Ergonomic Assessment and Improvement of the XYZ+ Assembly Line

by

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Abstract

The purpose of this study is to reduce the risk of ergonomic injury during the material handling processes at Company ABC in their XYZ+ process. In order to achieve this, the following goals serve as the basis for this study: assess the current ergonomic requirements to move, load, and unload material rolls from the XYZ+ process with the Rapid Entire Body Assessment (REBA), the Rapid Upper Limb Assessment (RULA), and the National Institute for Occupational Safety and Health (NIOSH) lifting equation; accurately project future ergonomic design and equipment needs of the XYZ+ process; and recommend needed changes and/or equipment needed for said changes in production. The main recommendations to reduce the risk of ergonomic injury include the use of ergonomic lift assisting equipment, the use of carts to transport materials, the redesign of production equipment to improve ergonomics and reduce awkward postures, and monitoring of improvements made to ensure effectiveness of treatment.

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Chapter I: Introduction

Company ABC manufactures disk drive suspension systems used in computer hard drives. Customers of ABC include hard drive manufacturers for the desktop and notebook computer market, digital video recorders, personal data storage devices, and portable media players. ABC employs a number of manufacturing processes, and innovations are constantly being explored. A recent improvement developed by ABC, known as XYZ+, allows flexures, critical to hard drive suspensions, to be built smaller and with more features than previously possible. Traditionally, flexures were produced on 8.5x11 sheets of stainless steel and required a large amount of material handling between processes. XYZ+ allows rolls of stainless steel to be processed as opposed to individual sheets, reducing material handling. This highly automated process uses material rolls weighing as much as 65lbs which are roughly 1 foot wide and have a diameter of 1 foot.

The material rolls used in the XYZ+ process could lead to ergonomic injuries by requiring employees to exceed their anthropometric limits. Using current material handling processes, employees will not be able to load/ unload the material without significant risk of a musculoskeletal injury or product loss without additional help provided by other employees or mechanical assisted lifting devices.

National Trends

Ergonomic injuries are a leading cause of loss in industry today. According to the Occupational Health and Safety Administration (OSHA), work-related MSDs currently account for one-third of all occupational injuries and illnesses reported to the Bureau of Labor Statistics (BLS) by employers every year. These disorders thus constitute the largest job-related injury and illness problem in the United States today. In 1997, employers reported a total of 626,000 lost workday MSDs to the BLS, and these disorders accounted for $1 of every $3 spent for workers' compensation in that year. Employers pay between $15-$20 billion in workers' compensation costs for these disorders every year, and other expenses associated with MSDs may increase this total to $45-$54 billion a year. Workers with severe MSDs can face permanent disability that prevents them from returning to their jobs (1999). The potential for loss from ergonomic injuries varies from company to company due to many factors including work performed, where work is performed, along with many other stressors. This has a huge significance for ABC company as many of its processes require high amounts of material handling.

Statement of the Problem

The material handling process described above potentially poses too great a risk for ABC workers stemming from ergonomic concerns.

Goals of the Study

The goals of this study include the following:

- Assess the current ergonomic requirements to move, load, and unload material rolls from the XYZ+ process with the REBA, RULA, and NIOSH lifting equation.
- Accurately project future ergonomic design and equipment needs of the XYZ+ process based on successive increases in material roll size.
- Recommend needed changes and/or equipment for changes in production, and justify the changes using the ergonomic assessment findings.

Methodology

The methodology used in this paper includes an array of ergonomic assessment tools including;

- o Rapid Entire Body Assessment (REBA)

- Rapid Upper Limb Assessment (RULA)
- The Revised NIOSH Lifting Equation
- Video and Digital picture documentation
- Goniometer
- Scale

Assumptions of the Study

One assumption of the study is that the conclusions and recommendations of this study are made under the assumption that material weights and sizes will remain at or not exceed the weights and sizes comprehended by this study.

Definition of Terms

XYZ+. A Process created by ABC which uses rolls of material to process product as opposed to traditional "sheets" of material.

Ergonomics. The applied science of equipment design, as for the workplace, intended to maximize productivity by reducing operator fatigue, discomfort, and eliminating injury.

Rapid Entire Body Assessment (REBA). The REBA is a survey method developed for use in ergonomic investigations. The REBA is a screening tool that assesses biomechanical and postural loading on the whole body.

Rapid Upper Limb Assessment (RULA). The RULA is a survey method developed for use in ergonomic investigations. The RULA is a screening tool that assesses biomechanical and postural loading on the whole body with particular attention to the neck, trunk and upper limbs.

Revised NIOSH Lifting Equation. The NIOSH Lifting Equation is a tool used to identify, evaluate, or classify some risks associated with a lifting task. NIOSH stands for the National Institute for Occupational Safety and Health.

Cumulative Trauma Disorder (CTD). Cumulative Trauma Disorder is a condition where a part of the body is injured by repeatedly overusing or causing trauma to that body part. Trauma occurs when the body part is worked harder, stretched farther, or otherwise function at a greater level then it is prepared for. The immediate impact may be minimal, but when it occurs repeatedly the constant trauma cause damage.

Musculoskeletal Disorder (MSD). Musculoskeletal Disorders can affect the body's muscles, joints and tendons. Most work-related MSDs develop over time and typically affect the back, neck, shoulders and upper limbs

Anthropometry. The science dealing with measurement of the size, weight, and proportions of the human body

Limitations of the Study

A limitation of this study was the trade secret nature of the product and process. Because of this, specific information was published to this paper. For this reason much of the information recorded in this paper was left vague and generalized.

Chapter II: Literature Review

The goal of this study is the investigation of the ergonomic demands of material core handling resulting from the XYZ+ manufacturing process at Company ABC. The XYZ+ manufacturing process developed by ABC allows flexures, critical hard drive suspension components, to be built smaller and with more features. Unlike ABC's past processes, the XYZ+ process uses rolls of material in a highly automated production system. This automation eliminates much of the repetitive material handling required by older processes. However, due to the dimensions and weight of the large material cores, XYZ+ creates new ergonomic issues. Without proper practices in place, employees handling these heavy material cores risk musculoskeletal injuries, resulting in significant cost and productivity loss. The following is a review of selected topics related to this study. These include: ergonomics, types of ergonomic injuries, the cost of ergonomic injuries, benefits of a strong ergonomic program, ergonomic control measures, and the tools of ergonomic assessment.

Ergonomics

Ergonomics is derived from the Greek words "ergon," meaning work, and "nomos" meaning law. Ergonomics therefore means the laws of work. The discipline of ergonomics involves studying how employees relate, physically and psychologically, to their working environment (Della-Giustina, 2007). In other words, "Ergonomics is the field of study that seeks to design tools and tasks to be compatible with human capabilities and limitations" (Macleod, 1995). To understand what human capabilities and limitations are, ergonomists use anthropometric data. These data, the human body's physical dimensions, are, "used to improve the human fit in the workplace or determine problems existing between facilities or equipment and the employees using them" (Friend, & Kohn, 2007). Anthropometrics is the study of human body measurements and properties and ergonomics is the science of preventing and/or reducing injuries to employees using design and anthropometric data. Using anthropometric data, ergonomists isolate workplace variables responsible for employee injury and illness and work to eliminate or minimize them. These stressors include weight, repetitive motion, posture, and workplace temperature (Daugherty, 1999). Beyond the benefits of a safe and healthy workplace, applied ergonomics is a work multiplier, improving productivity by reducing conflict between worker and the work environment (Humantech, 2005). An effective ergonomics program accomplishes this through the systematic identification and elimination of ergonomic risk factors.

Ergonomic Risk Factors

As stated above, ergonomics involves the identification of stressors in the workplace, from load to heat and cold, which negatively impact worker health and performance. Ada Craven expands on these risk factors and identifies the eventual outcome if left unaddressed, namely musculoskeletal disorders (MSD), "Some leading causes of MSDs are; exerting excessive forces, repetitive movements, awkward postures, excessive vibrations and cold temperatures" (2003). This section explores the various risk factors and their effect on employees.

Excessive Forces/Heavy Loads. Material handling often requires employees to exert excessive forces by lifting, pushing, pulling, carrying, or holding heavy loads. Handling even small, lightweight objects can strain workers because it requires them to stretch, move, bend, or straighten out body parts. However, heavy loads pose additional strain on the body due to their weight, bulk, or lack of handles. Poor handles put excessive strain on arms, hands, and fingers as it requires more effort to lift and hold the object (Kromer, Kromer, & Kromer-Elbert, 1994).

Heavy objects requiring excessive force to move affect the body by causing strain to muscles and tendons. When the body is frequently strained due to heavy lifting, the risk of developing a cumulative trauma disorder (CTD) is increased (Tayyari, & Smith, 1997).

Repetitive Motions are the same movements recurring repetitively. By repeating the same movements over and over, the muscles involved eventually become fatigued. A highly repetitive task is defined as having a cycle length of 30 seconds or less, meaning that the task is performed at least twice every minute. A cycle length of 1.5 minutes is considered optimal for fast paced tasks. A cycle time shorter than 1.5 minutes results in muscle tension and fatigue. High frequencies of repetition, even with small forces, can cause CTDs. The prolonged use of tense and fatigued muscles increases the risk of CTDs, as the muscles are not given a chance to recover. The chance of developing a CTD increases greatly if repetitive motions are combined with poor postures and excessive force/ heavy loads (Tayyari & Smith, 1997).

Awkward Postures are positions which require the body to deviate significantly from the neutral position while job tasks are being performed. The neutral position refers to the position of the body at rest. For example, when a person's arm is hanging straight down (perpendicular to the ground) with the elbow close to the body, the shoulder is said to be in a neutral position. However, when employees are performing work that requires them to extend their arms away from the body, such as performing overhead work, their arms are far from the neutral position (Iowa State University, 2005). Poor body positions, whether sitting or standing, place a person at risk of developing CTDs. Like in the example above, even if an employee is seated and performing overhead work, the arms are still in an awkward position. Fixed postures, even good ones, are also harmful if held or unchanged. When a position is held for an extended period of time, it is called a static position. An example of this would be working with a person's neck bent forward for long periods of time. When a person holds a static posture, muscle tension builds up and circulation is reduced. Awkward positions can cause CTDs by putting increased pressure on muscles, tendons, and nerves. However, the effects are amplified when combined with repetitious movements. Excessive bending of the wrists in any direction can lead to CTDs like carpal tunnel (Tayyari, & Smith, 1997). In general, the more extreme the posture, the greater the posture's deviation from the neutral position. When postures deviate further from neutral positions, they operate less efficiently, requiring more force to complete tasks. Therefore, awkward postures make forceful exertions even more forceful, which increases the recovery time needed by the muscles being used. When awkward postures are combined with one or more additional ergonomic risk factors the onset of fatigue is hastened, increasing the likelihood of injury from overuse. In some cases, awkward postures may be so extreme that they can turn a low-risk repetitive motion job into a high-risk job (Iowa State University, 2005).

