplish everything that I have. Also, I want to thank the company where I did my research, their passion for creating a safe environment and quality product made my research enjoyable and educational. Finally, a special thank you to my brother Ryan, without his guidance and assistance, this entire process would not have been possible.

Table of Contents

Page

Abstract ... 2

List of Tables ... 8

List of Figures ... 9

Chapter I: Introduction ... 10

Purpose of the Study ... 12

Goals of the Study ... 12

Background and Significance ... 13

Limitations of the Study ... 13

Assumptions of the Study ... 13

Definition of Terms ... 13

Chapter II: Literature Review ... 15

Benchmarking Ergonomic Losses ... 15

Ergonomic Risk Factors ... 18

Types of Ergonomic-Related Injuries/Illnesses ... 21

Ergonomic Assessment Tools ... 24

Rapid entire body assessment ... 25

Rapid upper limb assessment ... 28

Vibration monitor ... 31

Manual goniometer ... 32

Video analysis ... 32

Force gauge ... 33

Questionnaire 33

Anthropometrics/Design Considerations 34

Ergonomic Control Measures/Approaches 37

Administrative controls 37

Engineering controls 39

Personal protective equipment 40

Summary 45

Chapter III: Methodology 46

Subject Selection and Description 46

Instrumentation 47

Data Collection Procedures 48

Data Analysis 50

Limitations 51

Chapter IV: Results 52

Presentation of Collected Data 52

Goal number one 52

Rapid entire body assessment (REBA) 53

Rapid upper limb assessment (RULA) 54

Ergonomic risk factor checklist 55

Manual goniometer 56

Force gauge 57

Vibration monitor 58

Goal number two 58

Goal number three....60

Symptom survey....60

Discussion....65

Chapter V: Conclusions and Recommendations....70

Major Findings....71

Conclusions....71

Recommendations....73

Engineering controls....73

Elimination....74

Administrative controls....74

Areas of Further Research....75

References....77

Appendix A: Human Subject Consent Form....84

Appendix B: REBA Assessment of Seat-Sewing Line....86

Appendix C: RULA Assessment of Seat-Sewing Line....87

Appendix D: Ergonomic Risk Factor Checklist....88

Appendix E: Symptom Survey....90

List of Tables

Table 1: REBA Assessment Scoring Table 53

Table 2: RULA Assessment Scoring Table 54

Table 3: Ergonomic Risk Factor Checklist 55

Table 4: Force Analysis for Top-Stitch 58

Table 5: Recordable Injuries in the Seat Division 59

Table 6: Question Number One Answers 61

Table 7: Question Number Two Answers 62

Table 8: Question Number Three Answers 63

Table 9: Question Number Four Answers 64

Table 10: Question Number Five Answers 65

List of Figures

Figure 1: Rapid Entire Body Assessment Worksheet....27

Figure 2: Rapid Upper Limb Assessment Worksheet....30

Figure 3: Ergonomic Risk Factor Checklist....43

Chapter I: Introduction

Ergonomics, also known as the study of the design of work in relation to the physiological and psychological capabilities of people, plays a large part in preventing musculoskeletal disorders (MSDs) from occurring (Chengular, Rodgers, & Bernard 2004). For the most part, MSDs are induced slowly over a significant period of time due to deficiencies in how the work environment is designed. These disorders accounted for 29% of all workplace injuries nationwide in 2007 that required personal healing time away from work (Bureau of Labor Statistics, 2008).

Ergonomic hazards include repetitive and forceful movements, vibration, temperature extremes, and awkward postures that arise from improper work methods and/or poorly designed workstations, tools, and equipment (Canadian Centre for Occupational Health and Safety, 2009). Ergonomics has two distinct aspects: (1) study, research, and experimentation, which determines specific human traits and characteristics needed to know for engineering design and (2) the application and engineering, in which tools, machines, shelter, environment, work tasks, and job procedures are designed to fit and accommodate the human (Kroemer, Kroemer, & Kroemer-Elbert, 1994). In order to minimize the chance for an MSD to occur, it is generally accepted that the physical environment must accommodate the widest range of human functional limitations to enhance the usability of any area (Kearney, 2008).

Industrial sewing is a physically demanding job that has several ergonomic hazards associated with it. Workers involved in sewing activities, such as manufacturing garments, shoes, and airplane or car upholstery may be at risk of developing musculoskeletal disorders (MSDs). Sewing-related injuries have been documented in the areas of sewing stations, performing fine work or scissor work, and material handling, among others (OSHA, 2009).

Sprains and strains, which are two types of MSDs, are caused by excessive reaching, bending, gripping, or twisting of hands and shoulders (North Carolina Department of Labor, 2009). In 2005, 95 percent of injuries in the sewing and needlework industry were due to strains and sprains (Bureau of Labor Statistics, 2008).

Company XYZ is a manufacturer of recreational products that are used on snow, dirt, and paved roads. They have demonstrated innovation by selling market leading products and are a leader when it comes to the reliability of recreational products. The company as a whole embodies the belief that the products they make are a direct reflection of their passion for these sports. Company XYZ's manufacturing facility was started in 1991, when it was primarily used for stamping operations with 121 people working under one roof. Today, the facility employs over 800 people who work in manufacturing production, manufacturing engineering, recreational product design, and developmental engineering. The main facility covers nearly 200,000 square feet and is responsible for supplying component assemblies to the vehicle assembly plants in other cities. This plant's four business units consist of fabrication, seats, drive train, and exhaust.

Company XYZ's facility has several seat manufacturing processes which produces all of the seats for their product lines. Of the three major forms of seats, the first type is a foam pad which is mounted to a plastic plate by a heavy duty adhesive. This seat utilizes one large piece of vinyl to wrap the foam for a finished look. The next type of seat is a foam pad that has an alligator-like skin automatically sprayed onto it and thus there is no need for stretching the seat cover around the foam. The last type of seat is injection molded foam which has the fabric stretched over it and a plastic backer which is then pushed inside of the vinyl wrap. The vinyl for this seat has two different stitches that are used to hold it together. The first type is a single stitch, which is one line of thread that secures two pieces of vinyl fabric together. The second type is a top-stitch that is completed by first performing a single stitch, pulling the material back across itself very tight, and then a second line of thread is applied to give the intersection of the two fabrics a different appearance.

A cursory ergonomic-based assessment has identified that the three most notable risk factors for sewing fabric on the seats is abducting of the arms (i.e. raising the upper arm away from the body), extreme deviation of the wrists, and high repetition. These posture-related risks have a high potential to contribute to the cause of MSDs. In the past four years there have been four lost time injuries and there is still a potential for more musculoskeletal and cumulative trauma disorders. Due to the seriousness of MSDs and considering the rate at which employees have been injured in the seat sewing line it is apparent that more MSDs and cumulative trauma disorders (CTDs) will occur. The occurrence of these four injuries has cost the company money in lost productivity. Thus, the continued presence of arm and wrist-oriented musculoskeletal disorder risk factors on the seat-sewing line at Company XYZ is placing the organization at risk of incurring continued employee illness and other production/financial forms of loss.

Purpose of Study

The purpose of this study is to analyze the seat-sewing line at Company XYZ in order to determine the extent that ergonomic-based risk factors are present.

Goals of This Study

1. Perform a task analysis for the existing seat-sewing line using quantitative-based tools.

2. Review injury records and determine all ergonomic-based injuries that are associated with the seat-sewing process.

3. Perform qualitative surveys on employees and the tasks they perform to determine the extent of the problem.

Background and Significance

Since the introduction of a new product line in 2006, there have been four repetitive-based injuries associated with the seat-sewing line that have symptoms of being MSD related. This study has the potential to reduce the amount of injuries through the identification of the hazard causing factors. Through the reduction of MSD related injuries it will lower the workers compensation costs associated with the sewing department. Positive effects on productivity and quality may also be noticed through the improvement of existing workstations and overall employee safety.

Limitations of the Study

1. The employee's willingness to participate with this study may alter the results.
2. The analyzed process, conclusions, and recommendations for this study are only applicable to the seat sewing line at Company XYZ.

Assumptions of the Study

1. Employee responses in the questionnaire will be truthful and accurate.
2. Records that have been maintained on employee injuries are accurate and up-to-date.

Definition of terms

Anthropometry. The measurement and collection of the physical dimensions of the human body. It is used to improve the human fit in the workplace or to determine problems existing between facilities or equipment and the employees using them (Friend & Kohn, 2007).

Cumulative Trauma Disorders (CTD). Also referred to as repetitive motion injuries, result from excessive use of the hand, wrist, or forearm. Most common CTD's are carpal tunnel syndrome, cubital tunnel syndrome, tendinitis, and tenosynovitis (Friend & Kohn, 2007).

Ergonomics. The study of the design of work in relation to the physiological and psychological capabilities of people. The aim of the discipline is the evaluation and the design of facilities, environments, jobs, training methods, and equipment to match the capabilities of the users and workers, and thereby to reduce the potential for fatigue, error, and unsafe acts (Chengular, et al., 2004).

Musculoskeletal Disorders (MSD). Disorders of the muscles, tendons, ligaments, joints, cartilage, nerves, blood vessels, or spinal discs. Some examples are muscle strains, ligament sprains, joint and tendon inflammation, pinched nerves, and spinal disc degeneration (Chengular, et al., 2004).

Repetition. Repetition is the number of a similar exertions performed during a task. A warehouse worker may lift three boxes per minute from the floor to a countertop; an assembly worker may make 20 units per hour. Repetitive motion has been associated with injury and worker discomfort (ErgoWeb, 2009).

Chapter II: Literature Review

The purpose of this study was to analyze the seat-sewing line at Company XYZ in order to determine the extent that ergonomic-based risk factors are present. Employees in this process are potentially exposed to several ergonomic risks that have been proven to develop into musculoskeletal illnesses. In this chapter, the researcher will present a review of literature that involves the explanation of ergonomic losses, the risk factors associated with musculoskeletal illnesses, and the tools or controls which are used to implement the best technique for correction. Through the recognition of ergonomic risk factors and the implementation of proper controls, it will be possible to decrease the amount of musculoskeletal illnesses that employees develop.

Benchmarking Ergonomic Losses

One of the methods for recognizing the potential presence of uncontrolled ergonomic risk factors is through the benchmarking of ergonomic loss. Benchmarking of ergonomic loss can be broken down into two categories, reactive and proactive. Both of these benchmarking methods are used in unison to create an effective before and after system of determining employee exposure. The first method is reactive, which is used in industry to base the effectiveness of their safety/loss prevention programs. The reactive method analyzes losses that have already occurred and determines whether they were due to an equipment failure or human error. This method is not a transferable practice for correcting issues, because it will only identify and solve one specific problem before its usefulness is exhausted (Chengular, et al., 2004).

There are several reactive measurement-based rates and computations that can quantify or compare a company's past safety record. One of these measurement methods is the OSHA recordable incident rate. The OSHA rate is a calculation that describes the number of employees per 100 full-time employees who have been involved in a recordable injury or illness (OSHA, 2009). For many companies, incident rates remain the primary indicator of safety performance measurement. This is primarily because incident rates are fairly easy to calculate, can be easily compared between one company to another, and are used by both OSHA and industry (Rochester, 2008).

In 1997, the National Institute of Occupational Safety and Health (NIOSH) explained that proactive approaches to workplace ergonomics programs emphasize prevention of workplace musculoskeletal disorders (WMSDs) through recognizing, anticipating, and reducing risk factors in the planning stages of new work processes (NIOSH, 1997). This is accomplished by having the appropriate person or system apply ergonomics principles in designing the products, workstations, work area, plants, programs, and systems (Chengular, et al., 2004).

There are several methods used in the proactive approach to preventing injuries in the workplace; questionnaires and surveys, routine work-place assessments, and routine employee training. Questionnaires and surveys are informative methods which use either paper based or computer based questions to gather employee input on processes they are performing. Here are a few example questions given by the Occupational Health and Safety Bureau of Montana;

- Do discomforts in your wrist, arm, or shoulder interfere with your daily activities?
- Are you experiencing or have recently experienced any numbness, pain, tingling, soreness, discomfort, or fatigue during or after work?
- Does your current job require arm, hand, or finger actions to be repeated many times each hour and shift (State of Montana, 2009)?

A questionnaire is reliable if this instrument elicits the same responses when it is completed by the same person under the same conditions. Since reliability is a requirement for validity, the reliability of a questionnaire should be built on the consistency of the results that are achieved

(Bridger 2009). Questionnaires and surveys are designed to gain employee attitude towards the work environment or job responsibilities and are a method of recording information about a current situation or procedure for future use (Chengular, et al., 2004).

As an important part of the proactive approach, routine work-place assessments refer to the evaluation of day-to-day working practices in the work environment. The purpose of the assessments is to qualitatively evaluate worker exposures to hazards during various jobs, the adequacy of work-place controls, and worker exposure patterns. As the complexity of technology grows, work-place hazards must be systematically assessed to establish the impact of new work operations and practices (Tait, 1992). A work-place assessment should include information on what facility the work is being performed in, the presence and location of hazards, any conditions that may have changed since previous assessments, the identification of in place controls, and any foreseeable conditions that may arise (Owen, 2003). Information from the work-place assessments should be documented to verify that a detailed evaluation was performed on a routine basis (Norcini & Burch, 2007). From a pre-loss activity standpoint, one can greatly appreciate the extent that routine assessments are a comprehensive and systematic evaluation method for determining hazards surrounding the worker and controls needed to abate the situation.

An essential component of any comprehensive ergonomics and injury prevention and management program is training (Lunda & Peate, 2002). The purpose of training and education is to provide employees, managers, and supervisors with enough relevant information so that they can take an active role in the prevention and management of ergonomic-related injuries. By knowing the risk factors and causes of ergonomic related injuries, as well as signs and symptoms associated with these ergonomic injuries, an individual can take preventative action sooner.

Lunda and Peate (2002) continue by stating that "training is ongoing, it changes as a job or company changes, should be implemented from orientation through retirement, is a process that reinforces ergonomic information, and promotes development of skills or techniques." The purpose of ongoing training and professional development is to help the employees gain the knowledge, skills, and attitudes accentuated in training programs and to apply them to their day-to-day tasks. These actions can result in earlier reporting of signs or symptoms, which will allow for an earlier intervention which results in lower costs (Lunda and Peate, 2002). In a study performed for the *American Journal of Public Health* by Burke, et al. (2006), it was found that the most effective training was accomplished by actively involving the workers, keeping the engaged in the materials being taught, and allowing them to practice hands-on activities.