Heat/Cold Stress affects people in many different ways. Graciela Perez notes that cold temperatures can reduce dexterity and sensory perception, especially in the hands and feet. This happens as a result of vasoconstriction, or the body moving the blood away from the extremities to the organs to maintain a core temperature of over 96.8 degrees Fahrenheit. Cold stress can lead to more severe effects, including dehydration, numbness, shivering, frostbite, immersion foot (also known as trench foot), and hypothermia. Shivering is the result of the body trying to maintain its core temperature by increasing the rate of metabolism. In the most severe cases, hypothermia occurs as the body is no longer able to maintain its core temperature, which can result in death if untreated. As discussed in the above sections, the presence of one or more ergonomic risk factors can exacerbate fatigue. An example of this is the combined effect of cold and segmental vibration (1999).

Heat has its negative effects on the body as well. Like with cold stress, heat affects blood flow and heart rate in the body. Ada Kahn further explains the effects of heat on the body.

> Environmental factors that often affect the workers discomfort in a hot work area include temperature, humidity, radiant heat (such as from the sun or a furnace), and air velocity. The person's age, weight, fitness, medical condition, and acclimatization to heat are also factors. The body reacts to high external temperature by circulating blood to the skin, which increases skin temperature and allows the body to give off excess heat through the skin. However if muscles are being used for physical labor, less blood is available to flow to the skin and release the heat. The body sweats to maintain a stable internal body temperature in hot situations. However, sweating is only effective if the humidity level is low enough to permit evaporation and if the fluids and salts lost are adequately replaced. According to the Safety and Health Department of the International Brotherhood of Teamsters (IBT), the body stores excess heat if it cannot dispose of it. When this happens, the body's core temperature rises and the heart rate increases. As the body continues to store heat, the individual begins to lose concentration and has difficulty focusing on a task, may become irritable or sick, and loses the desire to drink, possibly resulting in fainting and death if the person is not removed from the heat stress (2004).

Excessive vibrations affect the body over a relatively long period of time, unlike heat and cold stress. When vibration is experienced over a prolonged period of time, it can damage bones and joints. The body parts most susceptible to vibration related CTDs are the arms and hands. The best known resulting condition from excessive vibration is white finger, an extremely painful condition that can be disabling. White finger is usually caused by the long-term use of handheld power tools such as chainsaws, impact drivers, or grinders. (Kahn, 2004).

However, arms and hands are not the only body parts at risk. Whole body vibration exposures have been observed in truck drivers, large metal stamping operations, and the use of large vibrating tools like jackhammers. These tasks vibrate the entire body for extended periods of time; exposure ranges from days to years depending on the task. These exposures have been associated with back and neck disorders, including micro fractures of vertebral endplates, and urinary and digestive discomfort. (Perez, 1999). Again, as with many other ergonomic risk factors, the presence of more than one can exacerbate the effects of each. In this case, using vibrating tools like powered drills, chippers, sanders, and saws under cold conditions can cause CTDs at a faster rate than if the risk factors are experienced separately (Tayyari, & Smith, 1997).

Types of Ergonomic Injuries

As demonstrated in the previous section, employees performing a task with ergonomic risk factors for an extended period of time can develop musculoskeletal disorders and cumulative trauma disorders. The terms MSD and CTD are sometime used interchangeably. This section defines these terms as used in this study.

MSDs, or musculoskeletal disorders, are among the most common medical problems in the United States today, “affecting 7% of the population. They account for 14% of physician visits and 19% of hospital stays"(Rosenstock, 1997). These disorders are defined as some form of degradation of the muscles, tendons, ligaments, joints, cartilage, nerves, blood vessels, or spinal discs. MSDs are illnesses of the body’s muscles and tendons. A few examples are muscle strains, ligament sprains, joint and tendon inflammation, pinched nerves, and spinal disc degeneration (Chengular, Rodgers, and Bernard, 2004). They represent a wide range of disorders, which can differ in severity from mild periodic conditions (a bruised arm) to those which are severe, chronic, and debilitating (a severe back injury). Some musculoskeletal disorders have specific diagnostic criteria and clear pathological mechanisms (like hand/arm vibration syndrome). Most are defined primarily by the location of pain and have a more variable or less clearly defined pathophysiology (like back disorders) (Rosenstock, 1997). MSDs can be caused by a single ergonomic stress factor or the combination of several. For example, back injuries can be caused by an excessive force/heavy lifting, or the combination of a heavy load and repetitive lifting from an awkward position. A musculoskeletal injury is usually associated with an injury occurring in a relatively short amount of time; however the terms MSD and CTD are sometime used interchangeably.

CTD or cumulative trauma disorder is a much more comprehensive term used to distinguish that group of musculoskeletal disorders which involve injuries to the nerves, muscles, tendon sheaths, ligaments, bones, and joints in the upper and lower extremities. These disorders are developed gradually, resulting from repeated stress on the body which exceeds its capacity to recuperate. Here is an example of the difference between a CTD and a MSD. The term back injury can be used to identify a group of musculoskeletal disorders to the vertebrae, intervertebral disks, and other tissues of the back. A back injury may be acute, that is occurring over a relatively short period of time or even a single exposure, and is considered to be a MSD. A back injury may also be chronic, meaning that it develops over some period of time and still considered a MSD. However, the chronic type of back troubles is usually due to either assuming awkward postures or to overexertion during manual material handling. Since these types of back injuries are developed over time, they are usually classified under CTD (Tayyari, & Smith, 1997).

The Cost of Musculoskeletal Disorders

Ergonomic injuries are a major source of financial, material, and time loss for many organizations. The costs necessary to cover these losses must come from somewhere, and that is out of a company's bottom line. In the present national and international competitive business culture, companies with excellent safety and health programs can better control their overhead costs and be more competitive (Colvin, & Colvin, 1999). Ergonomist Dan Macleod adds, "There are a variety of costs associated with inadequate design, both in the workplace and in the use of products and services. Many of these costs can threaten the viability of the company. Ergonomics can help reduce these costs and make an organization more competitive. Employers often assume that many costs in the workplace are merely a part of doing business and beyond their control. In fact, many of these costs can be controlled, through effective ergonomic applications" (1995). The costs associated with poor ergonomic design, programs, and practices can be divided into two groups; direct and indirect costs.

Direct Costs are costs that are directly accountable to a particular function or incident. These costs can include medical costs, fines, and lost wages. Medical costs account for most of the direct costs associated with MSDs/CTDs, with back injuries being some of the most costly MSDs. This study focuses on just a few MSDs related to material handling performed at Company ABC, with back injuries targeted as the most likely MSD resulting from ABC's implementation of XYZ+.

Back injuries suffered in the workplace can be some of the most costly injuries to incur. Back pain affects 5.4 million Americans each year, costs 16 billion annually for treatment, and is cited in 30%-40% of all workers' compensation claims, according to OSHA's Office of Ergonomics (Kearney, 2008). Back injuries are a dreaded and lingering problem that can easily reach the twenty thousand dollar mark for surgical repair of several ruptured disks requiring fusion, not including rehabilitation, therapy, lost wages, and disability pay. Recovery from back injuries is a slow process, and even with a return to work, most employees must be put on restricted duty or transferred to another task to avoid reoccurrence (Sharma & Moody, 2001). Once a back is injured, it is unlikely it will ever fully recuperate. A first-time back injury can be very costly, but successive back injuries can cost far more, "For a first-time back injury, the cost of drugs, doctor's visits, and physical therapy can add up to as much as $10,000. But for more severe cases -- the kind that result when a person is hurt over and over again -- the costs can climb as high as $300,000" (Gorder, 2001)

Indirect Costs are business costs that are not directly accountable to a particular function or incident. Ray Colvin and Rosemary Colvin, owners of Safety Training Dynamics have compiled a list of indirect costs that are often over looked. These costs include

- Lost and/or reduced production until the injured employee returns to work full time
- Long term physical restrictions (light duty) of employees work activities from causes such as carpel tunnel or repetitive motion problems, back injuries, strains, etc.
- Reduced production until a replacement employee comes up to speed with the operations, if the employee's duties are done by someone else.
- Increased insurance costs (insurance companies add a surcharge to the premium for the money they pay out over and above the basic insurance contract
- The total cost of the time lost by the injured employee beyond the actual time at home away from the job. For example, after the employee returns to work while being treated, examined, filling out questionnaires, talking about the injury with supervisor or accident investigation team, short term light duty, etc.

- Overtime for the employees who must perform the injured employee's duties, if a replacement cannot be obtained.
- Damage to machinery equipment, product, or facility during the accident (fork truck, materials handling, process, etc.)
- Production Interruption
- Delayed filling of production orders or contractual deadlines to complete work (1999)

Indirect costs can be hard to quantify, as they are not directly accountable to the function or incident itself, and oftentimes continue for months if not years. Understanding the full effect of ergonomic functions or incidents resulting from poor ergonomics is crucial, as the consequences can be much more extensive than what they initially appear to be.

Benefits of a Strong Ergonomic Program

The benefits resulting from an effective ergonomics program are many. A smoothly functioning ergonomics plan can reduce the risk of both cumulative trauma injuries and serious injuries such as amputations, lacerations, or broken bones. A reduction in injuries affects workers compensation costs. Unfortunately, workers compensation costs are often seen as a cost of doing business that cannot be avoided; however, these are controllable costs. Logically, lower risk leads to a lower rate of injury, thus reducing workers compensation costs (Della-Giustina, 2007). When good ergonomic designs are in effect, increases in productivity and quality can occur. This results when workers exert less effort to accomplish their task thereby reducing fatigue, and improving productivity and quality. Correcting or improving a poorly designed machine will have the same effects as designing a machine to be ergonomically friendly, however it is preferred that a machine be designed with ergonomics in mind. In this way time and money lost correcting bad designs can be saved (Humantech, 2005).

Ergonomic Control Measures

Good ergonomic designs are not accidents. Ergonomic designs are intended for the majority, fitting roughly 95 percent of all male workers in the workplace. Anthropometry is the study of people in terms of their physical dimensions such as height, reach distance, etc. Using anthropometric data, machine and equipment designers can accommodate the 5th percentile of women to the 95 percentile of men (Daugherty, 1999). Ergonomists rely on many different tools to help them create or correct a working environment. These tools are engineering controls, administrative controls, and personal protective equipment. These controls can be used individually or combined to obtain the desired ergonomic control.