Ergonomic Risk Factors

There are four major ergonomic risk factors that contribute to the development of musculoskeletal illnesses; awkward postures, excessive forces, high repetitions, and vibration. Awkward postures are extreme body-related positions that increase pressure on muscles, tendons, and nerves, or when the tendons are bunched together and are forced to operate while stretched (Tayyari & Smith, 1997). These postures are most common when employees are bending too far, reaching long distances, and twisting their spines to complete their tasks. Some examples of awkward postures include trunk postures with bending, flexion, or twisting; seated work that keeps the trunk-thigh angle about ninety degrees, and upper extremity postures such as excessive shoulder elevation, extreme elbow postures, and deviated wrists (Keyserling, Armstrong , & Punnett, 1991). It should also be noted that when the upper limbs (such as the wrist and hand) have adopted an awkward posture, the ability of the muscles to apply force is drastically reduced (Putz-Anderson, 1988). When the body is held in an awkward posture, it would seem likely that there is a potential for injury that can affect the workers' ability to complete their daily tasks.

Force is the amount of physical effort which is required by the person to perform a task and or maintain control of tools and equipment. The effort depends on type of grip, object weight, object dimensions, body posture, type of activity, slipperiness of object, temperature, the presence of pinching and vibration, duration of the task, and number of repetitions (State of Washington, 1993). In 1997, Tayyari and Smith explained that activities requiring excessive force can strain muscles and tendons, and hence increase the risk of developing cumulative trauma disorders. When muscle efforts increase due to performing a task, circulation of blood to the muscles decreases, causing the muscles to fatigue quicker (Putz-Anderson, 1988). Forces that are exerted in a task can vary, but when a force is held for an extended period of time it causes fatigue which requires the body to compensate resulting in the possibility of causing CTDs (Schoenmarklin, Marras, & Leurgans, 1994).

Repetitions are defined as performing the same motions repeatedly. The severity of risk depends on the frequency of repetition, speed of the movement or motion, the number of muscle groups involved, and the required force. Repetitiveness is often influenced by machine or line pacing incentive programs, piece work, and unrealistic deadlines (State of Washington, 1993). Repeating the same movements over and over will eventually fatigue the involved muscles. Frequent movements become much more risky if they are combined with poor postures and excessive forces. However, high frequencies of repetition, even with small forces, can cause or contribute to the development of cumulative trauma disorders (CTDs) (Tayyari & Smith, 1997). Tayarri and Smith (1997) also stated that the speed of work will influence the forces developed on the tendons of the hand, arm muscles, and this also appears to be associated with increased risk for MSDs. At higher speeds, larger peak forces are generated, and repeated work at these levels may aggravate symptoms in susceptible people (Chengular, et al., 2004). In 1988, Vern Putz-Anderson stated that when high repetition was combined with forceful and awkward postures, the worker is at risk of developing CTDs due to the recovery time being insufficient (Putz-Anderson, 1988). From this it is reasonable to conclude that high repetitions in daily tasks can fatigue the body and thus cause a worker to assume poor postures, thus compounding the chances for a MSD to occur.

Vibration is oscillatory motion, and as defined by Griffin (1990) "the motion is not constant but alternately greater and less than some average value. The extent of the oscillation determines the magnitude of the vibration and the repetition rate of the cycles of oscillation determines the frequency of the vibration" (Griffin, 1990). Griffin is stating here that vibration can be viewed as a wave moving across the water which continuously alternates between a specific high and low rate of recurrence. Vibrations through the hand and arm are transmitted to the hands through direct contact with the vibrating sources or body. Sources of vibration include industrial power hand tools such as grinders, sanders, and chainsaws. The harmful frequency range of hand and arm vibration is typically between 8 Hz and 1,500 Hz. Personal reports associated with vibration exposure include tingling sensations in the hands and a decreased ability to guide or manipulate vibrating equipment (Chengular, et al., 2004). Chengular et al. continues by stating that injuries classified as hand and arm vibration syndrome can be attributed to the exposure to high levels of hand and arm vibration which is associated with a variety of vascular and neurological symptoms (Chengular, et al., 2004). Another vibration induced disease is Raynaud's disease, which affects the blood vessels and nerves of the hand and feet, but when associated with the use of vibrating tools it is called vibration white finger or VWF. VWF is characterized by local ischemia, pain, or numbness and is caused by operating tools with low amplitude vibration below 500Hz (Bridger, 2009). Thus, it can be concluded that vibration is a movement of the equipment that is absorbed by the operator, which at certain frequencies and durations can cause illnesses to develop in the person's musculoskeletal system.

Types of Ergonomic-Related Injuries/Illnesses

Musculoskeletal disorders (MSDs) are defined as some form of degradation of the muscles, tendons, ligaments, joints, cartilage, nerves, blood vessels, or spinal discs. MSD is a term used for illnesses of the body's muscles and tendons, and a few examples are muscle strains, ligament sprains, joint and tendon inflammation, pinched nerves, and spinal disc degeneration (Chengular, et al., 2004).

As stated by author Dan MacLeod in his book, *The Ergonomics Edge: Improving Safety, Quality, and Productivity,* automation removes the aspect of human interface from the original process, creating a new human interaction at a different point in the process causing new ergonomic hazards. However, not all processes can be automated due to the lack of technology to accomplish it (MacLeod, 1995). Even though industry has shifted their manufacturing processes from a more manual based system to a more mechanized system, it is likely unable to completely mechanize processes so that human interaction is completely removed from the hazardous environment. This makes it necessary to look more closely at cumulative trauma disorders that better define MSDs.

Cumulative trauma disorders (CTDs) are repetitive-motion injuries that occur in the upper extremities, specifically the hand, wrist, or forearm. The most common CTDs are carpal tunnel syndrome and tendinitis (Friend & Kohn, 2007). In 1995, MacLeod stated that these disorders can interfere with all aspects of daily life, sometimes to the point where the simplest of work tasks, household chores, and social events can become unmanageable. Affecting the upper extremities and causing difficulty to perform everyday tasks, CTDs have become a real problem in the workplace and a closer look at them will help determine their symptoms.

Some form of a CTD may occur in most workers, and yet such individuals might not be able to recognize the symptoms that correspond with the illnesses. These basic symptoms include soreness and pain, limited range of motion, stiffness in joints, numbing and tingling, popping or cracking joints, burning sensations, redness and swelling, or weakness and clumsiness. CTDs are relatively widespread in the general population; most people have experienced this ailment at one point or another in their lives in at least a mild form, such as low back pain (MacLeod, 1995). Tayyari and Smith (1997) stated that prolonged use of the tense and fatigued muscles increase the risk of CTDs. In order to better understand some of these CTDs, a closer look will help explain the causes and effects that both carpal tunnel and tendinitis have on the human body.

The carpal tunnel is defined by Tayyari and Smith (1997) as a small tunnel-like structure in the wrist that is enclosed by eight carpal bones and the transverse carpal ligaments. Nine tendons, which function as finger flexors, and the median nerve pass through the tunnel, from forearm to the hand. Tayyari and Smith explain that sensory and motor function of the hand can be impaired when the wrist tendons become irritated and swollen, resulting from the compression forces exerted on the median nerve. Trapping and/or pinching the median nerve can increase pressure on the bony tunnel causing occasional numbness, pain and tingling in the thumb, index and middle fingers. Compressing the median nerve, which is a vulnerable structure, can produce carpal tunnel syndrome by taking up space in this already crowded tunnel (Tayyari & Smith, 1997). Carpal tunnel occurs most commonly in women of middle age or older and produces pain and paresthesia in the sensory distribution of the median nerve in the hand (Salter, 1971). There are several symptoms that can indicate the presence of carpal tunnel syndrome (CTS) these are: numbness or tingling, difficulty in moving fingers, loss of grip strength, loss of sensation in the fingers, and the feeling of swollen fingers with little or no swelling aparant (Tayyari & Smith, 1997). Carpal tunnel syndrome is a musculoskeletal illness that distresses the functionality of the wrist, often times resulting in the loss of motor and sensory functions causing the affected individual extreme discomfort.

Cubital tunnel syndrome is the second most common compressive neuropathy next to the previously explained carpal tunnel syndrome. Designated as a musculoskeletal illness, cubital tunnel syndrome affects the ulnar nerve in the elbow (Verheyden, 2009). The ulnar nerve travels through a constricted tunnel away from the axis of rotation in the elbow which requires the nerve to both stretch and slide through the cubital tunnel. The ulnar nerve can stretch up to 5 millimeters to accommodate the flexion in the elbow (Cutt, 2007). The dangerous aspect of flexion in the elbow is when the nerve slides through an ellipse-shaped tunnel compared to an oval shape when the elbow is in extension. Two of the top risk factors for cubital tunnel syndrome are holding a tool in a constant position and performing repetitive tasks (Cutt, 2007). Affected individuals often experience numbness and tingling along the little and ring fingers accompanied by weakness of grip (Cutt, 2007). Cubital tunnel syndrome is an incapacitating musculoskeletal illness that affects an individual's motor skills and sensitivity of the hand with a potential to cause wasting of the muscles in the hand and forearm (Verheyden, 2009).

Tendonitis is also considered a CTD and is defined as a tendon inflammation that occurs when a muscle/tendon unit is repeatedly tensed. Over-exertion can cause some of the fibers in the tendon to fray and tear apart, resulting in the tendon becoming thickened, bumpy, and irregular (Putz-Anderson, 1988). Exposure to non-neutral postures with high force or high repetition may cause the tendons or tendon sheaths to become inflamed or irritated. The affected body area may become inflamed as a result of this contact. Common symptoms are a dull aching sensation over the tendon, discomfort with specific movements, and tenderness to touch (Humantech, 2007). From the above explanation of tendonitis it is reasonable to conclude that when tendons are repeatedly tensed or over-exerted there is a great likelihood that the inflammation and irritation will be enough of a nuisance that it will affect the ability to complete every-day tasks.

Tenosynovitis is an illness that affects the body through the inflammation of the lining that surrounds a tendon in its sheath. The sheath is a tube like structure around the tendon that allows a tendon to move with the assistance of a lining called the synovium (Lapidus & Seidenstein, 1950). Frequently repeated action of the same muscles produces inflammatory changes which causes constriction of the tendon and sheath (Zenone, et al., 1999). There are several symptoms that include swelling, tenderness, and pain with motion. The feet, wrists and hands are the most commonly affected areas (Likes, 2009). Most individuals will fully recover with treatment, however if the ailment is caused by over-use and is not stopped, tenosynovitis will come back. When chronic conditions are considered, it is possible to damage the tendon causing recovery to be sluggish or incomplete (Chen, 2008). Tenosynovitis is a musculoskeletal disorder that can affect motor skills by causing discomfort, swelling and pain, but can be treated by rest or elimination of specific motions (WebMD, 2010).

Ergonomic Assessment Tools

There are several tools that can be used for the assessment of the sewing workstations and they include the Rapid Entire Body Assessment (REBA), Rapid Upper Limb Assessment

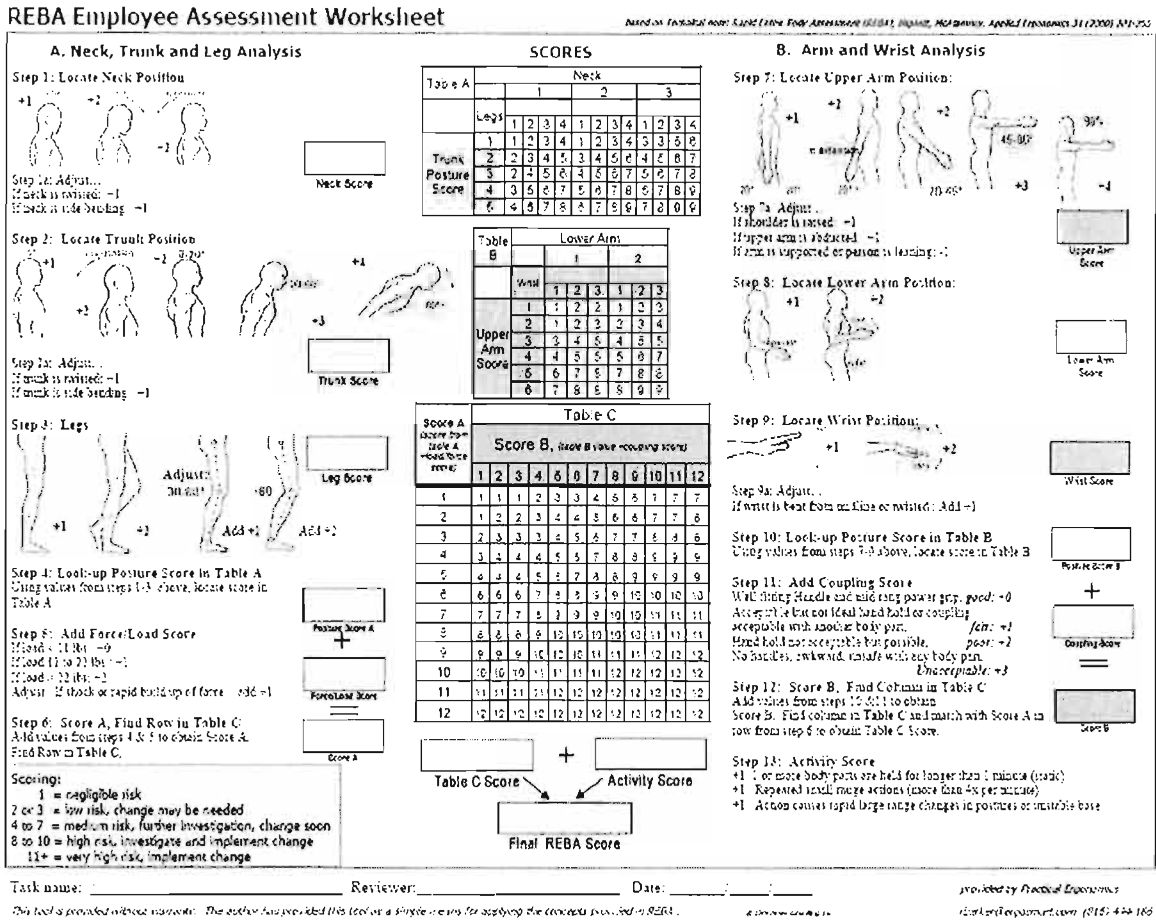
(RULA), various forms of ergonomic instrumentation and a questionnaires to determine the extent of present symptoms. These assessment methods are essentially analytical processes that measure behavior on the job against time to determine the physiological demands of a job on the workers. In essence, these assessment methods involve measuring the performance required of a person and a machine, their interactions, and the presence/effects of various environmental conditions.

Rapid entire body assessment (REBA). The REBA was developed by Dr. Sue Hignett and Dr. Lynn McAtamney in 1993 to associate the risk of musculoskeletal injury with the recorded postures. Since prior postural analysis techniques had two contradictory qualities in generality and sensitivity, there was a need within the postural analysis tools specifically with sensitivity to the type of unpredictable working postures found in health care (Hignett & McAtamney, 2000). According to Hignett and McAtamney the development of REBA was aimed to:

- Develop a postural analysis system sensitive to musculoskeletal risks in a variety of tasks.
- Divide the body into segments to be coded individually, with reference to movement planes.
- Provide a scoring system for muscle activity caused by static, dynamic, rapid changing, or unstable postures.
- Reflect that coupling is important in the handling of loads but may not always be via the hands.
- Give an action level with an indication of urgency.
- Require minimal equipment – pen and paper method (Hignett & McAtamney, 2000).

The REBA worksheet is a reasonable tool for evaluating a variety of body movements used in performing specific tasks. However, the worksheet's weakness comes from only allowing for minimal input when it considers operations like seated work and twisting of the spine. The REBA however, does place a considerable amount of emphasis on evaluating the extremities like the wrists, arms, and legs. The numbering system used to rank the severity of potential ergonomic hazards appears to work well with this assessment methodology as long as the calculated values are only used for evaluating the applicable job/task. This tool may not take into account all aspects of the task being performed, but it will give the researcher a great sense as to where the highest potential for injury can occur. Following is an example of the worksheet used for the REBA.

Figure 1. Rapid Entire Body Assessment Worksheet[1]



[1]From "REBA: A Survey Method for the Investigation of Work-Related Upper Limb Disorders," by Hignett, S. and McAtamney, L. (2000), *Applied Ergonomics*, (31), p. 201-205.

In 2005, Coyle performed a study titled "Comparison of the Rapid Entire Body Assessment (REBA) and the New Zealand Manual Handling 'Hazard Control Record', For Assessment of Manual Handling Hazards in the Supermarket Industry" that supports the work performed by Hignett and McAtamney in 2000. REBA scores a specific posture within a task by assessing the position of the trunk, legs, neck, upper arms, lower arms, and wrists. The researcher also takes into account the load or force required, hand-to-object coupling, repetition, and the duration of the cycle (Coyle, 2005). REBA was developed to assess working postures that involve use of the whole body, statically or dynamically, rapidly changing or in an unstable manner, and where manual handling may occur. According to McAtamney, the use of REBA is beneficial in supporting manual handling risk assessments where a case is needed to fund equipment or changes in working practices (Hignett & McAtamney, 2000). Through the use of quantifiable action levels, REBA can effectively rank employee exposure to hazardous postures helping management determine which corrective actions need to take place.

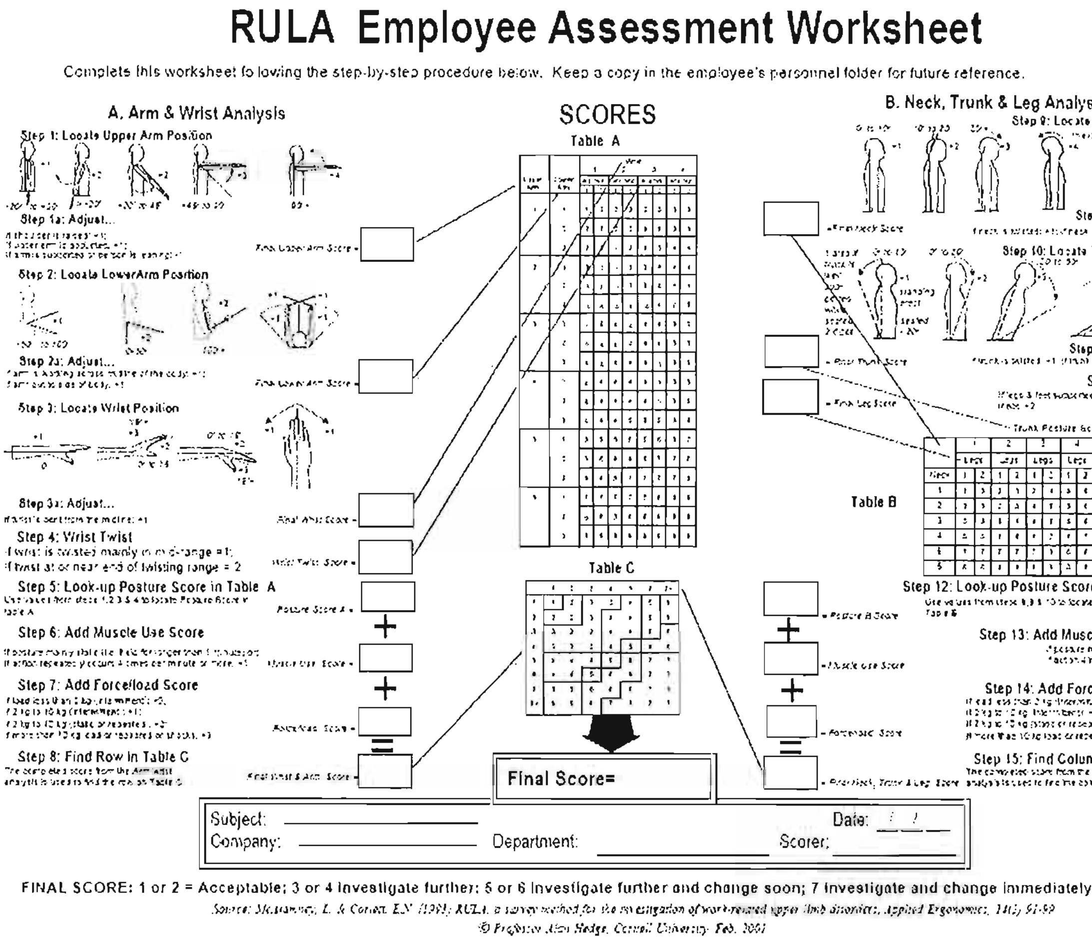
Rapid upper limb assessment (RULA). The RULA method was developed by Dr. Lynn McAtamney and Professor E. Nigel Corlett, ergonomists from the University of Nottingham in England. RULA is a postural analysis method that is used to estimate the potential for work-related upper limb disorders to occur. Part of the development of this assessment technique occurred in the garment-making industry, where operators performed tasks such as cutting while standing at a cutting block, machining using one of a variety of sewing machines, clipping, inspection operations, and packing (McAtamney & Corlett, 1993). The RULA assessment is a quick and systematic method for determining postural risks to an employee and can be completed before and after an intervention to determine the success of lowering the possible risk of injury to an employee.

RULA was developed without the need for special equipment and therefore provides the opportunity for a number of investigators to be trained in performing ergonomic-based assessments without the need for additional equipment expenditure (McAtamney & Corlett, 1993). It was developed to provide a method of screening a working population quickly for an exposure to a likely risk or work-related upper limb disorders. RULA also identifies the muscular effort which is associated with working posture, exerting force, and performing static or repetitive work which may contribute to muscle fatigue (Drinkaus, et al., 2003). The method uses diagrams of body postures and three scoring tables to provide evaluation of exposure to risk factors. The risk factors under investigation are:

- Numbers of movements
- Static muscle work
- Force
- Work postures determined by the equipments and furniture
- Time worked without a break (McAtamney & Corlett, 1993).

The RULA assessment provides a method of quickly assessing posture (whether seated or standing), paying particular attention to the neck, trunk, and upper limb segments. Moreover, it assesses the contribution of the muscular effort, whether arising from exerting external force, from the postural effort, or from muscle loading in the task activities such as holding tools (Haslegrave & Corlett, 1995). Based on observation of specific work cycles, the investigator records the positions of the upper arm, lower arm, wrist, neck, and lower back in order to associate a number with each body section. The final score is a combination of an interpolated number from each bodily section which is then put into the final table to determine the coding level.

Figure 2. Rapid Upper Limb Assessment Worksheet[2]



[2]From "RULA: A Survey Method for the Investigation of Work-Related Upper Limb Disorders," by L. McAtamney and E.N. Corlett, 1993, *Applied Ergonomics*, (24)2, p. 91-99.

The RULA assessment has a four-level coding system that determines the priority for ergonomic change to a task in order to reduce the risk of work-related musculoskeletal disorders. These four action levels are:

- Level 1: Posture is acceptable if not maintained for a long period of time.
- Level 2: Indication of further investigation and changes may be needed.
- Level 3: Investigation and changes are needed soon.
- Level 4: Investigation and changes are needed immediately (Drinkaus, et al., 2003).

The RULA worksheet is an upper limb assessment technique that effectively analyzes neck, arm, wrist, and trunk position. Compared to its strengths, there are a few weaknesses that are present with this method. The first is that RULA does not take into account leg or feet positioning in accordance with standing or seated work. Differentiating between standing or seated work could change the final score drastically. Another aspect that can be a weakness is that a researcher might interpret the severity levels differently, thus giving the assessment final scores that are not similar for the same task. This can be a problem when trying to compare the hazards of this task to another because the inter-rater reliability in not present. However, if the same researcher evaluates each task the reliability increases and this assessment method becomes a very effective technique for determining hazardous working conditions.

Vibration monitor. A vibration monitor determines the oscillatory motion that the worker is subject to in a coordinate system of three orthogonal axes. An accelerometer, which is part of the vibration monitor, measures properties like magnitude of acceleration, frequency, direction, and exposure time. The accelerometer produces its readings by generating an electrical signal that is proportional to the acceleration applied to it. This measurement is then displayed in meters per second squared (m/s^2) to associate it with the units of acceleration received (CCOHS, 2008) and is typically the method of measurement to evaluate the vibration of the equipment itself as well as the vibrations being transferred to the worker through their interaction with the machinery (Harada & Griffin, 1991). The measurement taken on the output of the tool will not necessarily be the exposure that the worker receives (Wolcott, 2004). This is due to the transmittability or the ability for the tool to transfer the vibration it produces to the hand of the user. The transmittability is highly variable and truly depends on the materials the equipment is made of and the materials ability to transfer or absorb their own vibrations

(Walcott, 2004). Workers with high hand vibration exposures will typically be exposed to acceleration levels of five to forty meters per second squared (Chengular, et al., 2004). Vibration monitoring uses an accelerometer which records information to establish the magnitude of acceleration, frequency, direction, and exposure time in order to determine the amount of hazardous vibration the human body is absorbing.

Manual goniometer. The manual goniometer is an instrument that is used to measure joint angles and determine range of motion demands for a given task. Through observations from the researcher, the goniometer is useful in determining the exact range of motion used. When used with recorded video footage it is possible to track the full range of motion throughout the completion of a task. The recorded angles of flexion/extension or adduction/abduction can then be compared to the reasonable limits expected of the task.

Video analysis. Recorded video analysis is the process of using a camera or camcorder to record the interaction of the employee and equipment. Iin order for the researcher to best judge joint movement, the video shall be recorded at a 90 degree angle to the subject so the manual goniometer can be used most effectively. This allows the researcher to break down the process step by step. Croasmun and Jacobs (2003) stated that before the researcher starts recording they should have an exact idea of what they will be using the tape for. A camcorder is a great way to capture uncountable details that would never fit in a checklist, proving that a picture is worth more than a thousand words. A video can record movements and gestures used in a task that note taking or still pictures can miss, giving the researcher a more reliable method of recording movements. It is also suggested that the video start out wide to show the entire process and zooming in on specific points of the process from several angles. Video analyses are like instant replay in that they offer the ergonomist a second set of eyes and an extra opportunity to make the correct call.

Force gauge. The force gauge is a tool designed to measure the muscular effort used by an employee to perform a task. This device normally has a spring that is compressed or a weight that is sustained, which is recorded by a gauge or dial to show the work that has been performed (Michael, 2002). These devices are used to measure forces involved in tasks such as pushing, pulling, or tensile tests. There are two different types of force gauges; spring mechanical and hydraulic. Radwin and Yen (1999) stated that spring scales usually have an accuracy within one percent of full scale and are offered in load levels that range from just a few grams to thousands of kilograms. By being within 1% of full scale it means that the force gauge accuracy will be within 99% of the actual force being recorded. The hydraulic dynamometers give results that are more accurate than the spring push pull versions. The technology used with the hydraulic dynamometer also allows it to be lighter and easier to handle at 1 1/2 pounds compared to 6 pounds for the average spring dynamometer (NexGen Ergonomics, 2007).

Questionnaire. A questionnaire is a simple and quick method to acquire related information on work-related factors that contribute to the task being performed. Through the analysis of the information provided, it is possible to determine what worker groups or workstations should be concentrated on for further ergonomic analysis (Hildebrandt et al, 2001). Even though the calculation of exposure levels has its limitations with this method, the data collected can be substantial enough to rank units in accordance with their exposure levels (Burdoff & Van der Beek, 1999). A questionnaire will typically have several sections including an introduction about the survey and its intentions, information on how to fill the survey out, and core questions designed to meet the survey's objectives (Dickinson ,et al., 1992). The core questions of a survey are designed to attain information in these sections:

- Background variables (age, gender, duration of employment).
- Tasks (task demands).
- Musculoskeletal workload (postures, forces, movements).
- Health pertaining to musculoskeletal symptoms.
- Lifestyle (sports, smoking, activities).
- Ideas for improvements to the process (Hildebrandt, et al., 2001).

A questionnaire is a simple and quick method to acquire information about the association between work-practices and musculoskeletal symptoms derived from these tasks.

Anthropometrics/Design Considerations

Anthropometry is the measurement and collection of the physical dimensions of the human body and is ultimately used to improve the human fit in the workplace or to determine problems existing between facilities or equipment and the employees using them (Friend & Kohn, 2007). With the accommodation of ninety-five percent of workers' anatomical dimensions in mind, Pheasant and Haselgrave (2006) state that clearance, reach, posture, and strength are the four cardinal constraints used in ergonomic design. The ninety-five percent confidence level means that the design is accommodating the largest and smallest user inside the ninety-fifth percentile of a given population. This means that the smallest 2.5% and the largest 2.5% of the population will be excluded from the design consideration. These percentages are excluded because the 95^{th} percentile between them ensures the greatest accommodation, compatibility, operability, and maintainability between average size users (NASA, 2008). This approach allows the workstation to be designed to accommodate the most workers possible within the chosen percentile.

Some key ideas that help determine what distances need to be used for certain constraints prove that clearance should always accommodate the largest of users while reach should always accommodate the smallest of users (Roebuck, 1995). Workstations should be designed to fit each individual worker, but with changing workforces and shrinking budgets, it becomes more difficult for a company to afford changing the process to fit the employee. Anthropometrics is critical in ergonomics because it takes the dimensions of the workers and applies them to the design of the workstations, jobs, tools, and equipment (Chengular, et al., 2004). As explained earlier, the approach of ergonomics is the study of the design of work in relation to the physiological and psychological capabilities of people. The aim of the discipline is the evaluation and the design of facilities, environments, jobs, training methods, and equipment to match the capabilities of the users and workers, and thereby to reduce the potential for fatigue, error, and unsafe acts (Roebuck, 1995).

From an ergonomics perspective, when most of the potential workforce can perform well without excessive stress, it is considered to be a well-designed job (Chengular, et al., 2004, p. 435). Following are several characteristics of a well-designed job:

- Physical dimensions are such that reaches, clearances, and work heights accommodate the capabilities and characteristics of at least 90 percent of the workforce.
- Peak loads are within the strengths or endurance capacities of at least 90 percent of the workforce.