Engineering controls change the physical design of the machine or process being investigated. When machines are designed to be ergonomic, that is usually represented in an engineering control. Examples of engineering controls include adjustable table heights, suspended tool systems, or lift-assist systems. (Tayyari, & Smith, 1997). Ergonomic design of load, task, equipment, and work station, including the work environment and the total facility, is the most successful single approach. Whenever possible, it is preferred that engineering controls be implemented first as they are the most successful approach to correcting poor ergonomics. Engineering solutions can avoid or remove causes of possible over exertion injuries, thus generating fundamentally safer, more efficient, and more agreeable working conditions. Ergonomic design does not just correct the symptom or depend on worker education or involvement as administrative and a PPE control do, but actually eliminates the ergonomic hazard. (Kromer, Kromer, & Kromer-Elbert, 1994) When a working environment is designed for ergonomics, as opposed to requiring correction after it is designed and built, the benefits are far reaching. Cost effectiveness in ergonomics is a result of design incentives. Good design costs no more than bad design. Not only do good designs cost the same as bad designs, good designs save time and money required to retrofit poorly designed machinery and working environments (Kearney, 2008).

Administrative Controls are recommended when engineering tools are not immediately available or fail to be economically feasible. These controls are used to limit risk exposure, but not remove the exposure. These controls include policies, procedures, and regulation. Examples of these include training for exposed employees, exposure time limits, and other standard procedures meant to reduce exposure or the risk of injury. If an engineering control cannot be incorporated into a job requiring repetitive motions, work-rest cycles can be modified to allow muscles to recover from work induced fatigue and tension (Tayyari, & Smith, 1997).

Training allows employees to protect themselves by learning how to reduce the risk of developing CTDs. Training should make them aware of what they can do to achieve this goal (Tayyari, & Smith, 1997). Training has been attempted in many different ways. Training relies on the assumption that there are "safe" procedures that can be identified, taught and followed. Unfortunately no single technique submitted to scientific scrutiny has yet been proven enduringly successful. Even when training is successful, rarely if ever will it be 100% effective in mitigating the exposure (Kromer, Kromer, & Kromer-Elbert, 1994). More drawbacks of training include time required for training. Each affected employee must be trained, requiring them to stop production. Training must be repeated on a regular basis to ensure retention and convey changes.

Rotating Workers among Jobs is a method used to limit the amount of exposure an employee has to an ergonomic stressor. The general idea is to cross train employees in a work group in several different tasks, then rotate employees within the work group exposed to stressful and repetitive tasks to tasks that are less repetitive or stressful. Employees should be rotated to tasks not requiring use of the same muscles or motions. This may be implemented in daily or weekly schedules so that workers perform various tasks instead of performing the same repetitive tasks every day. However, rotation of jobs within each day is preferred over rotating them between days. An example of an ideal job rotation would be to have an employee working an 8 hr work day rotate to 4 separate and different tasks at 2 hour intervals (Kromer, Kromer, & Kromer-Elbert, 1994).

Personal Protective Equipment or PPE is normally recommended as a last resort when engineering and administrative controls have not been successful. PPE is meant to protect workers from the working environment and is worn on the body. PPE should not be confused with medical devices. PPE is a preventative measure while medical devices are used in posttraumatic situations. Examples of PPE for hand-arm protection include gloves, finger guards, hand pads, sleeves, and protective hand creams. (Tayyari, & Smith, 1997). Personal protective equipment such as gloves can be effective in preventing lacerations, however the use of personal protective equipment can result in additional ergonomic stressors. For example, helmets can add extra strain to the neck. Lifting belts may be considered by some companies as a form of PPE; however the use of such belts for industrial material handling does not seem to be an effective way of preventing overexertion injuries: even competitive weight lifters do suffer back injuries, and there is reason to believe belts could restrict mobility and provide a false sense of security. By restricting mobility, the employee is required to exert more force to accomplish a task (Kromer, Kromer, & Kromer-Elbert, 1994). Personal protective equipment can be costly as well. An engineering design can be a one-time cost where PPE is a reoccurring cost. PPE is normally recommended only as a last resort.

Tools of Ergonomic Assessment

This study used several different established tools for ergonomic assessment. These include the REBA, RULA Surveys, Goniometer, and the NIOSH Lifting Equation. These tools are described in detail below.

RULA or Rapid Upper Limb Assessment is a survey method developed for use in ergonomic investigations of workplaces where work related upper limb disorders are reported or suspected. RULA is a screening tool that assesses biomechanical and postural loading on the whole body with particular attention to the neck, trunk and upper limbs. A RULA assessment requires little time and training to complete. The general purpose of the RULA is to generate a scoring system that can be used to measure individual ergonomic tasks and compare them to standard or other tasks. The RULA is only an initial screening tool and is intended to be used as part of a broader ergonomic study (McAtamney, & Corlett, 1992). A broader ergonomic study will include other survey forms, an assortment of ergonomic tools, and may be performed by a Certified Industrial Ergonomist of medical practitiingoner (Humantech, 2005) The REBA and RULA are risk analysis tools targeted at a worker's environment that quickly assesses risk to their performance. Scores are based on observations including:

- Posture
- Repetition
- Muscle loading
- Joint angles (COPE)

To perform a RULA assessment, observations are made of the limbs and body postures most frequently used, paying close attention to extreme joint angles, duration, and forces. First, lower arm, upper arm, and wrist postures are examined. The postures are then given a numerical value in relation to how far they deviate from the neutral position. Then a posture score is determined from table A using the numerical values of the previous observations. Next a muscle use score and force score are added to the value determined by table A. Next are the trunk, neck, and leg observations. The postures are then given a numerical value in relation to how far they deviate from the neutral position. A posture score is determined from table B using the numerical values of the previous observations. Next a muscle use score and force score are added to the value determined by table B. Once the values from section A and B have been calculated, they are used to find a final score from Table C. The RULA then lists a range of values that have recommendations assigned to them (Corlett, 1999). The lowest score indicates no intervention is required. The score recommendations are designed to indicate possible ergonomics interventions to lower the overall score. (COPE). The RULA includes instructions of use within the document. An example of the RULA can be found in appendix D.

REBA, or Rapid Entire Body Assessment, is a survey method developed for use in ergonomics investigations of workplaces where work-related entire body disorders are reported or suspected to occur. No special equipment and minimal training is required to conduct a quick assessment of the postures of the neck, upper trunk and lower limbs (COPE). It functions much in the same way as the RULA does, however focuses on the lower body as well. As mentioned above the REBA and RULA are risk analysis tools targeted at a worker's environment that quickly assesses risk to their performance. Also like the RULA, the REBA is only an initial screening tool and is intended to be used as part of a broader ergonomic study.

To perform a REBA assessment, observations are made of the limbs and body postures most frequent used, paying close attention to extreme joint angles, duration, forces. First, observations are made of the trunk, neck and legs. The postures are then given a numerical value in relation to how far they deviate from the neutral position. Then a posture score is determined from table A using the numerical values of the previous observations. Next a muscle use score and force score are added to the value determined by table A. Then, the lower arm, upper arm and wrist postures are examined. The postures are then given a numerical value in relation to how far they deviate from the neutral position. Then a posture score is determined from table B using the numerical values of the previous observations. Next a muscle use score and force score are added to the value determined by table B. Once the values from section A and B have been calculated, they are used to find a score from Table C. The table C score is combined with an activity score to produce a final score. The REBA then lists a range of values that have recommendations assigned to them. The lowest score indicates no intervention is required. The score recommendations are designed to indicate possible ergonomics interventions to lower the overall score (COPE). The REBA includes instructions of use within the document. An example of the REBA worksheet can be found in appendix E.

The NIOSH Lifting Equation is an ergonomic tool created by The National Institute for Occupational Safety and Health (NIOSH). The Lifting Equation is a tool used to identify, evaluate, or classify some risks associated with a lifting task and is an appropriate tool to use when:

- Estimating the risk of a two-handed, manual lifting task.
- Evaluating a job characterized by multiple lifting tasks.

- Evaluating a lifting task that may include trunk rotation, different types of hand coupling, repetitiveness, and duration.
- Determining a relatively safe load weight for a given task.
- Determining a relatively unsafe load weight for a given task.
- Deciding the appropriate style of abatement for a job that has been identified as having a lifting hazard.
- Comparing the relative risk of two lifting tasks.
- Prioritizing jobs for further ergonomic evaluation (Michael, 2002)

"The revised lifting equation for calculating the Recommended Weight Limit (RWL) is based on a multiplicative model that provides a weighting for each of six tasks variables. The weightings are expressed as coefficients that serve to decrease the load constant, which represents the maximum recommended load weight to be lifted under ideal conditions." (NIOSH, 1994) The RWL is defined as the following equation:

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

EMC Insurance Companies lists in detail how the variables of the NIOSH lifting equation are calculated. This detailed explanation and diagrams can be found in appendix F.

Once the RWL has been calculated, it is then time to calculate the Lifting Index or LI. The Lifting Index (LI) provides a relative estimate of the physical stress associated with the manual lifting job which is expressed as a numerical value.

$$LI = \frac{\text{Load weight}}{\text{Recommended Weight Limit}}$$

Where Load Weight (L) = weight of the object lifted (lbs or kg)" (NIOSH, 1994).

Goniometer is a device used to measure joint angles or range-of-motion. A traditional goniometer is a protractor with extending arms. In ergonomic studies, a goniometer is used to measure joint angles (in degrees), which is required by various ergonomic assessment tools. Using a goniometer, an ergonomist can quantify posture, including measuring joint angles during performance of a task. The goniometer can be used after changes are made in an ergonomic design to ensure the change was effective. To use a goniometer:

(1) Align the fulcrum of the device with the fulcrum or the joint to be measured

(2) Align the stationary arm of the device with the limb being measured

(3) Hold the arms of the goniometer in place while the joint is moved through its range of motion

The degree between the endpoints represents the entire range-of-motion (Workers' Compensation Board of B.C.)

Summary

Excessive forces/ heavy loads, awkward postures, repetitive motions, heat and cold stress, and excessive vibrations are all associated with MSDs and CTDs. Any of these alone can be the cause of ergonomic an injury; however the combination of several can hasten the onset of a MSD or CTD.

To determine if any of these ergonomic stressors appear within specific tasks, such as a material handling task, ergonomic tools can be used. These tools are well developed and recognized as industry standards. These ergonomic assessment tools aid the researcher in identifying, analyzing, and prioritizing changes of ergonomic stress factors that put employees at risk. In addition to the assessment tools, other instrumentation such as a scale, goniometer, and video/digital photos ensure accuracy of measurement and proper analysis of identified stressors.