- Environmental factors do not place unacceptable risk or performance limits on most healthy workers.
- Perceptual, cognitive, and visual demands are within the capacities of most workers, including the older ones.
- Job repetition rates and pacing are not excessive, and the workers have control over their work patterns (Chengular, et al., 2004).

When considering the design of a workstation, it is best practice to use dimensions that will accommodate at least 90 percent of the workforce. This will allow for the most inter-changeability so that multiple workers are able to perform the same task at the same workstation. By keeping the physical and mental demands average, the designer is allowing for the largest variety of workers to complete the task. The practice of designing a workstation so that a healthy average adult can perform tasks within a company will allow for managers to recruit from the largest pool of available workers.

Chengular, et al. (2004) state that in the design of jobs, reducing the static or exertion of a force without motion component of any task can prevent local muscle fatigue from limiting productivity . Most industrial tasks involve both static and dynamic work. Since static work more likely limits productivity, it is a good general practice to reduce the static component of work whenever possible (Chengular, et al., 2004). The following guidelines for workplace and job design have the goal of reducing static effort:

- Avoid forward reaches of more than 20 inches in front of the body when standing and 15 inches in front when sitting.
- Design foot pedals to reduce or eliminate the need for sustained pressure.
- Provide rest breaks with highly repetitive jobs (Chengular, et al., 2004).

These are design guidelines that are suggested to be followed to help guarantee that a task is not exhausting or over-working the employee. Through the reduction of manual effort in a task, the company will be providing an environment for the employee that is more conducive to higher productivity.

Ergonomic Control Measures/Approaches

Controls can be defined as procedures, method changes, or processes that correct existing health problems and minimize the risk of health hazards in the workplace (Friend & Kohn, 2007). There are three approaches to minimizing or controlling risk factors that are associated with job tasks in the manufacturing industry: administrative controls, engineering controls, and personal protective equipment (PPE). This three-tier hierarchy of controls is a widely accepted strategy for controlling workplace hazards. According to Chen, et al these three tiers are:

- Reducing or eliminating potentially hazardous conditions using engineering controls.
- Changes in work practices and management policies, sometimes called administrative controls.
- Use of personal protective equipment (Chen, et al., 1997, p. 31).

Through the use of engineering controls, an engineer is eliminating the hazard through designing the equipment or process to fit the employee. Administrative controls take the opposite path compared to engineering controls in that they remove the worker from the process or limit the exposure time that a worker receives from each task. The use of personal protective equipment can help reduce hazardous atmospheres, but are generally designed to reduce the hazards that employees are exposed to.

Administrative controls. Administrative controls are management-dictated policies and work practices to minimize the exposure to ergonomic risk factors. Administrative control strategies include changes in procedures and job rules, such as scheduling more rest breaks, using rotation for tasks that are physically demanding or tiring, and training workers to understand risk factors and to learn or reinforce techniques for reducing stress and strain while performing their tasks (Chen, et al., 1997). Although engineering (i.e., workplace design) controls are preferred, administrative controls can be helpful as provisional measures when it is not possible to use engineering controls or when there is lag time until the engineering controls can be implemented (Chen, et al., 1997). Since administrative techniques are only temporary, they do not eliminate the hazard so management must make sure that the policies and practices are followed. Several examples of administrative controls are as follows:

- Reducing the shift length or curtailing the amount of overtime.
- Rotating workers through several jobs with different physical demands to reduce the stress on limbs and body regions.
- Scheduling more breaks to allow for rest and recovery.
- Broadening or varying the job content to offset certain risk factors (e.g., repetitive motions, static and awkward postures).
- Adjusting the work pace to relieve repetitive motion risks and give the worker more control of the work process.
- Training in the recognition of risk factors for work-related musculoskeletal disorders (WMSDs) and instruction in work practices that can ease the task demands or burden (Chen, et al., 1997, p. 34).

Administrative controls are designed to reduce worker exposure to ergonomic risk factors. This is accomplished by reducing shift length, promoting job rotation, and scheduling more breaks. These are all methods to reduce the amount of time a worker interfaces with a demanding task. The reduction of exposure time will help keep employees safer and possibly more productive due to less physically demanding job duties.

With the proper oversight from management and the correct training measures implemented it is likely that administrative controls can temporarily eliminate hazards until permanent measures can be introduced.

Engineering controls. An engineering control is the implementation of work methods or tool designs that will eliminate the risk factor or hazard completely. The preferred approach to preventing musculoskeletal disorders in the workplace is to design the task with consideration to the workstation layout, selection and use of the tools, and the work methods through determining the capabilities and limitations of the workforce. Engineering control strategies to reduce ergonomic risk factors include the following:

- Changing the way materials, parts, and products can be transported for example, using mechanical assist devices to relieve heavy load lifting and carrying tasks or using handles or slotted hand holes in packages requiring manual lifting.
- Changing the process or product to reduce worker exposures to risk factors; examples include maintaining the fit of plastic molds to reduce the need for manual removal of flashing, or using easy-connect electrical terminals to reduce manual forces.
- Modifying containers and parts presentation, such as height adjustable material bins.
- Changing workstation layout, which might include using height-adjustable workbenches or locating tools and materials within short reaching distances.
- Changing the way parts, tools, and materials are to be manipulated, for example using fixtures to hold pieces to relieve the need for awkward hand and arm positions.
- Changing assembly access and sequence (Chen, et al., 1997).

Engineering controls are implemented to remove or reduce a hazard in a process. This can be done by changing the chemical makeup of a product, using mechanical lifting devices, or changing a process to reduce or limit worker exposure to ergonomic hazards. These methods are all conforming the process to protect the employee from potential hazards conducive of that process. The existing employees are a great asset to a company due to their knowledge of the processes and materials, so it would be a smart idea to design processes around these existing assets.

Engineering controls consist of work methods and tool designs that eliminate the risk factor altogether and make the job less fatiguing and stressful. These controls are usually the most effective long-term approach to reducing the risk factors associated with work-related musculoskeletal disorders (Chengular, et al., 2004). Engineering controls are a design method that removes the hazards from the point of contact for the employees by changing materials, processes, and workstation layouts so the work environment can be more productive and less hazardous (Asfahl, 1990).

Personal protective equipment. Personal protective equipment (PPE), including clothing, gloves, or equipment, can help to minimize risk factors in the workplace. Respirators, ear plugs, safety goggles, chemical aprons, safety shoes, and hard hats are all examples of PPE. A drawback of PPE is that employees need training in why the PPE is necessary and how to properly use and maintain it (OSHA, 2009). Another important aspect to know about PPE is that it is not suitable for every situation (OSHA, 2009). Employees are also in need of positive and consistent reinforcement to ensure compliance (FEMA, 1994). It is considered the last line of defense because the barrier separating the employee from the health hazard must be worn correctly and consistently. If employees do not wear PPE or it fails, they will be at greater risk for illness or injury (Friend & Kohn, 2007).

Implementing personal protective equipment-based controls normally consists of utilizing the following steps:

- Trials or tests of the selected solutions.
- Making modifications or revisions.
- Full-scale implementation.
- Follow up on evaluating control effectiveness.

Regarding the above steps of introducing a piece of PPE into the workplace, it is imperative that there be testing or trials to determine which product performs best. During this testing process, revisions and corrections will be made to the original ergonomic control measures until a consensus decision can be made (Malchaire, 2000). Once a decision has been made, a full scale implementation of the control measures can take place. After the implementation it is best practice to evaluate and review the effectiveness of the control measures in order to determine if the control method has achieved the desired results as well as employee compliance (Malchaire, 2000). PPE can be awkward and a nuisance, but in the end it is usually intended to prevent some form of a personal injury.

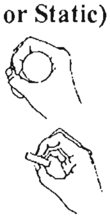
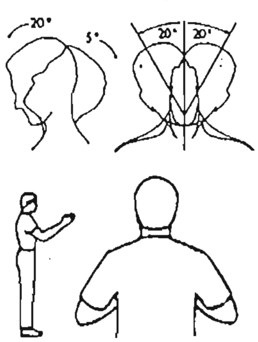
Testing and evaluation of the ergonomic control measures will verify that the proposed solution actually works and identifies any additional enhancements or modifications that may be needed. Employees who perform the evaluated task can provide valuable input into the testing and evaluation process. Worker acceptance of the changes put into place is important to the success of the intervention (Chen, et al., 1997). Follow up assessments are necessary to guarantee that the controls decreased or removed the ergonomic risk factors and that new risk factors were not introduced. These follow up evaluations should use the same risk factor checklists and any other method of job analysis that first documented the presence of ergonomic risk factors (Chen, et al., 1997). Following is an example of a work-place ergonomic risk factor checklist:

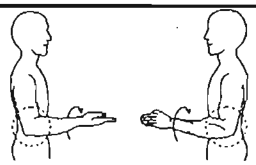
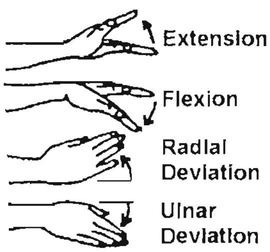
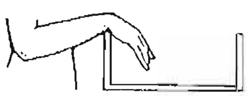
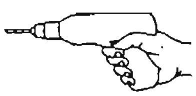
Figure 3. Ergonomic Risk Factor Checklist[3]

ERGONOMIC RISK FACTOR CHECKLIST

UPPER EXTREMITY RISK FACTOR CHECKLIST

Date: ________ Analyst: ____________ Job: ______________ Location:

RISK FACTOR CATEGORY	RISK FACTORS	EXPOSURE Is the risk factor present within the job or task?	TIME				SCORE
			0% to 25% of total job time	25% to 50% of time	50% to 100% of time	If total time for job is >8hrs, add 0.5 per hour	
Upper Limb Movements	1. Moderate: Steady motion with regular pauses	☐ YES ☐ NO	0	1	2		
	2. Intensive: Rapid steady motion without regular pauses	☐ YES ☐ NO	1	2	3		
Keyboard Use 	3. Intermittent Keying	☐ YES ☐ NO	0	0	1		
	4. Intensive Keying	☐ YES ☐ NO	0	1	3		
Hand Force (Repetitive or Static) 	5. Squeezing Hard with the Hand in a Power Grip	☐ YES ☐ NO	0	1	3		
	6. Pinch More than 2 pounds	☐ YES ☐ NO	1	2	3		
Awkward Postures 	7. Neck: Twist/Bend (twisting neck >20°, bending neck forward >20° or back < 5°)	☐ YES ☐ NO	0	1	2		
	8. Shoulder: Unsupported arm or elbow above mid-torso height	☐ YES ☐ NO	1	2	3		

RISK FACTOR CATEGORY	RISK FACTORS	EXPOSURE Is the risk factor present within the job or task?	TIME				SCORE
			0% to 25% of job time	25% to 50% of time	50% to 100% of time	If job time is >8hrs, add 0.5 per hour	
	9. Rapid Forearm Rotation	☐ YES ☐ NO	0	1	2		
	10. Wrist: Bend or Deviate	☐ YES ☐ NO	1	2	3		
Contact Stress 	11. Hard/Sharp objects Press into Skin	☐ YES ☐ NO	0	1	2		
	12. Using the Palm of the Hand or Wrist as a Hammer	☐ YES ☐ NO	1	2	3		
Vibration 	13. Localized Vibration (without dampening)	☐ YES ☐ NO	0	1	2		
	14. Whole-body Vibration (without dampening)	☐ YES ☐ NO	0	1	2		
Environment	15. Lighting (poor illumination or glare)	☐ YES ☐ NO	0	0	1		
	16. Adverse Temperatures	☐ YES ☐ NO	0	0	1		
Control Over Work Pace	17. One control factor present = 1 Two or more control factors present = 2	☐ YES ☐ NO					
TOTAL UPPER EXTREMITY SCORE							

[2]From "Ergonomic Risk Factor Checklist and User's Guide," by Safe Work Manitoba, 2010, http://safemanitoba.com/ergonomic_risk_factor_checklist_and_user_s_guide.aspx

Summary

Risk factors such as force, awkward postures, repetition, and vibration each affect the human body differently, however they are each associated with musculoskeletal disorders that affect the workforce in highly repetitive jobs. There are several recognized ergonomic tools that can be used in the workplace to identify and analyze risk factors or health hazards. Ergonomic tools establish the severity of the risk and help determine which risk factor should be remediated first. It is essential that an assessment be performed using the proposed ergonomic tools in order to evaluate the extent of ergonomic exposure the sewing line workers are being subjected to. In conjunction with the assessment methods there are several pieces of ergonomic instrumentation such as video recording, force gauges, and manual goniometer measurements that are vital to ensuring the assessment worksheets are properly completed. With the aid of these assessments, instrumentation and proper training, MSDs and CTDs should be reduced in the workplace. When the exposures have been evaluated, it will be possible to establish the hierarchy of controls to eliminate or reduce the existence of the risk factors. The control hierarchy includes administrative controls, engineering controls, and personal protective equipment. It should be cautioned that PPE has certain ergonomic drawbacks that make it much more difficult to control than administrative or engineering controls. These drawbacks are all based upon the willingness of the employees to accept the implemented changes. In order to reduce the potential for exposure to risk factors, recommendations must be established from the quantitative and qualitative assessments.

Chapter III: Methodology

The purpose of this study is to analyze the seat-sewing line at Company XYZ to determine the extent at which ergonomic-based risk factors are present. In order to assess the ergonomic risks of the seat-sewing line, several tools will be used to determine the extent of awkward postures, forces applied, and reach distances that may be required to complete the work. If necessary, this research paper will also provide recommendations on ways to improve the current process. The seat-sewing process was analyzed while keeping these goals in mind:

1. Perform a task analysis for the existing seat sewing line using quantitative-based tools.

2. Review injury records and determine all ergonomic-based injuries that are associated with the sewing process.

3. Perform qualitative surveys on employees and the tasks they perform to determine the extent of the problem.

The methods and procedures used in the ergonomic analysis of the seat-sewing line at Company XYZ are explained under the following headings of subjects studied, the research design, the instrumentation used, data collection, and data analysis.

Subject Selection and Description

The subjects of this study were selected by the safety director of Company XYZ. At Company XYZ the process of hand-sewing the seat covers is performed in one unit consisting of six to eight workers. The focus of the observations and assessments were based on the workers who hand-sew the seat covers for a specific product line. The excessive forces and amount of manual labor required in the process is of concern, potentially exposing employees to ergonomic risk factors. Before conducting any assessments, the researcher will clearly notify all participating workers of the study. The researcher will explain all the necessary documentation needed to inform the subjects within the study. The researcher and subjects will review the observation schedule, assessments, and equipment used to conduct the study. The subjects will be encouraged to ask any questions before agreeing to participate in the study.

Instrumentation

A review of literature was conducted to identify key components and benefits of an ergonomic analysis. From the key components and benefits found in the review of literature it was possible to determine the tools to use in order to obtain the data needed to effectively analyze the ergonomic hazards. The specific tools used in this study include the RULA assessment, the REBA assessment, the manual goniometer, the single axial force gauge, an ergonomic stressor checklist, and a short questionnaire.