Once the ergonomic stressors have been properly assessed, controls will be implemented to eliminate or reduce them. The hierarchy of controls used to mitigate or eliminate ergonomic stressors are listed here from most to least desirable: elimination, substitution, engineering controls, administrative controls, and personal protective equipment

Recommendations will be made in response to the finding of the ergonomic assessments described above.

Chapter III: Methodology

The XYZ+ process requires the handling of large material rolls which could result in a musculoskeletal injury if performed without mechanical assistance. The procedures for handling material cores for the XYZ+ process were observed, measured, and documented. This chapter discusses the actions taken by the researcher to collect and analyze the appropriate data. The following is a review of the methodology used in this study, and includes: Subject Selection and Description, Instrumentation, Data Collection Procedures, Data Analysis, Limitations, and Summary

Subject Selection and Description

Subjects were chosen on a random basis. The subjects observed were working the day the study was conducted. On that day, potential subjects were identified and the best candidates were chosen by the researcher based on the following criteria. First, it was preferred that the subjects had experience with the material handling processes of XYZ+. Second, preference was given to subjects who had a low hesitance for being electronically recorded or observed. These criteria ensured that the collected data was an accurate representation of material handling practices performed by the subject, eliminating either unfamiliarity with the work or the novelty of being recorded from the results. When a subject was selected, the consent form (appendix A) was given to them to review and sign after any questions they had were answered. The researcher then verbally reassured the subject that the electronic documentation was to be used for this purpose only, to be viewed only by the researcher, and destroyed after the study was complete. Three subjects in total were observed.

Instrumentation

The literature review of this paper covers the ergonomic stressors that are responsible for MSDs and CTDs. Several ergonomic assessment tools were selected to identify and analyze the ergonomic stressors present in the material handling procedures of the XYZ+ process. The assessment tools selected include the RULA, REBA, and NIOSH Lifting Equation. To accurately complete the assessments, an electronic scale, manual goniometer, digital camera, and digital video recorder were used.

The goniometer used for this research, a Baseline Stainless manual goniometer, is a device used to measure joint angles or range-of-motion. A TIF 9010A Slimline Electronic Scale was used to find the weight of objects and displays its readings in kilograms or pounds. Digital camcorders and cameras can be useful for assessment purposes, as the task can be played back and stopped. This helps to ensure accuracy when determining measurements with the goniometer, or later observations regarding frequency and duration. Other tools used include a Stanley 25ft tape measure and a standard desktop computer.

Data Collection Procedures

Once a subject was identified and informed about the research project, the subject was asked to carry out the tasks of loading, unloading, and moving the material cores in the fashion they normally would. As this was done, video and/or digital pictures of the tasks performed were captured by the researcher. The following is an expanded explanation of steps taken to collect data.

RULA Survey Data Collection Procedures. The following describes the actions taken to collect data for the RULA survey, as well as the procedures for using the collected data to complete the RULA. Three different angles of observation, 90 degrees, 180 degrees, and 230 degrees roughly from the front of the employee, were used to obtain the clearest documentation of required angles and positions.

1. The subject was asked to perform the task of loading, unloading, and moving material. As the subject performed the task, the researcher recorded the actions using the video camera for later data analysis. The camera was held by the researcher to ensure best possible line of sight for recording the process. Still photos were taken as necessary to ensure clarity of small movements such as wrist positions.
2. After the video was taken, the duration and frequency of each task were collected.
3. The video and pictures were uploaded onto the desktop computer. From there, the required angles of each section could be easily viewed by pausing or slowing the video as needed.
4. The upper arm, lower arm, and wrist postures were examined. The most extreme postures used were located in the video and measured using the manual goniometer. Depending on the measurements taken, the postures were assigned a numerical value depending on the range they fell into determined by the RULA survey.
5. The numerical values were added up and the posture score was determined using Table A in the RULA survey.
6. The muscle use score and the force/load score were added into the numerical value. The score was then marked in Table C of the RULA survey.
7. The neck, trunk and leg postures were observed using the video and pictures, again focusing on the most extreme postures required by the task. A numerical score was assigned depending on the range the fell into determined by the RULA survey. The scores were entered into table B of the RULA survey.

8. A muscle use score and a force load score were then added to the score from table B. This score was then also marked in table C of the RULA survey.
9. The two values marked in table C were then used to determine the final score. Depending on the value of the final score, the RULA recommended different courses of action ranging from acceptable posture to investigate and implement change.

REBA Survey Data Collection procedures. The data collection process for the REBA survey was very similar to the RULA survey data collection procedures. Observations were made at 90 degrees, 180 degrees, and 230 degrees to obtain the clearest documentation of required angles and positions. Along with the detailed data collection procedures, this section also includes the procedures for completing the REBA survey using the data collected.

1. The subject was asked to perform the task of loading, unloading, and moving material. As the subject performed the task, the researcher recorded the actions using the video camera for later data analysis. The camera was held by the researcher to ensure best possible line of sight for recording the process. Still photos were taken as necessary to ensure clarity of small movements such as wrist positions.
2. After the video, the duration and frequency of each task were collected.
3. The video and pictures were uploaded onto the desktop computer. From there, the required angles of each section could be easily viewed by pausing or slowing the video as needed.
4. The neck, trunk, and leg postures were first examined. The most extreme postures used were located in the video and measured using the manual goniometer. Depending on the measurements taken, the postures were assigned a numerical value depending on the range they fell into as determined by the RULA survey.

5. The numerical values were entered into table A of the REBA survey and the posture score was determined.
6. The force/load score was then added into the posture score determined in Table A. The score was then marked in Table C of the REBA survey.
7. The arm and wrist postures were observed using the video and pictures, again focusing on the most extreme postures required by the task. A numerical score was assigned depending on the range the fell into determined by the REBA survey.
8. The scores were then entered into table B of the REBA survey.
9. A coupling score, determined by the quality of handle on the object being handled, was then added to the score from table B. This score was then recorded in table C of the RULA survey.
10. The two values in table C were then used to determine the Table C score. That score then had an activity score added to it depending on the amount of activity the task required. This produced a final REBA score.
11. Depending on the value of the final score, the REBA recommended different courses of action ranging from acceptable posture to investigate and implement change.

The Revised NIOSH Lifting Equation. This section describes the methods used for collecting data to be used in the Revised NIOSH Lifting Equation. Once the data was collected, it needed to be inserted into the formula using calculations and charts provided by the lifting equation. This section also includes a detailed description of the procedures for completing the equation using the data collected.

1. The subject was asked to perform the task of loading, unloading, and moving material. As the subject performed the task, the researcher recorded the action using the video

camera for later data analysis. Three different angles, 90 degrees, 180 degrees, and 230 degrees roughly from the front of the employee, were used to obtain the clearest documentation of required angles and positions. The camera was held by the researcher to ensure best possible line of sight for recording the process.

2. A standard tape measure was then used to determine horizontal location (the horizontal distance between the hands and midpoint of the feet) and the vertical travel distance (the difference between the origin and destination of the lift). Each measurement was then recorded.
3. The goniometer was used to determine the angle of symmetry (the difference between the angle of origin and destination). That measurement was then recorded.
4. Frequency rate and duration were determined through observations and inquiries. The value associated with the frequency rate was determined using the Applications Manual for the Revised NIOSH Lifting equation. The data values were then recorded.
5. The coupling was observed. The value associated with this coupling variable was determined using the Applications Manual for the Revised NIOSH Lifting equation. This value was documented.
6. The recommended weight limit (RWL) was calculated using the measurements recorded by entering the variables into the equation and solving for the solution. The measurements, variables and complete calculation can be found in the tables 4 and 5.

Goniometer. The goniometer used was a Baseline Stainless manual goniometer. It was used for the measurement of angles required by the different tasks. This was accomplished by using the video footage to determine the most extreme postures. By pausing the video, the goniometer could then be used to measure the angle as observed on the video screen.

Electronic Scale. The electronic scale employed was a TIF 9010A Slimline Electronic Scale. It was used to measure the weights of the various material core rolls. The 4 types of material rolls used in production were weighed, and are here assigned the numbers 1-4. The scale was first zeroed, and then each roll was weighed. Three of each of the 4 core types were weighed, with the average used as the value for that type.

Data Analysis

With data collected as described above, the researcher was able to use the ergonomic assessment tools to accurately determine what ergonomic stressors are present in the XYZ+ material core handling process. The RULA and REBA surveys served in collaboration to identify stressors that are present and eliminate those that are not. The NIOSH lifting equation was used to determine a RWL to compare to the actual weight being lifted. This was done to reinforce the findings of the REBA and RULA surveys. The findings are published in the results section of this paper.

Limitations

Limitations of the study included:

- The assessment tools, the REBA, RULA, and NIOSH lifting equation are considered initial screening tools.
- Trade secrets prohibit the publishing of precise information such as lengths, width, type, and thickness of material on cores, extensive explanation of processes, and other supplemental information.
- The findings, conclusions, and recommendations for this study are only applicable to ABC's XYZ+ process.
- Individual employee participation and reactions may affect results.

Chapter IV: Results

The purpose of this study was to evaluate the current material handling practices of the XYZ+ line at ABC and recommend changes, if needed, to ensure safe material handling. This was done using the REBA survey, RULA survey, and the NIOSH lifting equation. For each assessment method, several measurements were used. Table 1 is a complete list of measurements used in the differing assessment methods. The data used to determine the values in table 1 can be found in Appendix B of this paper.

Table 1.

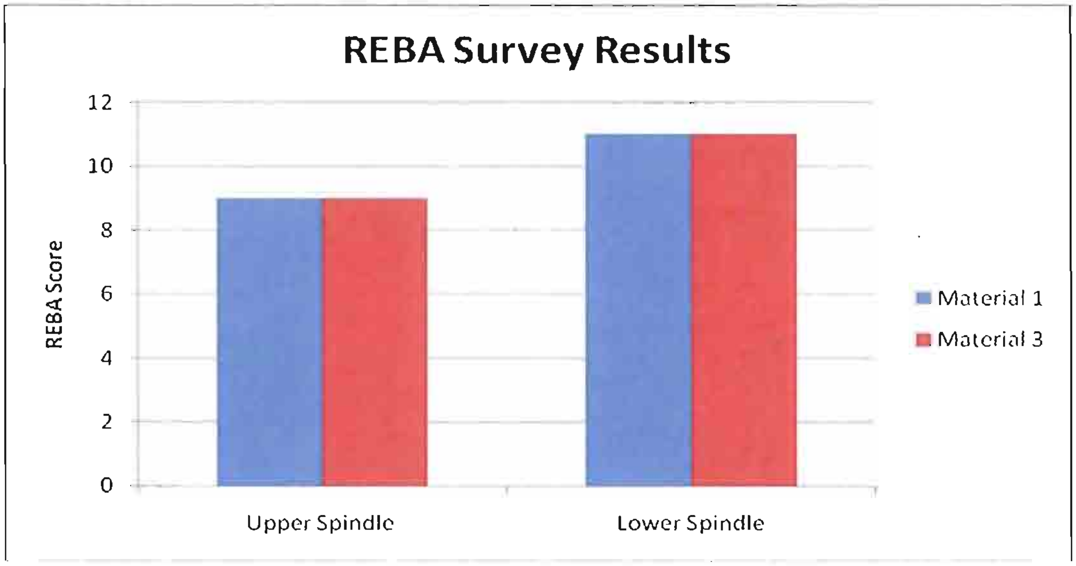
Measurement Values used in Surveys

Material	Material Average Wt	Two Hand Transport Ht.	Lower Spindle Ht.	Upper Spindle Ht.
Material 1	62.7 lbs	40 inches	31 inches	58 inches
Material 2	55.5 lbs	40 inches	31 inches	58 inches
Material 3	24.3 lbs	40 inches	31 inches	58 inches
Material 4	37.2 lbs	40 inches	31 inches	58 inches

The REBA survey was conducted for both the loading and unloading task of the XYZ+ process. Each machine has an upper and lower spindle where material cores may need to be loaded and unloaded from. The spindle heights were recorded at 58 inches from the floor for the upper spindle and 31 inches from the floor for the lower spindle. In each case, a REBA survey was performed for the heaviest material core (Material 1) and lightest material core (Material 3). Figure 1 displays the results of the REBA surveys.

Figure 1.

REBA Survey Results



As Figure 1 illustrates, the survey score remains the same even as the material core weights change. When the results are compared to the REBA scoring system (table 2), the task of loading and unloading the lower spindle is classified as Very High Risk, and that change should be implemented quickly.

Table 2.

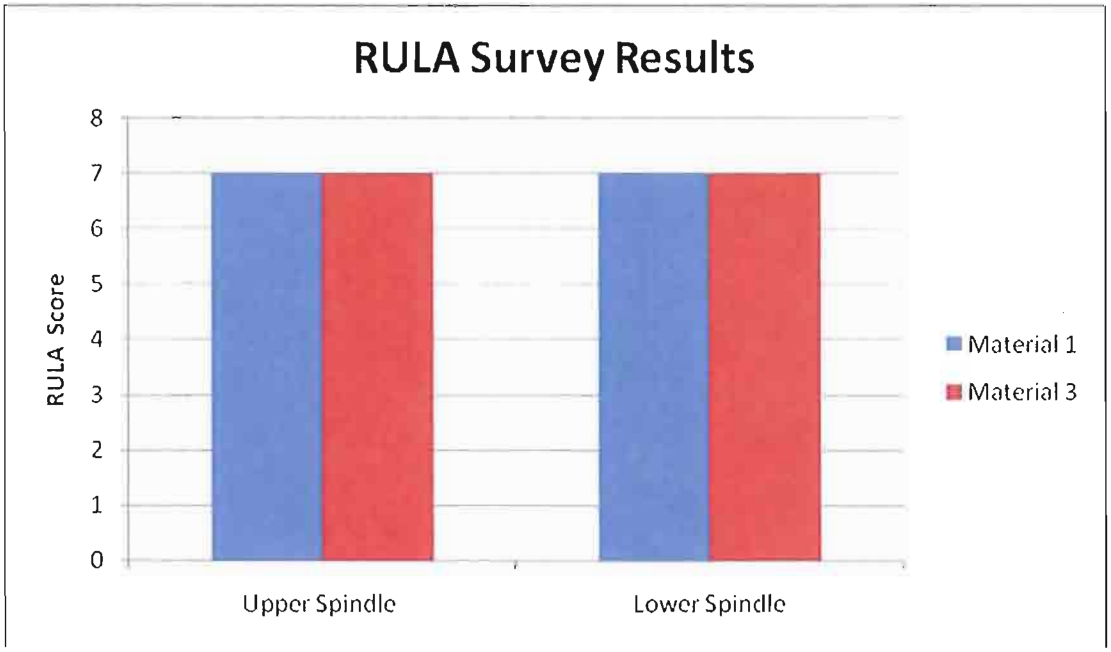
REBA Scoring System

REBA Scoring System		
1	=	Negligible risk
2 or 3	=	Low risk, change may be needed
4 to 7	=	Medium risk, further investigation, change soon
8 to 10	=	High risk, investigate and implement change
11+	=	Very high risk, implement change

The RULA survey was also conducted for both the loading and unloading task of the XYZ process at the upper and lower spindle heights using the heaviest and lightest material cores (Materials 1 & 3). Figure 2 displays the results of the RULA surveys.

Figure 2.

RULA Survey Results



As Figure 2 illustrates, the survey score was identical for both the upper and lower spindle loading and unloading tasks, and each remained the same even as the material core weights changed. When the results are compared to the RULA scoring system (table 3) we find that the tasks of loading and unloading for both the upper and lower spindle requires investigation and change.

Table 3.

RULA Scoring System

RULA Scoring System		
1or 2	=	Acceptable posture
3 or 4	=	Further investigation, change may be needed
5 to 6	=	Further investigation, change soon
7	=	Investigate and implement change

The NIOSH Lifting Equation was calculated for the lifting requirements for loading and unloading material cores from the XYZ+ process. As in the RULA and REBA surveys, the upper and lower spindle heights were measured, and in this case, the median height of 40 inches was used as the end/start point of the lift. Table 4 describes the calculations for the NIOSH

Table 4

Lifting Equation for the Upper Spindle.

NIOSH Lifting Equation = RWL= LC x HM x VM x DM x AM x FM x CM							
RWL	LC x	HM	VM	DM	AM	FM	CM
RWL	51 lbs	10/H	1-(.0075[v-30]	.82+(1.8/D)	1-(.0032A)	Table 5	Table 7
RWL	51 lbs	H= 16 in	V= 40 in	58-43 = 15 in	A= 100 deg	1*	1**
18.846	51 lbs	0.625	0.925	0.94	0.68	1	1

The Recommended Lifting Weight (RWL) for the upper spindle according to the Revised NIOSH Lifting Equation is 18.846 lbs which is approx 5lbs less than even the lightest material core. Table 5 describes the calculations for the NIOSH Lifting equation for the lower spindle.

Table 5

Lifting Equation for the Upper Spindle.

NIOSH Lifting Equation = RWL= LC x HM x VM x DM x AM x FM x CM							
RWL	LC x	HM	VM	DM	AM	FM	CM
RWL	51 lbs	10/H	1-(.0075[v-30]	.82+(1.8/D)	1-(.0032A)	Table 5	Table 7
RWL	51 Lbs	H= 16 in	V= 31 in	43-31 = 12 in	A= 100 deg	1*	1**
20.867	51 lbs	0.625	0.9925	0.97	0.68	1	1

The Recommended Lifting Weight (RWL) for the lower spindle according to the Revised NIOSH Lifting Equation is 20.867lbs which is approx 3lbs less than even the lightest material core. The measured values used in tables four and five can be found in Appendix C of this paper.

Discussion of the Revised NIOSH Lifting Equation

In tables four and five in the previous sections, several asterisks appear next to the frequency and coupling multipliers. These asterisks are present to bring attention to how those variables were determined. The frequency multiplier value (followed by *) was chosen from Table 5 of the Applications Manual for the Revised NIOSH Lifting Equation. The value was chosen as the task is classified as an infrequent lifting task and the duration of equal to or less than an hour could be used. The lifting frequency was less than or equal to .2 lifts per hour. The coupling multiplier value (followed by **). This value was chosen from Table 7 of the Applications Manual for the Revised NIOSH Lifting Equation. The value was chosen as the coupling was determined to be a fair coupling with a height above 30 inches. The coupling can vary depending on individual employee's gripping and lifting preferences.

Limitations and Discussion

There were several limitations to the study, including:

1. The assessment tools, the REBA, RULA, and NIOSH lifting equation are considered initial screening tools.
2. Trade secrets prohibit the publishing of precise information such as lengths, width, type, and thickness of material on cores, extensive explanation of processes, and other supplemental information.
3. The findings, conclusions, and recommendations for this study are only applicable to ABC's XYZ+ process.
4. Individual employee participation and reactions may affect results.

As the study progressed, and data was collected and analyzed, more limitations arose. One important limitation was the ever changing and unusual work routines present. From day to day, production speed, material sizes and weights, product type, and run times could change. This significantly impacted the amount and type of material handling done by individual employees on a daily basis which could have made the collection and analyzing data difficult.

Another major limitation was the REBA and RULA surveys. As stated above, these are only considered initial screening tools. As such they are best suited to direct further investigation. Along with that, the REBA and RULA surveys appear to be more concentrated on small tasks that occur frequently and not heavy lifting jobs that occur sporadically over a long period of time.

The Revised NIOSH Lifting Equation had several issues as well. First, the Revised NIOSH Lifting equation is very focused and narrow and can only truly be used effectively in a handful of situations. For the purposes of this research it was utilized as best as possible. One example is that the Lifting Equation requires a beginning and an end lift. This was not applicable to the material handling tasks being performed in the XYZ+ area as the material rolls were carried by an employee to another area such as the next process or a material holding area. During the calculations, a height of 40 in was used as the end or beginning lift point, as that was the approximate height at which the material cores were carried.

For the Revised NIOSH Lifting Equation to work, the material must be lifted with both hands. In all cases, two hands were used to load and unload the material core from the spindles. However, a significant number of employees used a one armed/handed method for carrying or moving the materials cores. This was accomplished by pulling the material core off of the machine spool and sliding ones arm through the center of the spool. While this makes the Lifting Equation unusable, it also brings to light an even higher risk material handling procedure. Employees who choose this method for lifting and transportation are at higher risk of developing an MSD or CTD, as much of the force and weight is now placed on one hand/arm/shoulder instead of two. The Revised NIOSH Lifting Equation is unable to calculate the recommended weight limit or provide any analysis for this material handling procedure.

The last issue with the Revised NIOSH Lifting Equation is that its calculations are based on an 8 hour maximum shift. ABC operates 12 hour shifts, and should the frequency of lifts ever exceed 0.1 lifts per min, or 72 lifts in a shift, the equation would not be applicable. It was only applicable in this instance as infrequent lifting (F<.1 lift/minute) which considers the recovery period long enough to use the 1-hour duration category.