The RULA assessment tool will effectively assess the movements and postures that the body is held in while completing the task. The completion of this assessment tool will provide a specific score for the entire upper body while delineating sections for arms, wrists, shoulder, neck, and the trunk of the body. RULA is used for determining the associated risk of CTDs for assembly line workers. The RULA will take into account the force, repetition, and awkward positions held by the employee. The final score of this tool will help determine the potential for CTDs and help the researcher rank the score based on other tools used. The REBA assessment tool focuses on many of the same body functions as the RULA, except the scoring process is slightly different. The final scoring system of each tool will yield different numbers and scoring categories, but they will both conclude similar recommendations and outcomes.

A questionnaire and checklist will be utilized in order to determine the locations of pain or discomfort and the ergonomic risks that are present while performing a task. The questionnaire method also allows the subjects to remain anonymous while expressing their experiences and thoughts about the task design. The checklist will be filled out by the researcher to determine the risk factors that are apparent while the subjects perform their task. These are paper-based formats that gather employee input on the processes they are performing. The questions that are administered are designed so that they will elicit similar answers from the same person under the same conditions. The results from these exercises will help the researcher determine the ergonomic risk factors that are present in Company XYZ's sewing line.

Two instruments will be used to produce ranges of motion, postural angles, and forces exerted to move materials through the sewing machines. The manual goniometer is essentially a protractor that determines postural angles. The force gauge measures push, pull, and lifting stresses of an activity. A force gauge is a single axial tool, which means it will only provide measurements in one direction.

Data Collection Procedures

Completing the RULA survey:

1. Observe the entire task cycle to become familiar with the postures and work practices.

2. A part of the task cycle is identified that includes postures to assess.

3. Score the postures and forces on the diagrams of the RULA worksheet for each body part in chosen postures.

4. Scores can be put into a table by following the instruction on the score sheet.

5. Intervention, action levels, or the types of investigation needed will be determined by the final score.

Completing the REBA survey:

1. Observe the entire task cycle to become familiar with the postures and work practices.
2. Repetitions, postures, and muscular activity involved in completing the task will be selected and recorded in appropriate sections.
3. Postures are then scored and totaled for sections A and B.
4. A single score is then calculated from the two sections.
5. An activity score is then calculated with the REBA score to give a final score.
6. Interventions, action levels, or the types of investigation needed will be determined by the final score.

Manual goniometer/video analysis:

1. Observe the entire task cycle to become familiar with the movements needed to perform the task.
2. Set the video recorder up at a ninety degree angle to the employee performing the task.
3. Record the movements performed to complete the task.
4. Align the fulcrum of the device with the fulcrum or the joint to be measured.
5. Align the stationary arm of the device with the limb being measured.

6. Hold the arms of the goniometer in place while the joint is moved through its range of motion.

7. The degree between the endpoints represents the entire range-of-motion.

8. A computer and video monitor will be used to later review the movements and postures assumed throughout the process.

Force gauge:

1. Hook force gauge to stationary object on the workstation surface and measure the force reading when the subject pulls material apart to be sewn.

2. Hook force gauge to stationary object on the workstation to measure the pushing force when feeding material through the sewing machine.

Completing the risk factor checklist:

1. Observe the entire task cycle to become familiar with the postures and work practices.

2. Muscular activity, vibration, contact stresses, and other risk factors involved in completing the task will be selected and recorded in appropriate sections.

3. Risk factors are then scored and then totaled for an overall rating.

4. The entire checklist will then be kept to determine if future corrective actions lower any of the risk factors.

Data Analysis

Through a review of the data collected during the task analysis, the researcher will be able to identify which potential risk factors are most severe in the seat-sewing line. The data from the questionnaire will be used to correlate the data collected from the ergonomic surveys

(RULA, REBA, and risk factor checklist) which will be evaluated using the tables on the respective worksheets for each specific tool. Based on the ergonomic survey used for the identification of movements, angles, and postures for the body and limbs, it is possible to assign a number to evaluate the risk potential found in each survey. The REBA, RULA, risk factor checklist, and the manual goniometer will identify the joint angles that will need to be compared to anthropometric data. This will be accomplished by determining the acceptable limits and joint angles for the ninety-fifth percentile and comparing the measurements of this study to the anthropometric data. The tables given at the end of each tool will be used to give quantitative proof that risk factors are present.

Limitations

The limitations of this study include:

1. The employee's willingness to participate with this study may alter the results.

2. The analyzed process, conclusions, and recommendations for this study are only applicable to the seat sewing line at Company XYZ.

Chapter IV: Results

The purpose of this study was to analyze the seat-sewing line at Company XYZ in order to determine the extent that ergonomic-based risk factors are present. The goals of the study were to:

1. Perform a task analysis for the existing seat-sewing line using quantitative-based tools.

2. Review injury records and determine all ergonomic-based injuries that are associated with the seat-sewing process.

3. Perform qualitative surveys on employees and the tasks they perform to determine the extent of the problem.

The methodology used to collect data consisted of performing participant observations, digital video/picture recording, and the administration of an employee questionnaire. Forces applied during the sewing task were measured using a single axial hydraulic force gauge and the angles of identified posture were measured using a manual goniometer. The Rapid Upper Limb Assessment (RULA) and the Rapid Entire Body Assessment (REBA) assessment techniques, along with the ergonomic checklist, were all performed by observing the participants, asking them details about production rates, and inputting the identified force and posture angles into the previously mentioned assessment techniques.

Presentation of Collected Data

Goal number one. The first goal of this study was to perform a task analysis for the existing seat sewing line using quantitative-based tools. The REBA and RULA assessment methods, a force gauge and a manual goniometer were used to produce quantitative data on the workers who were performing the top-stitch activity in the seat-sewing line.

Rapid entire body assessment (REBA). The researcher used the REBA assessment tool to assess the movements and postures that the body is held in while completing the top-stitch. Forces, repetitions, and awkward postures were all considered when determining the final score for the REBA assessment. The researcher examined the top-stitch sewing methods in the seat-sewing line using a digital video recorder. Through the use of a digital video recorder, it was possible for the researcher to assess the repetition involved in the task and the postures assumed to move the materials through the sewing machine. The REBA assessment was suitable for this application because it specifically takes into account the neck, trunk, arms, wrists, and leg placement.

Table 1 below identifies the REBA score that was generated from the worker performing the top-stitch:

Table 1

REBA Assessment Scoring Table

REBA	Neck, Trunk, & Leg Score	Arm & Wrist Score	Table C Score	Activity Score	Final Score
Top Stitch	3	10	8	1	9

Table 1 above indicates a final score of nine for the worker performing the top-stitch sewing method. The neck, trunk, and leg score is a three on a scale of nine indicating that there is low risk associated with the positioning of these body parts. The arm and wrist score is a ten on a scale of twelve signifying that there is high risk associated with the positioning of the upper extremities. The Table C score is an eight on a scale of twelve which indicates high risk with the combination of the lower and upper extremity scores. The activity score is added to the Table C score giving a final score of nine due to the repeated small range actions that are performed more than four times per minute. The score of nine indicates that the process is high risk and it should be investigated further for implemented changes. The completed REBA survey which reflects the above table can be found in Appendix B.

Rapid upper limb assessment (RULA). The researcher used the RULA assessment tool to assess the movements and postures that the body is held in while completing the task. The RULA assessment tool was used in conjunction with the recorded video to assess the forces, repetitions, and postures assumed to perform the top-stitching task. The RULA assessment tool was suitable for this application because it focused on the neck, trunk, and upper extremities. Table 2 below identifies the score that was generated from the RULA assessment tool:

Table 2

RULA Assessment Scoring Table

RULA	Arm & Wrist Score	Neck, Trunk, & Leg Score	Table C Score	Final Score
Top Stitch	7	4	6	6

Table 2 indicates a final score of six for the worker performing the top-stitch sewing method. The arm and wrist score is a seven on a scale of eight indicating that there is a high risk associated with the positioning of the upper extremities. The neck, trunk, and leg score is a four on a scale of seven indicating that there is a medium risk associated with the postures. The Table C score is a combination of the upper and lower extremity scores which determines the final RULA score. The RULA final score of six indicates that the process needs to be investigated further and changed soon. The completed RULA survey can be found in Appendix C.

Ergonomic risk factor checklist. The researcher also used the ergonomic risk factor checklist tool to assess the ergonomic risks that were apparent in the seat-sewing line. The risk factor checklist was used in conjunction with the recorded video and digital still photography to determine the upper extremity score for the top-stitch sewing task and thus establish a baseline score before any corrections can be made to the process. This tool was suitable for this application because it focused on upper extremity postures, vibration forces, and contact stress. Table 3 below identifies the score that was generated from the ergonomic risk factor checklist for upper extremities:

Table 3

Ergonomic Risk Factor Checklist

Risk Category	Score
Steady Motion	2
Pinch of > 2 Lbs.	2
Neck Bend	2
Arm Unsupported	3
Wrist Bend/Deviate	2
Contact Stress	1
Localized Vibration	2
Final Score	14

Table 3 indicates a score of fourteen for the worker performing the top-stitch sewing method. The ergonomic checklist score is a benchmark score that is used to determine the ergonomic risks of a task before corrections are made. This baseline score is intended to be compared to the same checklist once the task has had corrections made and can be reviewed again for ergonomic risks. The areas of concern that are indicated in this table are the pinch grip of two pounds or greater, the bending of the neck in greater than a twenty degree downward angle, arms or elbows unsupported above the mid-torso height, and the localized vibration without dampening. These risk factors are of concern because they are being performed from fifty to one hundred percent of the time. The risk factor that scored the highest and should be considered for investigation first is the unsupported arms or elbows above the mid-torso height. The completed ergonomic risk factor checklist can be found in Appendix D.

Manual goniometer. The manual goniometer was used in the same process as the REBA and RULA assessment tools, which used recorded video and picture still-shots to measure the various joint angles of the workers performing the top-stitch. The following joint angles were measured with the manual goniometer for the workers performing the top-stitch. These measurements were recorded when the worker was beginning to move the vinyl seat covers through the sewing machine. All of these measurements are indicating the maximum angle of abduction, flexion, or extension that occurred while the worker fed the seat cover through the sewing machine.

- Upper arm position is at a 51° angle abducted from the body, which was held throughout the process.

- Lower arm position at 96° angle while feeding the vinyl material through the sewing machine.
- Wrists were in flexion at a 15° angle when bunching the material to pull the joint apart for the top-stitch.
- Wrists were in extension at a 15° angle when the worker would feed the material through after pulling the joint taut.
- Neck position had flexion of 25° throughout the entire sewing process.
- Trunk position had flexion of 10° throughout the entire sewing process.

The joint angle measurements listed above were used in the REBA and RULA assessment tools to tabulate a final REBA and RULA score.

Force gauge. The force gauge was used to measure the pulling force which was required to keep the two vinyl materials taut enough to perform the top-stitch. This device is performed in a single direction (single axial). This test was performed by anchoring one end of the force gauge to the edge of the working surface and using a small rope looped around the workers right hand which was pulling away from the force gauge. This allowed the worker to keep both hands on the material while spreading the joint to complete the top-stitch. Since the edge of the working surface to the sewing foot was the same on all of the sewing machines, this measurement was able to be repeated with other workers performing the same top-stitch maneuver. The researcher performed multiple tests on several workers to get an average pulling force needed to keep the joint taut. Four tests were performed on individual workers to get an average amount of the static force that is required to keep the joint taut enough to perform the top-stitch. Table 4 below identifies the amount of static force it took to keep the materials taut enough to perform the top-stitch:

Table 4

Force Analysis for Top-Stitch

Force	Worker #1	Worker #2	Worker #3	Worker #4	Final Average
Lbs.	3	4	4	3	3.5

As indicated in Table 4, the final average static force required to keep the materials taut was 3.5 pounds. This average static force was used in the REBA and RULA assessment tools to tabulate a final REBA and RULA score.

Vibration monitor. A vibration monitor was also used to determine if there was any vibration transfer present during the top-stitch process. It was not possible to couple the attachment that contains the accelerometer to the workers hand properly. Since the readings could not be recorded, the vibration monitor and its attachments are considered a limitation to this study.

Goal number two. The second goal of this study was to review injury records and determine all ergonomic-based injuries that are associated with the sewing process. Once the review of injury records was completed, it was determined that since 2006, four ergonomic-based injuries had occurred on the seat-sewing-line. All of these injuries are indicative of an increase of product needing the top-stitch sewing method to be performed. The focus of this study was to examine the effects of the top-stitch after the introduction of a new recreational vehicle in the year 2006. This new product caused a larger demand for the top-stitch to be performed compared to the years leading up to this new product. Prior to the new product being introduced, from 1996 to 2005, there were five OSHA recordable injuries that were related to high repetitions and awkward postures while performing the sewing operation. However after the new product was introduced, from 2006 to 2008, there were four OSHA recordable injuries that were more severe when compared to the past and required more lost time away from work. None of the injuries that have occurred in the seat-sewing line have been associated with a single event. All of the injuries that have occurred in the sewing-line are connected to ergonomic-based injuries that are induced slowly over time due to the exposure of high repetition, awkward postures, and vibration. In the analysis of the injury records, the researcher developed Table 5 to illustrate the injuries that have occurred since the new product was introduced and which body parts have been affected in the past four years:

Table 5

Recordable Injuries in the Seat Division

Employee	Wrist	Elbow	Forearm
An X will mark each injury the employee has had occur			
1			X
2	X		
3		X	
4	X		

Table 5 indicates the most common injury that has occurred in the past four years is associated with the wrist. Two of the injuries listed under the wrist were diagnosed as carpal tunnel syndrome and resulted in the employee experiencing lost time away from work. The other two injuries sustained in recent years affected the tendons in the forearm and elbow. The forearm injury was diagnosed as tendonitis and resulted in a lost time injury. The elbow injury was diagnosed as bilateral epicondylitis, which is a form of tendonitis where the tendons attached to the lateral and medial epicondyle (bone in the elbow) begins to tear and causes discomfort in the forearm and wrist areas making it difficult to grip and causes severe pain (MD Guidelines, 2009). These injuries are significant because when compared with the five injuries that occurred over a ten year span from 1996 to 2005, the past four years has yielded four injuries of similar or greater consequence.

It appears from the data collected through the review of injury records that Company XYZ should be concerned about upper extremity injuries that are occurring from performing top-stitch sewing operations. There is an indication, based on the injury record review and the analysis of the ergonomic-assessment methods from goal one, that the upper extremity injuries occurring are related to employees performing repetitive motion-based activities for multiple years.

Goal number 3.

Symptoms survey. The third goal of this study was to perform qualitative surveys on employees and the tasks they perform to determine the extent of any ergonomic-based problems that may exist on the sewing line. To accomplish this goal, a symptom survey was used to identify potential areas of discomfort that the workers may currently experience or have experienced. Six of the full-time employees completed the survey, while two of the full-time and all six temporary employees were not willing to participate in the questionnaire. The six full-time employees completed the survey, allowing them to identify specific points of pain, discomfort, numbness, tingling, or fatigue. The questionnaire also asked the employees whether they were being affected by the discomfort while performing their daily tasks.

The first question asked if the workers experienced discomfort in their wrist, arm, or shoulder that would interfere with daily activities. This was simply a "yes" or "no" question to determine if the worker needed to move on to question two in order to explain where the discomfort appeared or if they should move directly to question three. Table 6 below provides the responses:

Table 6

Question 1 Answers

Yes	No
5	1

The data provided in Table 6 indicate that five of the six full-time workers felt some discomfort while they performed their daily activities. If the worker answered yes to question one, they were instructed to answer question two. However, if the worker answered no, they were instructed to move on to question 3. An example of the symptom survey can be found in Appendix E.

The second question asked the workers to please mark the areas where they have experienced repeated pain within the last month on the picture provided. They were then asked to mark an N for numbness, a P for pain, a T for Tingling, an S for soreness, a D for discomfort, and/or an F for fatigue. Since there was a possibility of confusion between definitions for the pain, soreness, and discomfort descriptors, this question needs to be considered a limitation of the study. Thus, it may be that the workers did not know the meaning of each descriptor, making it impossible to correctly verify the true cause of distress. Even with the limitation of the descriptors, the researcher was still able to determine the locations of distress. The workers' responses for question two are located in Table 7 below:

Table 7

Question Number Two Answers

Location of Distress	Number of Workers Experiencing Distress
Right Hand Soreness	2
Neck Soreness	1
Neck Discomfort	1
Shoulder Discomfort	3
Right Hand Discomfort	1
Left Hand Discomfort	1
Right Hand Numbness	1
Left Hand Numbness	1
Right Hand Tingling	2
Left Hand Tingling	2
Wrist Discomfort	2

The results provided in Table 7 indicates that three of the workers have shoulder discomfort, two of the workers have right and left hand tingling, and two more report having right hand soreness. The rest of the symptoms that the employees also indicated to be experiencing included left and right hand numbness, wrist discomfort, left and right hand numbness, left and right hand discomfort, neck discomfort, and neck soreness. All of these symptoms are important due to the fact that they are all symptoms closely related to highly repetitive tasks that involve the upper extremities.

The third question asked the workers if they are experiencing or have experienced any numbness, pain, tingling, soreness, discomfort, or fatigue during or after work. The workers' responses are located in Table 8 below:

Table 8

Question Number Three Answers

Yes	No
4	2

The data presented in Table 8 indicates that four of the six full-time workers had recently or were currently experiencing discomfort. The results of question number three correlate to the results of question number one by identifying that workers have experienced discomfort during or after work that affects the completion of their daily activities. These answers help validate the questionnaire based on similar distresses that affects their work during a task or after they leave work for the day.

The fourth question asked the workers if their current job required arm, hand, or finger actions to be repeated many times each hour and shift. This was also a "yes" or "no" answer to determine if the workers were subject to the same daily activities. The workers' responses are located in Table 9 below:

Table 9

Question Number Four Answers

Yes	No
6	0

Table 9 indicates that all six of the full-time workers are subject to the same daily activities including; arm, hand, and/ or finger actions to be repeated many times each hour and shift. The information contained in Table 9 correlates closely with the data collected in the REBA, RULA, and checklist assessments. The REBA, RULA, and checklist assessments also determined that there were small range actions being performed many times during the top-stitch method. In both the REBA and RULA assessments it was found that the upper extremities were at the highest risk for musculoskeletal illness due to the repetitions and awkward postures involved with performing the top-stitch. Question four also closely correlates with the review of injury records through the fact that the injuries occurring are associated with arm, hand, and finger actions that are repeated many times during every work shift.

The fifth question asked the workers the specific task that the pain and/or discomfort appeared. This question helped determine if there was one activity that affected the workers more than others. The workers' responses are located in Table 10 below:

Table 10

Question Number Five Answers

Top-Stitch	None
4	2

Table 10 indicates that four of the six full-time workers experience pain or discomfort during the top-stitch sewing operation. The other two workers felt that there was not a specific sewing task that caused them pain or discomfort. Question five is closely associated with questions one, two, and three which provides data that indicates repetitive small range motions performed with awkward postures will lead to upper extremity distress and injury. The close correlation between these questions validates the usefulness of this questionnaire and its ability to correctly identify the locations of distress in the workers body. The REBA, RULA, and checklist assessments also correlate with question five in determining that repeated small range motions performed with awkward postures necessary to complete the top-stitch sewing task will lead to upper extremity injuries in the future.

Discussion

The results of the methodology used in this study indicate that there are a variety of risks involved when the workers perform the top-stitch in Company XYZ's sewing-line operation. Although Company XYZ has administrative controls in place that switch the workers from one sewing station to another every hour and developed a stretching program for the upper extremities, the workers are still feeling distress in their upper extremities. A discussion of the

REBA and RULA assessment methods, review of injury records, and symptom survey will demonstrate how the data from each method closely correlates.

The REBA and RULA both identified that the arms, elbows, and wrists are at a high risk for developing CTDs due to the abducted arm postures, the flexion and extension of the wrists, and the repeated small-range actions involved when the workers perform the top-stitch in the seat-sewing line operation. The risk factors that have been identified by both assessment methods correlate with the information discussed in Chapter II of this study. Previous studies performed by Tayarri and Smith (1997) identified that, when repeating movements similar to those in the top-stitch process, workers will fatigue important muscle groups and may assume awkward postures to complete their work tasks. Tayarri and Smith (1997) also stated that the high-frequency repetitions, small actions, and awkward postures identified in the REBA and RULA assessments can cause or contribute to the development of CTDs. The outcomes of both the REBA and RULA assessments indicate that (1) there is a high risk of developing CTDs, (2) the process needs to be investigated further, and (3) changes must be implemented to protect employees.

The Upper Extremity Risk Factor Checklist identified that the ergonomic risk factors that are present in the top-stitch process aligned with the same risk factors discussed by Vern Putz-Anderson in the review of literature. The checklist identified the presence of steady motion, pinch grips greater than two pounds, neck twisting, unsupported arms and elbows above the mid-torso height, wrist extension and flexion 50 % of the time, and localized vibration that does not have dampening. The same risk factors discovered in the checklist and review of literature were also recognized in the REBA and RULA assessments. The review of literature and injury records indicate that the presence of these risk factors is associated with the development of

CTDs such as tendinitis, carpal tunnel, and cubital tunnel syndrome. Through the identification of these risk factors, Company XYZ will be able to use the risk factor information to (1) gauge the extent that such risk factors are abated and to (2) examine the effectiveness of the MSD-based improvements.

An injury record review identified that in the past four years, four injuries had occurred. This is significant because the amount of top-stitching also rose due to the introduction of a new recreational vehicle model. The higher demand in production has increased the likelihood for an injury from a rate of one OSHA recordable every two years during the period of 1996 to 2005 to a rate of one OSHA recordable every year during the period from 2006 to 2009. The injuries that have been documented in the past four years are all tendon and nerve-related injuries that are due to inflammation that causes the tendons to pinch or trap nearby nerves (Tayyari and Smith, 1997). As indicated in the review of literature by Putz-Anderson (1988), injuries such as carpal tunnel and cubital tunnel syndrome, which were present in the review of injury records, are associated with over-exertion of the wrist and forearm tendons due to high repetitions and reduced recovery times. The increased demand for seats that require the top-stitch has caused the sewing-line workers to perform more repetitions involving small-range motion than they performed before 2006. The injury review aligns with the data collected from the symptom survey and the REBA/RULA assessments in that each method identified awkward postures and high repetition in the arm, elbow, and wrist locations which are likely to have contributed to the reported injuries.

A symptom survey was administered to the workers of the seat-sewing line to identify symptoms of discomfort, pain, or numbness. Once the locations of distress were identified it was possible to compare the results of the questionnaire to the data collected in both the

REBA/RULA assessment methods and the review of injury records. The questionnaire identified that the wrists, hands, forearms, and shoulders were the areas where symptoms appeared the most. These identified symptoms align with the results of the REBA/RULA assessments which also identified the arms, wrists, and shoulders as being at the highest risk for developing CTDs. The injury record review also confirmed this data by identifying that there have been injuries occurring in the wrist, forearm, and elbows of the sewing-line workers.

The observations at Company XYZ have determined that awkward postures, high repetitions, and deviated wrists were present during the top-stitch process. The following literature review confirms that the risk factors present have the strong likelihood of developing into CTDs. Tayarri and Smith (1997), indicated that the four major risk factors which contribute to the development of CTDs include awkward postures, excessive forces, high repetitions, and vibration. The State of Washington (1993) also indicated that when high repetition was combined with forceful and awkward postures, the worker is at risk of developing CTDs due to the recovery time being insufficient. Examples of awkward postures include upper extremity postures such as excessive shoulder elevation, extreme elbow postures, and deviated wrists (Keyserling, Armstrong, & Punnett, 1991). It should also be noted that when the upper limbs (such as the wrist and hand) have adopted an awkward posture, the ability of the muscles to apply force is drastically reduced (Putz-Anderson, 1988). When comparing the data collected to the information presented in Chapter II, there appears to be a relationship between the injuries that the employees sustained in the sewing-line and the work that they are performing. High repetition, small range motions, and awkward postures are all present when performing the top-stitch. Putz-Anderson (1988) specifically notes that the combination of these risk factors will result in the development of CTDs. As identified in the data collected and the review of literature, the top-stitch sewing method is placed in the high risk category for the development of CTDs and change should be implemented.

Chapter V: Conclusions and Recommendations

The continued presence of arm and wrist-oriented musculoskeletal disorder risk factors on the seat-sewing line at Company XYZ is placing the organization at risk of incurring continued employee illness and other production/financial forms of loss. Therefore, the purpose of this study was to analyze the seat-sewing line at Company XYZ in order to determine the extent that ergonomic-based risk factors are present. In order to achieve this purpose, three goals were developed:

1. Perform a task analysis for the existing seat-sewing line using quantitative-based tools.

2. Review injury records and determine all ergonomic-based injuries that are associated with the seat-sewing process.

3. Perform qualitative surveys on employees and the tasks they perform to determine the extent of the problem.

The methodology used to collect data consisted of performing participant observations, digital video/picture recording, and the administration of an employee questionnaire. Forces applied during the sewing task were measured using a single axial hydraulic force gauge and the angles of identified posture were measured using a manual goniometer. The Rapid Upper Limb Assessment (RULA) and the Rapid Entire Body Assessment (REBA) techniques, along with the ergonomic checklist, were all performed by observing the participants, asking them details about production rates, and inputting the identified force and posture angles into the REBA and RULA assessment techniques.

Major Findings

The REBA assessment tool used in the study generated a final score of nine, which indicates that the process is high risk, needs to be investigated, and the process should be altered. The RULA assessment tool generated a score of six which indicates that further investigation is needed and change should be implemented to minimize upper extremity exposures. Company XYZ's past loss experience indicates that upper extremity injuries were the foremost injury suffered by employees working on the seat-sewing line over the past four years. The symptom survey indicated that workers in the seat-sewing line who are performing the top-stitch have and/or are experiencing distress in their upper extremities.

Conclusions

Based on the data collected in this study, the following conclusions can be made about the workers performing the top-stitch in the seat-sewing line at Company XYZ:

- The REBA/RULA assessment tools used in this study identified that the seat-sewing line process is at high risk for the occurrence of MSDs and therefore the process should be further investigated in order to implement changes that will reduce the ergonomic risk factors currently present. This conclusion was drawn due to the workers sewing with high repetition, adjusting the vinyl materials with abducted arms, pinching the vinyl material with deviated wrists, and repeating small-range motions to perform the top-stitch.
- The ergonomic risk factor checklist tool used in this study identified that workers in the seat-sewing line are routinely exposed to steady motion, pinch grips greater than two pounds, neck twisting, unsupported arms and elbows above the mid-torso

height, wrist extension and flexion 50 % of the time, and localized vibration that does not have dampening.

- Reviewing the injury loss records revealed that injuries in the past four years have occurred twice as often when compared to the ten years prior to 2006. This increase in injury occurrence can be attributed to the increase in production rates based on the introduction of a new recreational vehicle in 2006.
- The review of injury loss records also determined that upper extremity injuries are the only injuries occurring on the seat-sewing line. Performing the top-stitch is an exhaustive task where the arms are unsupported, the hands and wrists are performing small-range motions, and the production rates are causing high repetition. These risk factors were found throughout the study, so it can be concluded that they are contributing to the development of MSDs.
- Based on the employee symptom survey, employees identified that they were feeling discomfort, numbness, tingling, and/or fatigue in their wrists, arms, and shoulders while they were performing their daily tasks in the seat-sewing line. As discussed throughout this study, these symptoms are all indicators of the possible development of MSDs.
- Based on the REBA/RULA assessment methods, loss data collected, and the employee symptom survey, the risks associated with the seat-sewing line are repetitive motions, awkward postures, and small-range motions. Through the identification of past injuries, present risk factors, and the review of employee feedback from the symptom survey, it is possible to conclude that ergonomic issues are present in the seat-sewing line.

Recommendations

Based on the conclusions of this study and the hierarchy of controls, the following control measures are recommended to reduce the exposure of ergonomic-based risk factors and the occurrence of musculoskeletal disorders while performing the top-stitch in the seat-sewing line at Company XYZ:

Engineering controls.

- Work with the engineering department or the seat manufacturer to develop forearm supports that can be mounted to either the chair or sewing machine workstation. This will allow the sewing-line employees to support their arms while feeding the material through the sewing machine. This will eliminate the presence of shoulder shrug by allowing the workers to support their arms on the sewing table.
- Integrate a rounded and padded edge to the sewing machine workstation. As indicated by Putz-Anderson (1988), the reduction in contact stress with hard edges will decrease the amount of trapping and/or pinching of the median nerve, reducing the likelihood for the development of carpal tunnel syndrome.
- Design the sewing table top so that it can be slightly pitched or angled toward the sewing machine operator. This adjustment would keep the wrists in a more neutral posture as the employee feeds the vinyl material through the sewing machine. By pitching or angling the sewing machine towards the operator it will also reduce the awkward neck and upper back posture by providing an improved view of the material, thus reducing the likelihood of flexion in the spine and neck to perform the top-stitch.

Elimination.

- Elimination of the top-stitch would reduce the amount of small-range motions with deviated wrists that the seat-sewing line workers perform. As indicated in the review of literature, the combination of awkward postures and high repetitions can lead to the development of musculoskeletal disorders which affect the workers' ability to complete their daily tasks.
- Complete automation of the sewing process would eliminate the need for human interaction with the seat-sewing process.
- Implement a new seat cover spraying technology similar to an alligator-like skin that eliminates the use of vinyl covers. This is an automated process that eliminates the need for sewn covers.

Administrative controls.