Chapter V: Discussion

Summary

Statement of the Problem

Ergonomic analysis of ABC's proposed XYZ+ process shows an unacceptable level of employee injury risk during material handling.

Purpose of the Study

The purpose of the study was to evaluate the current material handling practices required by the XYZ+ process and determine best practices for future operation. This was expressed through several goals stated in the introduction of this paper. Those goals are as follows:

- To assess the current ergonomic requirements to move, load, and unload material rolls from the XYZ+ process with the REBA, RULA, and NIOSH lifting equation.
- To accurately project future ergonomic design and equipment needs of the XYZ+ process based on successive increases in material roll size.
- To recommend needed changes and/or equipment needed for said changes in production, and justify the changes using the ergonomic assessment findings and cost benefit analysis.

Conclusions

Several conclusions can be made about the material handling processes used by ABC in the XYZ+ area from the results of the REBA, RULA, and the Revised NIOSH lifting equation. In each case it was found that the current material handling processes present a high risk of musculoskeletal injury resulting from:

- Heavy Loads/ Excessive Forces- According to the Revised NIOSH Lifting Equation the loads should be reduced to less than 19lbs for the upper spindle and less than 21lbs for the lower spindle.
- Awkward Postures- According to the REBA and RULA surveys, the awkward postures that account for a large portion risk for ergonomic injury are neck, upper arm, and trunk postures.

Losses associated with ergonomic injuries include direct costs, such as medical costs, fines, and lost wages, and indirect costs which can include reduced production, long term physical restrictions (light duty) of employees work activities, increased insurance costs, the total amount of time lost, and so on. Reflecting on the information presented in chapter 2 of this paper, it would be in ABC's best interests to make changes to the current material handling processes in order to reduce the risk of ergonomic injuries.

Recommendations

From the results of this study, several recommendations can be made to in an effort to reduce or eliminate the risk of ergonomic injuries in the XYZ+ material handling process. These include;

1. Use of Ergonomic Lift Assisting Equipment - Several ergonomic lift assisting machines were present for employee use. These devices were not observed being used during the data collection procedures. An employee explained that the devices were often used for the heaviest of material cores however were not used frequently. A recommendation of this study is that mechanical assisted lifting devices be required whenever loading, unloading, or moving materials. In this way excessive force/heavy loads and awkward postures should be limited if not eliminated.

2. Use of Carts- If ergonomic lift assisting devices are deemed an impractical option, then minimally carts should be required for the transport of material cores between destinations. This will eliminate the practice of transporting/ carrying material cores on one arm, greatly reducing the risk of ergonomic injuries from heavy loads and falls.
3. Redesign of Production Equipment- Improving the design of current or future equipment to be more ergonomic can eliminate or reduce the risk of ergonomic injury, especially if combined with recommendations 1 and/or 2. The following are several approaches to accomplish this.
    - A. Changes of spindle heights to approx. 40 inches. Current spindle heights are at 31 inches and 51 inches. Changing heights to approx. 40 inches would reduce or eliminate awkward postures and excessive forces, thereby greatly reducing the risk of ergonomic injury.
    - B. Designing processes to integrate into each other using robotic assistance. This could be accomplished by arranging processes to end/start within a close proximity and having automated machinery to load and unload the rolls of materials.
    - C. Incorporate individual processes into a single continuous process if feasible, to reduce material handling.
4. Further Research – It is strongly recommended that further research into this area be undertaken. This may include researching and using alternative assessment methods that more accurately analyze the processes, longer observation of practices (up to several weeks), and consulting other industries that have material handling practices similar to

ABC's XYZ+ process. By performing further research, an even better understanding of the issue may be obtained, allowing better recommendations to address the issues present.

5. Monitoring of Improvements- After any improvements are implemented, it is highly recommended that the practices be reevaluated to determine the effectiveness of the improvement.

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Appendix A: Consent to Participate

Consent to Participate In UW-Stout Approved Research

Title: What are the best practices to move, load and unload materials for the proposed XYZ+ process to reduce the risk of ergonomic injury?

Investigator:	**Research Sponsor:**
Benjamin Nicholson	Dr. Brian Beamer
Phone: 715-218-3747	Phone: 715-232-5178
Email: nicholsonbe@my.uwstout.edu	Email: beamerb@uwstout.edu

Description:

You will be observed loading, unloading, and moving material rolls that are used by the XYZ+ process. 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 loading, unloading, and moving material from the process. You will be asked to perform the task using a mechanical material handeling device, and the more common method of manual material handling. 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 30 min. 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 photos or video will be destroyed after the research is complete and will not be published with or within the research paper. No other personal information will be collected.

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.

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Advisor:
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Statement of Consent:

I ________________________ (printed name) have read and understand the requirements of my participation in this research study. I understand that at anytime I wish to no longer be involved in this research project I may withdraw without repercussion or remand. By signing this consent form I agree to participate in the project entitled, "What are the best practices to move, load and unload materials for the proposed XYZ+ process to reduce the risk of ergonomic injury?" under the terms laid out within this consent form.

____
Signature Date

Appendix B: Raw Data Collected

Sample Material Weights

Material	Sample Weight 1	Sample Weight 2	Sample Weight 3	Average Weight
Mylar	62.8 lbs	62.4 lbs	62.9 lbs	62.7 lbs
Interleaf	55.0 lbs	55.8 lbs	55.6 lbs	55.5 lbs
Raw Stainless	24.1 lbs	24.5 lbs	24.3 lbs	24.3 lbs
Production	37.8 lbs	34.3 lbs	39.4 lbs	37.2 lbs

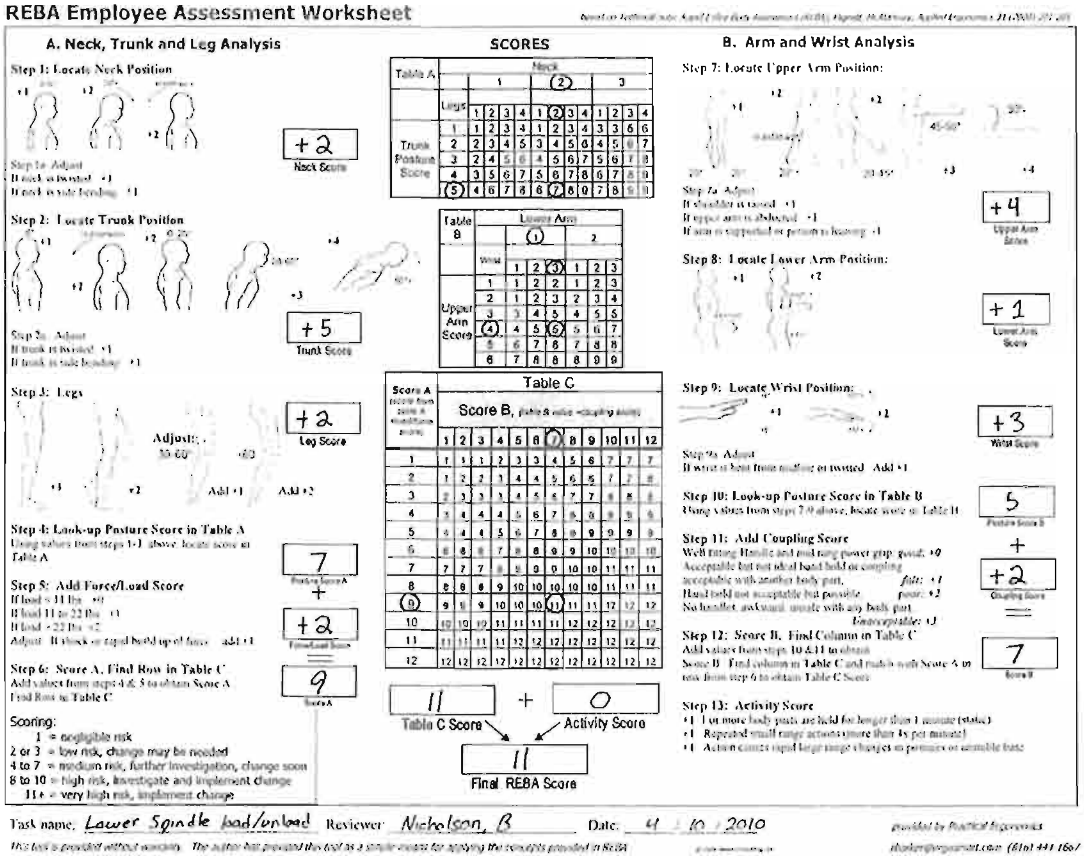
Data Collected for the Revised NIOSH Lifting Equation (Upper Spindle)

Greatest distance from Center of ankles to center of load.	16 inches
The vertical location from the ground to the center of the hands.	40 inches
Distance vertically traveled by the material during the lift.	15 inches
The most significant angle of rotation that occurred during the lift.	100 degrees
Frequency multiplier	1
Coupling multiplier	1
Carrying height	40 inches
Upper spindle height	58 inches

Data Collected for the Revised NIOSH Lifting Equation (Lower Spindle)

Greatest distance from Center of ankles to center of load.	16 inches
The vertical location from the ground to the center of the hands.	31 inches
Distance vertically traveled by the material during the lift.	12 inches
The most significant angle of rotation that occurred during the lift.	100 degrees
Frequency multiplier	1
Coupling multiplier	1
Carrying height	40 inches
Lower spindle height	31 inches

Appendix C: Completed REBA and RULA Forms



REBA Employee Assessment Worksheet

Based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

+1 0-20° +2 20°+ in extension +2

Step 1a: Adjust
If neck is twisted: +1
If neck is side bending: +1

+2
Neck Score

Step 2: Locate Trunk Position

+1 0° +2 in extension +2 0-20° +3 20-60° +4 60°+

Step 2a: Adjust
If trunk is twisted: +1
If trunk is side bending: +1

+5
Trunk Score

Step 3: Legs

+1 +2 Adjust: 30-60° Add +1 60° Add +2

+2
Leg Score

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above, locate score in Table A

7
Posture Score A

+

Step 5: Add Force/Load Score
If load < 11 lbs: +0
If load 11 to 22 lbs: +1
If load > 22 lbs: +2
Adjust: If shock or rapid build up of force: add +1

+2
Force/Load Score

=

Step 6: Score A, Find Row in Table C
Add values from steps 4 & 5 to obtain Score A
Find Row in Table C

9
Score A

Scoring:
1 = negligible risk
2 or 3 = low risk, change may be needed
4 to 7 = medium risk, further investigation, change soon
8 to 10 = high risk, investigate and implement change
11+ = very high risk, implement change

SCORES

Table A	Neck	1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Table B	Lower Arm	1			2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Table C Score A (score from table A + load/force score)	Score B, (table B value + coupling score)											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

11
Table C Score

+

0
Activity Score

11
Final REBA Score

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:

+1 +2 in extension +2 +3 45-90° +4 90°+
20° 20° 20°+ 20-45°

Step 7a: Adjust
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

+4
Upper Arm Score

Step 8: Locate Lower Arm Position:

+1 +2

+1
Lower Arm Score

Step 9: Locate Wrist Position:

+1 +2 15° 15°+

+3
Wrist Score

Step 9a: Adjust
If wrist is bent from midline or twisted: Add +1

Step 10: Look-up Posture Score in Table B
Using values from steps 7-9 above, locate score in Table B

5
Posture Score B

+

Step 11: Add Coupling Score
Well fitting Handle and mid rang power grip, *good:* +0
Acceptable but not ideal hand hold or coupling acceptable with another body part, *fair:* +1
Hand hold not acceptable but possible *poor:* +2
No handles, awkward, unsafe with any body part, *Unacceptable:* +3

+2
Coupling Score

=

Step 12: Score B, Find Column in Table C
Add values from steps 10 & 11 to obtain Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score.

7
Score B

Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Task name: Lower Spindle load/unload Reviewer: Nicholson, B Date: 4 / 10 / 2010

This tool is provided without warranty. The author has provided this tool as a simple means for applying the concepts provided in REBA

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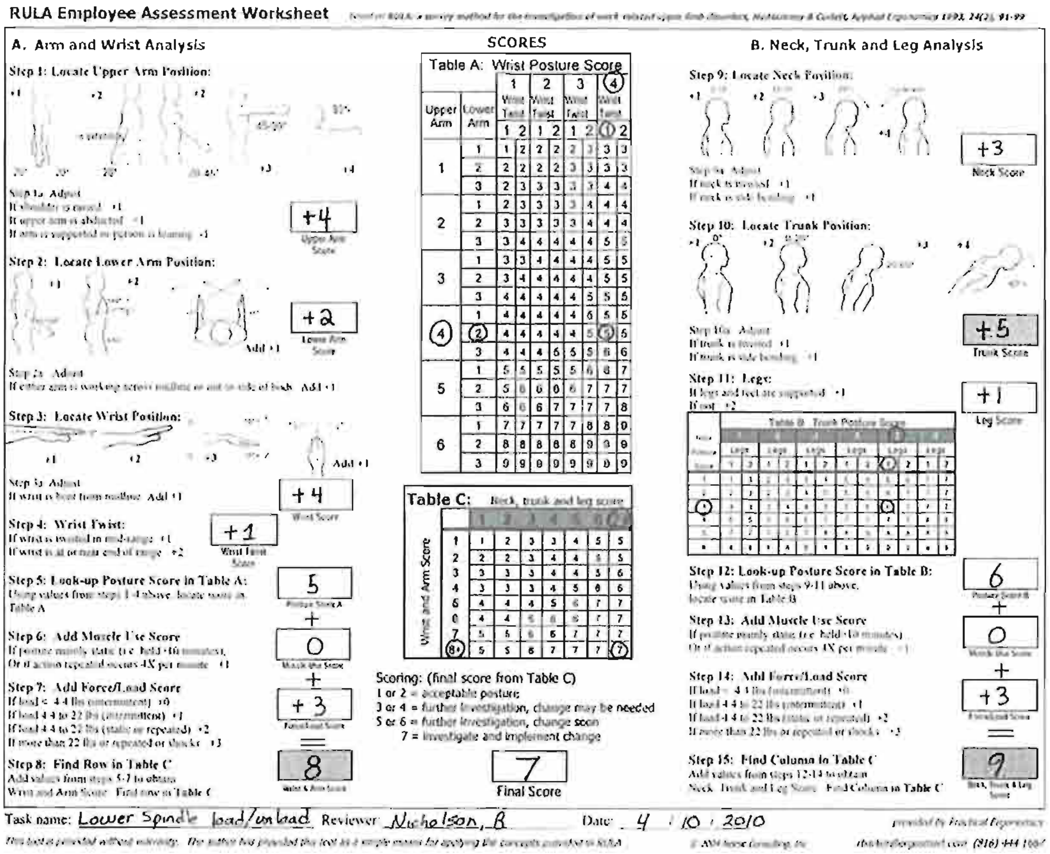

RULA Employee Assessment Worksheet

Based on RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:

Step 1a: Adjust
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

+4
Upper Arm Score

Step 2: Locate Lower Arm Position:

+2
Lower Arm Score

Step 2a: Adjust
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:

Step 3a: Adjust
If wrist is bent from midline: Add +1

+4
Wrist Score

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

+1
Wrist Twist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

5
Posture Score A

\+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held >10 minutes),
Or if action repeated occurs 4X per minute: +1

0
Muscle Use Score

\+

Step 7: Add Force/Load Score
If load < 4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

\+ 3
Force/Load Score

=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in Table C.

8
Wrist & Arm Score

SCORES

Table A: Wrist Posture Score

Upper Arm	Lower Arm	1		2		3		4	
		Wrist Twist		Wrist Twist		Wrist Twist		Wrist Twist	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C: Neck, trunk and leg score

Wrist and Arm Score	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1 or 2 = acceptable posture
3 or 4 = further investigation, change may be needed
5 or 6 = further investigation, change soon
7 = investigate and implement change

7
Final Score

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:

Step 9a: Adjust
If neck is twisted: +1
If neck is side bending: +1

+3
Neck Score

Step 10: Locate Trunk Position:

Step 10a: Adjust
If trunk is twisted: +1
If trunk is side bending: +1

+5
Trunk Score

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

+1
Leg Score

Table B: Trunk Posture Score

Neck Posture Score	1		2		3		4		5		6	
	Legs		Legs		Legs		Legs		Legs		Legs	
	1	2	1	2	1	2	1	2	1	2	1	2
1	1	3	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7
2	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7
3	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7	7
4	[illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7	[illegible]	[illegible]	[illegible]
5	[illegible]	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above, locate score in Table B

6
Posture Score B

\+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held >10 minutes)
Or if action repeated occurs 4X per minute: +1

0
Muscle Use Score

\+

Step 14: Add Force/Load Score
If load < 4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

+3
Force/Load Score

=

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find Column in Table C.

9
Neck, Trunk & Leg Score

Task name: Lower Spindle load/unload Reviewer: Nicholson, B Date: 4 / 10 / 2010

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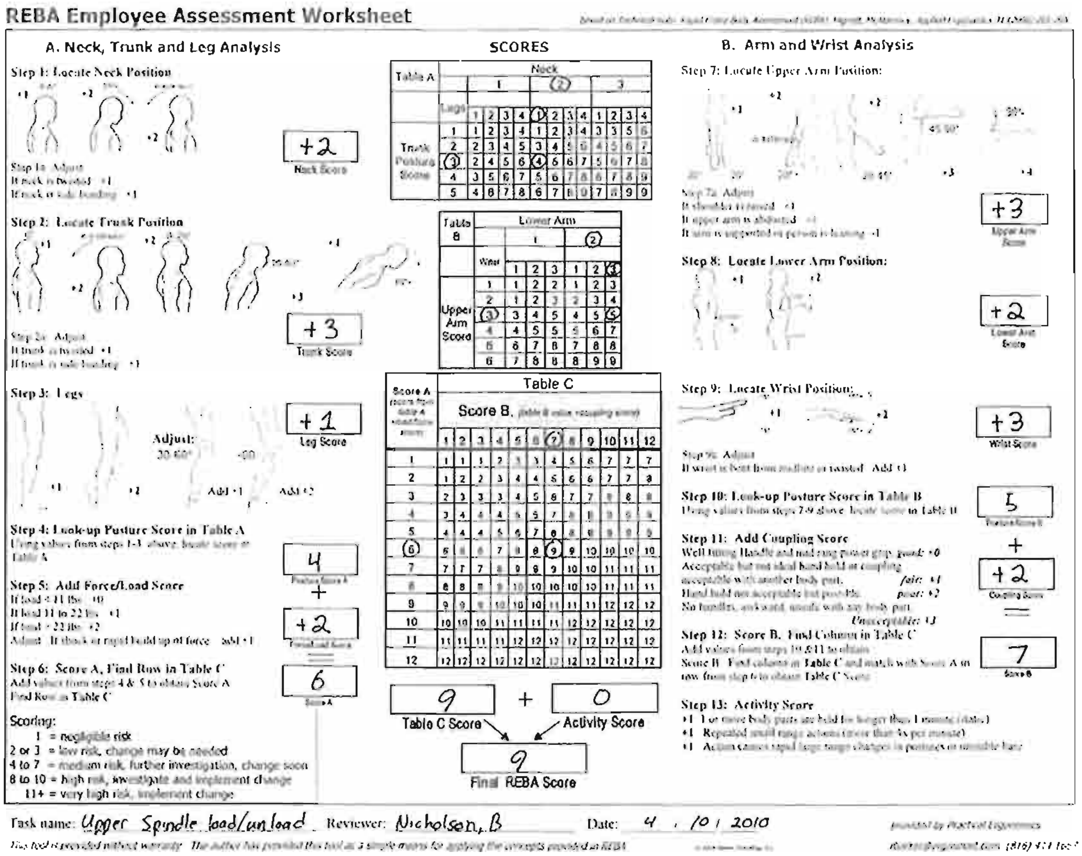

REBA Employee Assessment Worksheet

Based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

Step 1a: Adjust…
If neck is twisted: +1
If neck is side bending: +1

+2
Neck Score

Step 2: Locate Trunk Position

Step 2a: Adjust…
If trunk is twisted: +1
If trunk is side bending: +1

+3
Trunk Score

Step 3: Legs

+1
Leg Score

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above, locate score in Table A

4
Posture Score A

+

Step 5: Add Force/Load Score
If load < 11 lbs: +0
If load 11 to 22 lbs: +1
If load > 22 lbs: +2
Adjust: If shock or rapid build up of force: add +1

+2
Force/Load Score

=

Step 6: Score A, Find Row in Table C
Add values from steps 4 & 5 to obtain Score A
Find Row in Table C

6
Score A

Scoring:
1 = negligible risk
2 or 3 = low risk, change may be needed
4 to 7 = medium risk, further investigation, change soon
8 to 10 = high risk, investigate and implement change
11+ = very high risk, implement change

SCORES

Table A		Neck											
		1				②				3			
	Legs	1	2	3	4	①	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	③	2	4	5	6	④	6	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Table B		Lower Arm					
		1			②		
	Wrist	1	2	3	1	2	③
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	③	3	4	5	4	5	⑤
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Score A (score from table A +load/force score)	Table C											
	Score B, (table B value +coupling score)											
	1	2	3	4	5	6	⑦	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	5	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
⑥	6	6	6	7	8	8	⑨	9	10	10	10	10
7	7	7	7	8	9	8	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

9 + 0

Table C Score
Activity Score

9
Final REBA Score

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:

Step 7a: Adjust…
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

+3
Upper Arm Score

Step 8: Locate Lower Arm Position:

+2
Lower Arm Score

Step 9: Locate Wrist Position:

+3
Wrist Score

Step 9a: Adjust
If wrist is bent from midline or twisted: Add +1

Step 10: Look-up Posture Score in Table B
Using values from steps 7-9 above, locate score in Table B

5
Posture Score B

+

Step 11: Add Coupling Score
Well fitting Handle and mid rang power grip, *good: +0*
Acceptable but not ideal hand hold or coupling acceptable with another body part, *fair: +1*
Hand hold not acceptable but possible, *poor: +2*
No handles, awkward, unsafe with any body part, *Unacceptable: +3*

+2
Coupling Score

=

Step 12: Score B, Find Column in Table C
Add values from steps 10 &11 to obtain Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score.