- Train the sewing line employees about the benefits of proper stretching and implement a system to ensure the stretching is performed. Company XYZ currently has a posted stretching program, but there is not a system in place to ensure the stretching is performed.
- Implement a short stretching routine included with the rest break between every one hour station rotation to promote rest cycles so the sewing line employee's body can recover from the demands of the sewing tasks.
- Train the sewing line employees on the adjustability of their sewing workstations. Setting the correct height on the sewing workstation will help reduce the probability of employees assuming awkward postures to perform their sewing tasks.

- Train the sewing line employees on the adjustability of their new ergonomic chair systems. The adjustments that can be made to the chair will improve neck and back postures.
- Develop a rotation schedule that rotates workers from other divisions in and out of the seat-sewing line. This rotation would allow the sewing line employees to perform tasks that will require different physical demands than those needed to perform the sewing tasks.
- Review the process flow to ensure that the top-stitch is not being performed at more than one station in a row.
- Train the sewing line employees to recognize risk factors for work-related musculoskeletal disorders and instruct them in work practices that can ease the demands or burden of particular tasks.
- Develop a testing and evaluation process that utilizes employee feedback to verify that the proposed solution actually works and which would identify whether any additional enhancements or modifications may be needed.

Areas of Further Research

The scope of this study was considerably narrow consequently, a few areas have been identified for further research. The following areas should be considered for further investigation to identify the ergonomic-based risk factors that are present:

- Vibration was present during the top-stitch process, although the amount of vibration was not quantifiable. A quantitative analysis of the vibration present during the top-stitch process should be considered.

- Perform more in depth loss analysis research to determine the true costs of lost time away from work due to upper extremity injuries in the seat-sewing line.
- Expand the research to include other recreational vehicle seat covers that require the top-stitch to be performed at Company XYZ.
- Research what other recreational vehicle companies are using for their stitching patterns on their seat covers.

References

Asfalh, C.R. (1990). *Industrial safety and health management.* Englewood Cliffs, NJ: Prentice Hall

Bridger, R.S. (2009). *Introduction to ergonomics third edition.* Boca Raton, FL: CRC Press.

Burdoff, A. and Van der Beek, A.J. (1999). In musculoskeletal epidemiology are we asking the unanswerable in questionnaires on physical load? *Scandinavian Journal of Work and Environmental Health*, 25, 81 - 83.

Bureau of Labor Statistics, (2008, Dec. 02). Musculoskeletal disorders and days away from work in 2007. Retrieved June 12, 2009, from Bureau of Labor Statistics Web site: http://www.bls.gov/opub/ted/2008/dec/wk1/art02.htm

Burke, M.J., Sarpy, S.A., Smith-Krowe, K, Chan-Serafin, S, & Salvador, R.A. (2006). Relative effectiveness of worker safety and health training methods . *American Journal of Public Health* , 96(2), Retrieved from http://ajph.aphapublications.org/cgi/content/abstract/96/2/315 doi: 10.2105/AJPH.2004.059840

Canadian Centre for Occupational Health and Safety. (2008, October 21). *Vibration - measurement, control and standards.* Retrieved from http://www.ccohs.ca/oshanswers/phys_agents/vibration/vibration

Charlton, S.G., & B'Brien, T.G. (2002). *Handbook of human factors testing and evaluation second edition.* Mahwah, NJ: Lawrence Erlbaum Associates.

Chen, A.L. (2008, July 17). *Tenosynovitis.* Retrieved from http://www.nlm.nih.gov/medlineplus/ency/article/001242.htm

Chen, A.L., Gjessing, C.C., Fine, L.J., Bernard, B.P., & McGlothlin, J.D. (1997). *Elements of ergonomics program: a primer based on workplace evaluationsof musculoskeletal dissorders.* Cincinnati, OH: National Institute for Occupational Safety and Health.

Chengular, S.N., Rodgers, S.H., & Bernard, T.E. (2004). *Kodak's ergonomic design for people at work.* Hoboken, NJ: John Wiley & Sons, Inc..

Coyle, A. (2005). 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. *Work (Reading, Mass.)*, *24*(2), 111-116. Retrieved from MEDLINE database.

Croasmun, J, & Jacobs, P. (2003, July 18). *Using ergonomics to capture the moment.* Retrieved from http://www.ergoweb.com/news/detail.cfm?id=770

Cutt, S. (2007). Cubital tunnel syndrome. *Postgraduate Medical Journal*, *83*. Retrieved from http://www.nepsy.szote.u-szeged.hu/~kincsesz/docs/cubitaltunnel2007.pdf

Dickinson, C.E., Campion, K., Foster, A.F., Newman, S.J., O'Rourke, A.M.T., & Thomas, P.G. (1992). Questionnaire development: an examination of the nordic musculoskeletal questionnaire. *Applied Ergonomics*, *13*(3), 197-201.

Drinkaus, P., Sesek, R., Bloswick, D., Bernard, T., Walton, B., Joseph, B., et al. (2003). Comparison of ergonomic risk assessment outputs from Rapid Upper Limb Assessment and the Strain Index for tasks in automotive assembly plants. *Work (Reading, Mass.)*, *21*(2), 165-172. Retrieved from MEDLINE database.

Ergoweb. (2009). *Glossary of ergonomic terms.* Retrieved December, 15, 2009, from http://www.ergoweb.com/resources/reference/glossary.cfm

Federal Emergency Management Agency, . (1994, August). *Personal protective equipment study quide*. Retrieved from http://stargate.ornl.gov/EMCWeb/EMC/TrainingDocumentation/PPEStudentGuide.pdf

Friend, M.A. , & Kohn, J.P. (2007). *Fundamentals of occupational safety and health fourth edition*. Lanham, MD: Government Institutes.

Griffin, M.J. . (1990). *Handbook of human vibration*. San Diego, CA: Elsevier Academic Press.

Harada , N., & Griffin, M.J. (1991). Factors influencing vibration sense threshholds used to assess occupational exposures to hand transmitted vibration . *British Journal of Industrial Medicine*, 48(3), Retrieved from http://cat.inist.fr/?aModele=afficheN&cpsidt=11502164

Haslegrave, C.M., & Corlett, E.N. (Ed.). (1995). *Evaluation of human work: a practical ergonomics methodology*. Bristol, PA: Taylor and Francis Inc..

Hignett, S., & McAtamney, L. (2000). Rapid entire body assessment. *Applied Ergonomics*, 31(2), 201-205.

Hildebrandt, V.H., Bongers, P.M., Van Dijk, A.J.H., Kemper, H.C.G., and Dul, J. (2001). Dutch musculoskeletal questionnaire: description and basic. *Ergonomics*, *44*(12), 1038-1055.

Humantech. (2007). *Applied Industrial Ergonomics* (4.2 ed.) [Brochure]. Ann Arbor, MI: Humantech.

Kearney, D.S. (2008). *Ergonomics made easy*. Lanham, MD: Government Institutes.

Keyserling, W.M., Armstrong , T.J., and Punnett, L. (1991). Ergonomic job analysis: a structured approach for identifying risk factors associated with overexertion injuries and disorders. . *Applied Occupational & Environmental Hygiene* , 6(5), Retrieved from http://ioe.engin.umich.edu/ioe567/Keyserling1991.pdf

Kroemer, K., Kroemer, H., and Kroemer-Elbert, K. (1994). *Ergonomics: how to design for ease and efficiency.* Englewood Cliffs, NJ: Prentice Hall.

Lapidus, P.W., & Seidenstein, H. (1950). Chronic non-specific tenosynovitis with effusion about the ankle. *The Journal of Bone and Joint Surgery, 32A*(1), Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15401731

Li, K., Hsu, Y., and Tsai, C.(2003). Applying the brief survey in taiwan's high-tech industries [Electronic version]. *International Journal ofthe Computer, The* 58 *Internet and Management,* 11(2),78-86.

Likes, R.L. (2009, September 8). *Infectious and inflammatory flexor tenosynovitis.* Retrieved from http://emedicine.medscape.com/article/1239040-overview

Lunda, K.A., & Peate, W.F. (2002). *Ergonomics a risk manager's guide.* Rockville, MD: Government Institutes.

Malchaire, J. (2000). Strategy for prevention and control of the risks due to noise.. *Occupational and Environmental Medicine* , *57*(6), 361-369.

Michael, R. (2002, August 7). *Ergonomics tools: dynamometers and goniometers.* Retrieved December 16, 2009, from http://www.ergoweb.com/news/detail.cfm?id=574

McAtamney, L., & Corlett, E. N. (1993). RULA: A survey method for the investigation of workrelated upper limb disorders. *Applied Ergonomics,* 24(2),91-99.

MacLeod, D (1995). *The ergonomics: edge improving safety, quality, and productivity.* (pp. 98-107) New York, NY: Van Nostrand Reinhold.

MD Guidelines. (2009). *Epicondylitis, medial and lateral.* Retrieved from http://www.mdguidelines.com/epicondylitis-medial-and-lateral

National Aeronautics and Space Administration, . (2008, May 7). *Anthropometry and biomechanics*. Retrieved from http://msis.jsc.nasa.gov/sections/section03.htm

NexGen Ergonomics. (2007). *Baseline hydraulic push-pull dynamometers* . Retrieved from http://www.nexgenergo.com/ergonomics/baseline4.html

NIOSH, Initials. (1997, March). *Elements of ergonomics programs*. Retrieved from http://www.cdc.gov/niosh/docs/97-117/epstep7.html

Norcini, J., & Burch, V. (2007). Workplace-based assessment as an educational tool. *Meical Teacher*, 29(9), Retrieved from http://informahealthcare.com/doi/abs/10.1080/01421590701775453

North Carolina Department of Labor. (2009). *Sprains and strains.* Retrieved December 15, 2009, from http://www.nclabor.com/osha/etta/A_to_Z_Topics/Sprains.pdf

Occupational Safety and Health Administration. (2009). *Safety and health management systems etools.* Retrieved December 15, 2009, from http://www.osha.gov/SLTC/etools/safetyhealth/mod1_estimating_costs.html

Owen, S.J. (2003). *Have You completed your workplace hazard assessment*. Retrieved from http://www.maintenanceresources.com/referencelibrary/ezine/hazardassesment.htm

Pheasant, S, & Haslegrave, C. (2006). *Bodyspace: anthropometry, ergonomics, and the design of work* . Boca Raton, FL: Taylor and Francis Group, LLC.

Putz-Anderson, V. (Ed.). (1988). *Cumulative trauma disorders: A manualfor musculoskeletal diseases of the upper limbs.* New York: Taylor & Francis.

Radwin, R. G., & Yen, T. Y. (1999). Force dynamometers and accelerometers. In W. Karwowski & W. Marras (Eds.), *The occupational ergonomics handbook(pp.* 565-581). New York: CRC Press.

Rochester Institute of Technology, Initials. (2008, June 12). *Incedent rates.* Retrieved from https://www.rit.edu/cast/outreach/training/Module5/M5_IncidentRates.pdf

Roebuck, J.A. (1995). *Anthropometric methods : designing to fit the human body.* Santa Monica, CA: Human Factors and Ergonomics Society.

Salter, R.B. (1971). *Textbook of disorders and injuries of the musculoskeletal system.* Baltimore, MD: The Williams and Wilkins Company.

Schoenmarklin, R.W., Marras, W.S., & Leurgans, S.E. (1994). Rapid communication industrial wrist motions and incidence of hand/wrist cumulative trauma disorders . *Ergonomics, 37*(9), 1449-1459.

State of Montana. (2009). *Ergonomics prevention of ctds.* Retrieved from http://erd.dli.mt.gov/safetyhealth/brochures/ergonomicssample.pdf

State of Washington Department of Labor, (1993). Ergoweb - fitting the job to the worker: an ergonomics program guideline. Retrieved June 23, 2009, from Ergoweb Web site: http://www.ergoweb.com/resources/reference/guidelines/fittingjob.cfm

Tait, K. (1992). The Workplace exposure assessment expert system. *American Industrial Hygiene Association journal*, 53(2), Retrieved from http://www.cepis.org.pe/cursoepi/e/lecturas/mod4/articulo1.pdf

Tayyari, F, & Smith, J (1997). *Occupational ergonomics principles and applications.* London: Chapman and Hall.

Verheyden, J.R. (2009, June 26). *Cubital tunnel syndrome: workup.* Retrieved from http://emedicine.medscape.com/article/1231663-diagnosis

WebMD. (2010). Carpal tunnel syndrome. Retrieved May 10, 2010, from WebMD website: http://www.webmd.com/pain-management/carpal-tunnel/understanding-arthritis-about-carpal-tunnel-syndrome?page=2

Wolcott , C.L. (2004, February 2). Bad vibrations: hand-arm vibration exposure and havs prevention. *EHS Today*, Retrieved from http://ehstoday.com/standards/osha/ehs_imp_37195/

Zenone, T., Boibieux, A., Tigaud, S., Fredenucci, J.F., Vincent, V., Chidiac, C., and Peyramond, D. (1999). Non-tuberculous mycobacterial tenosynovitis: a review . *Scandinavian Journal of Infectious Diseases*, *31*(3), Retrieved from http://www.informaworld.com/smpp/content~content=a713933454

Appendix A: Human Subject Consent Form

Title: An Ergonomic Analysis of the Seat-Sewing Line at Company XYZ.

Investigator:
Joshua Check
Phone: 920-973-4401
Email: checkj@my.uwstout.edu

Research Sponsor:
Dr. Brian Finder
Phone: 715-232-1422
Email: finderb@uwstout.edu

Description:
You will be observed in the sewing operation of the problematic seat. Video and pictures will be taken for later analysis and review. Video and photo will not be published with or within the research paper, and will be destroyed after analysis is complete. You will carryout your normal task of sewing materials. After your actions have been observed, you will be notified that the observation is over.

Risks and Benefits:
Risks: The most prevelant would be the risk of discomfort of being observed and recorded. Many people do not care to have their pictures taken or be recorded. If you do not wish to be recorded through video or photograph, you will not be. Physical risk of discomfort is a possibility, however you will not be asked to do anything more than required by the normal everyday operations of your job.

Benefits: The benefits to you and others include avoidance of future injury or pain by better understanding the ergonomic demands of the task being observed. As the task will be dealing with larger material requirements in the near future, the risk of a musculoskeletal injury greatly increases. The purpose of this study is to reduce injury, pain, and loss (financial, quality of life, etc) due to increase of ergonomic stressors resulting from an increase in material size and weight.

Time Commitment:
The time commitment required by this observation is not expected to take more than an hour. Observations will be made during hours of operation while the subject is on-duty. The observation is expected to interfere with normal operation as little as possible.

Confidentiality:
Your name will not be included on any documents. We do not believe that you can be identified from any of this information. This informed consent will not be kept with any of the other documents completed with this project. Other identifying information such as video or photos will be destroyed after the study is complete and will not be published with or within the research paper. There will be no other collection of personal information.

Right to Withdraw:
Your participation in this study is entirely voluntary. You may choose not to participate without any adverse consequences to you. Should you choose to participate and later wish to withdraw

from the study, you may discontinue your participation at this time without incurring adverse consequences.

IRB Approval:
This study has been reviewed and approved by The University of Wisconsin-Stout's Institutional Review Board (IRB). The IRB has determined that this study meets the ethical obligations required by federal law and University policies. If you have questions or concerns regarding this study please contact the Investigator or Advisor. If you have any questions, concerns, or reports regarding your rights as a research subject, please contact the IRB Administrator.

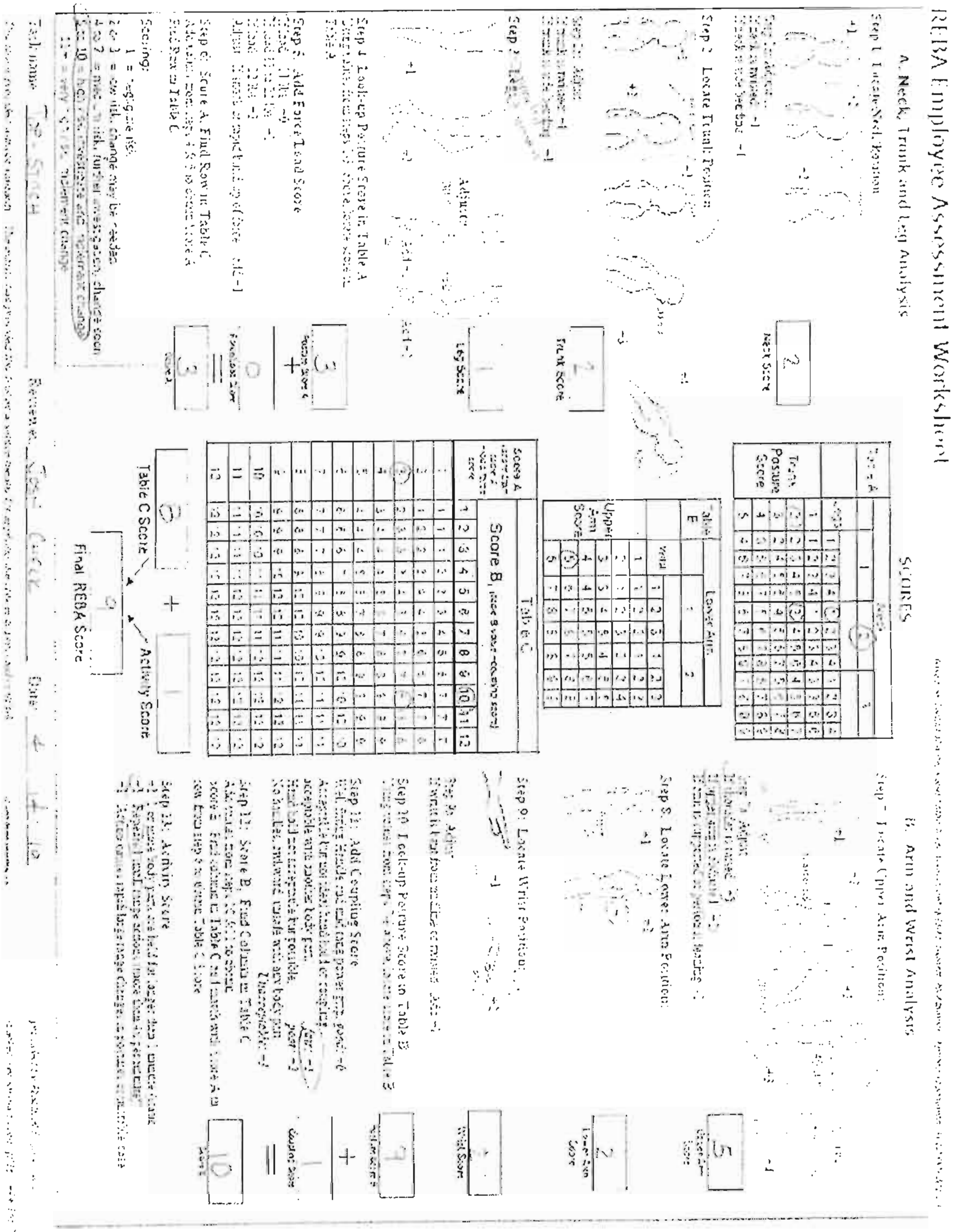
Investigator:
Joshua Check
Phone: 920-973-4401
Email:checkj@my.uwstout.edu

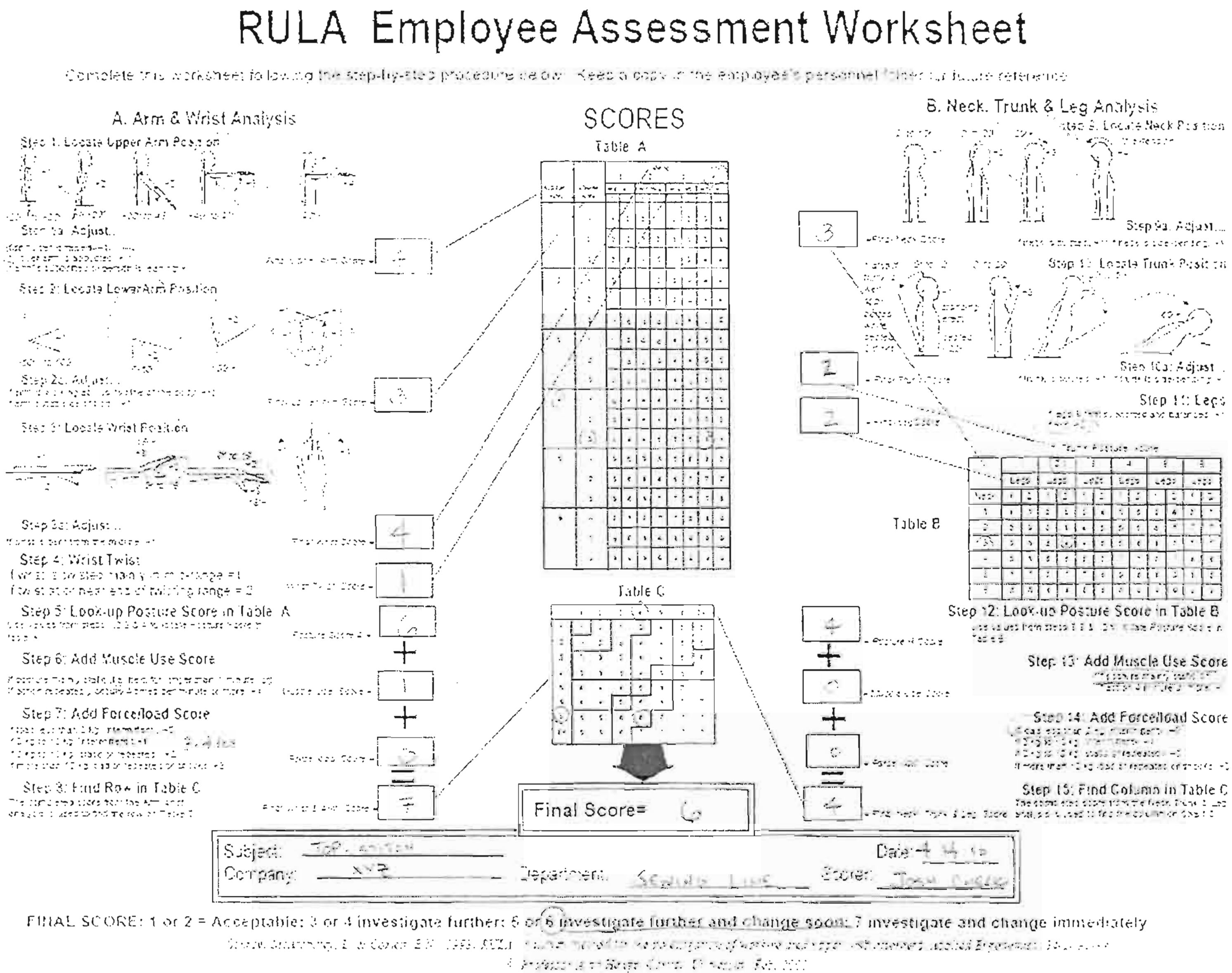
Advisor:
Dr. Brian Finder
Phone: 715-232-1422
Email: finderb@uwstout.edu

IRB Administrator:
Sue Foxwell, Director, Research Services
152 Vocational Rehabilitation Bldg.
UW-Stout
Menomonie, WI 54751
Phone: 715-232-2477
foxwells@uwstout.edu

Statement of Consent:
By completing the following survey you agree to participate in the project entitled "An Ergonomic Analysis of the Seat-Sewing Line at Company XYZ."

Appendix B: REBA Assessment of Seat-Sewing Line




RULA Employee Assessment Worksheet

A. Arm & Wrist Analysis

Step 1: Locate Upper Arm Position

Step 1a: Adjust...

Step 2: Locate Lower Arm Position

Step 2a: Adjust...

Step 3: Locate Wrist Position

Step 3a: Adjust...

Step 4: Wrist Twist

Step 5: Look-up Posture Score in Table A

Step 6: Add Muscle Use Score

Step 7: Add Force/load Score

Step 8: Find Row in Table C

SCORES

Table A

Table C

Final Score= 6

B. Neck, Trunk & Leg Analysis

Step 9a: Adjust...

Step 10: Locate Trunk Position

Step 10a: Adjust...

Step 11: Legs

Table B

Step 12: Look-up Posture Score in Table B

Step 13: Add Muscle Use Score

Step 14: Add Force/load Score

Step 15: Find Column in Table C

Subject:

Date:

Company: XYZ

Department:

Scorer:

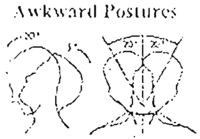
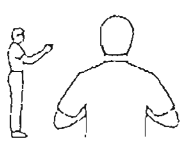
FINAL SCORE: 1 or 2 = Acceptable; 3 or 4 investigate further; 5 or 6 investigate further and change soon; 7 investigate and change immediately

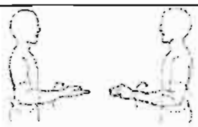
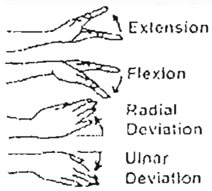
Appendix D: Ergonomic Risk Factor Checklist

ERGONOMIC RISK FACTOR CHECKLIST

UPPER EXTREMITY RISK FACTOR CHECKLIST

Date: 4/14 Analyst: [illegible] Job: Top-Stitch Location: Sewing Line

RISK FACTOR CATEGORY	RISK FACTORS	EXPOSURE Is the risk factor present within the job or task?	TIME				SCORE
			0% to 25% of total job time	25% to 50% of time	50% to 100% of time	If total time for job is >8hrs, add 0.5 per hour	
Upper Limb Movements	1. Moderate: Steady motion with regular pauses	X YES NO	0	1	(2)	—	2
	2. Intensive: Rapid steady motion without regular pauses	YES X NO	1	2	3	—	--
Keyboard Use 	3. Intermittent Keying	YES X NO	0	0	1	—	--
	4. Intensive Keying	YES X NO	0	1	3	—	--
Hand Force (Repetitive or Static) 	5. Squeezing Hard with the Hand in a Power Grip	YES NO	0	1	3	—	—
	6. Pinch More than 2 pounds	X YES NO	1	(2)	3	—	2
Awkward Postures 	7. Neck: Twist/Bend (twisting neck >20°, bending neck forward >20° or back < 5°)	X YES NO	0	1	(2)	—	2
	8. Shoulder: Unsupported arm or elbow above mid-torso height	X YES NO	1	2	(3)	—	3

RISK FACTOR CATEGORY	RISK FACTORS	EXPOSURE Is the risk factor present within the job or task?	TIME				SCORE
			0% to 25% of job time	25% to 50% of time	50% to 100% of time	If job time is >8hrs, add 0.5 per hour	
	9. Rapid Forearm Rotation	☐ YES X NO	0	1	2	—	—
	10. Wrist: Bend or Deviate	X YES ☐ NO	1	(2)	3	—	2
Contact Stress 	11. Hard-Sharp objects Press into Skin	X YES ☐ NO	0	(1)	2	—	1
	12. Using the Palm of the Hand or Wrist as a Hammer	☐ YES X NO	1	2	3	—	—
Vibration 	13. Localized Vibration (without dampening)	X YES ☐ NO	0	1	(2)	—	2
	14. Whole-body Vibration (without dampening)	☐ YES X NO	0	1	2	—	—
Environment	15. Lighting (poor illumination or glare)	☐ YES X NO	0	0	1		—
	16. Adverse Temperatures	☐ YES X NO	0	0	1		—
Control Over Work Pace	17. One control factor present = 1 Two or more control factors present = 2	☐ YES X NO					—
TOTAL UPPER EXTREMITY SCORE							14

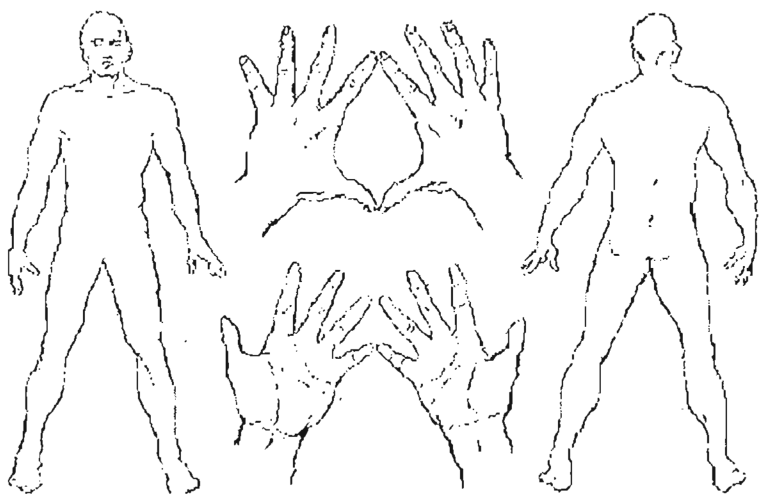
Appendix E: Symptom Survey

This project has been reviewed by the UW-Stout IRB as required by the Code of Federal Regulations Title 45 Part 46

Ergonomic Questionnaire

1. Do discomforts in your wrist, arm, or shoulder interfere with your daily activities?
   Yes or No.

2. If you answered yes to question 1, please mark on the picture below the areas where you have experienced repeated pain within the last month. Place an N for numbness, a P for pain, a T for tingling, an S for soreness, a D for discomfort, and/or an F for fatigue.



3. Are you experiencing or have recently experienced any numbness, pain, tingling, soreness, discomfort, or fatigue during or after work? Yes or No.

4. Does your current job require arm, hand, or finger actions to be repeated many times each hour and shift? Yes or No.

5. During what task does the pain and/or discomfort appear?________________________
   (If experiencing no pain write NONE)