7
Score B

Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Task name: Upper Spindle load/unload Reviewer: Nicholson, B Date: 4 / 10 / 2010

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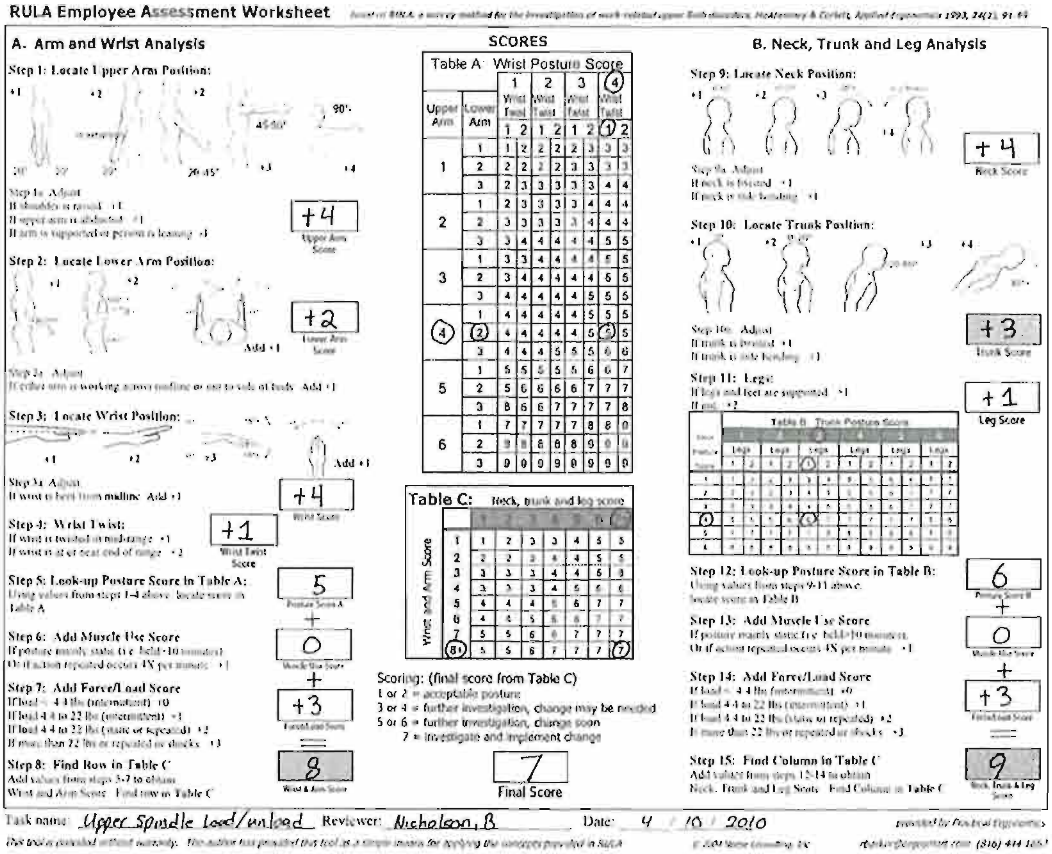


RULA Employee Assessment Worksheet

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:

Step 1a: Adjust
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score: +4

Step 2: Locate Lower Arm Position:

Lower Arm Score: +2

Step 2a: Adjust
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:

Step 3a: Adjust
If wrist is bent from midline: Add +1

Wrist Score: +4

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score: +1

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A: 5

+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held >10 minutes)
Or if action repeated occurs 4X per minute: +1

Muscle Use Score: 0

+

Step 7: Add Force/Load Score
If load < 4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score: +3

=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain
Wrist and Arm Score. Find row in Table C

Wrist & Arm Score: 8

SCORES

Table A: Wrist Posture Score

Upper Arm	Lower Arm	1 Wrist Twist		2 Wrist Twist		3 Wrist Twist		4 Wrist Twist	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C: Neck, trunk and leg score

Wrist and Arm Score	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1 or 2 = acceptable posture
3 or 4 = further investigation, change may be needed
5 or 6 = further investigation, change soon
7 = investigate and implement change

Final Score: 7

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:

Neck Score: +4

Step 9a: Adjust
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:

Step 10a: Adjust
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score: +3

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score: +1

Table B: Trunk Posture Score

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above,
locate score in Table B

Posture Score B: 6

+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held >10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score: 0

+

Step 14: Add Force/Load Score
If load < 4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score: +3

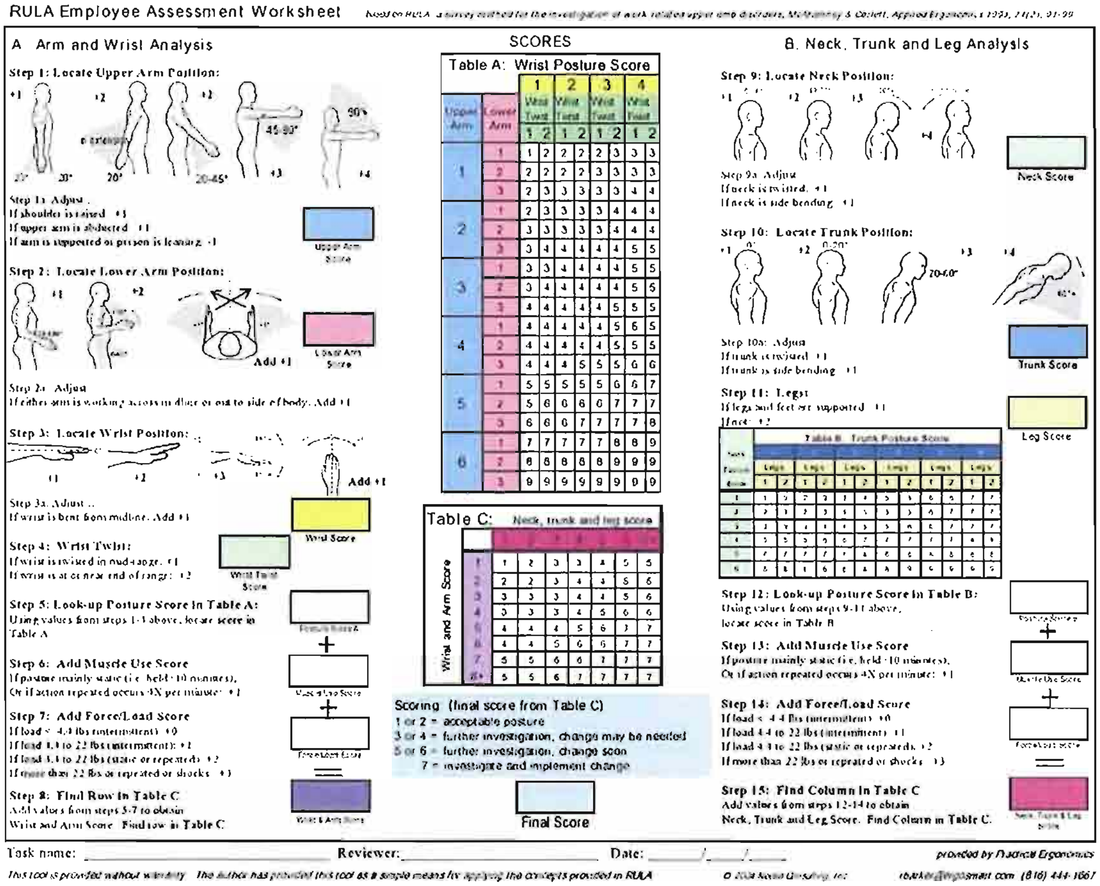
=

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain
Neck, Trunk and Leg Score. Find Column in Table C

Neck, Trunk & Leg Score: 9

Task name: Upper Spindle Load/unload Reviewer: Nicholson, B Date: 4 / 10 / 2010

Appendix D: Blank RULA Form



RULA Employee Assessment Worksheet

Based on RULA: a survey method for the investigation of work related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:

Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 2: Locate Lower Arm Position:

Lower Arm Score

Step 2a: Adjust
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:

Step 3a: Adjust...
If wrist is bent from midline: Add +1

Wrist Score

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A

+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held >10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 7: Add Force/Load Score
If load < 4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score

=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain
Wrist and Arm Score. Find row in Table C.

Wrist & Arm Score

SCORES

Table A: Wrist Posture Score

Upper Arm	Lower Arm	1 Wrist Twist 1	1 Wrist Twist 2	2 Wrist Twist 1	2 Wrist Twist 2	3 Wrist Twist 1	3 Wrist Twist 2	4 Wrist Twist 1	4 Wrist Twist 2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	6	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C: Neck, trunk and leg score

Wrist and Arm Score							
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	6
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

Scoring (final score from Table C)
1 or 2 = acceptable posture
3 or 4 = further investigation, change may be needed
5 or 6 = further investigation, change soon
7 = investigate and implement change

Final Score

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:

Step 9a: Adjust
If neck is twisted: +1
If neck is side bending: +1

Neck Score

Step 10: Locate Trunk Position:

Step 10a: Adjust
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Table B: Trunk Posture Score

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above,
locate score in Table B

Posture B Score

+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held >10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 14: Add Force/Load Score
If load < 4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score

=

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain
Neck, Trunk and Leg Score. Find Column in Table C.

Neck, Trunk & Leg Score

Task name: ______________________ Reviewer: ______________________ Date: ____/____/____

provided by Practical Ergonomics

This tool is provided without warranty. The author has provided this tool as a simple means for applying the concepts provided in RULA

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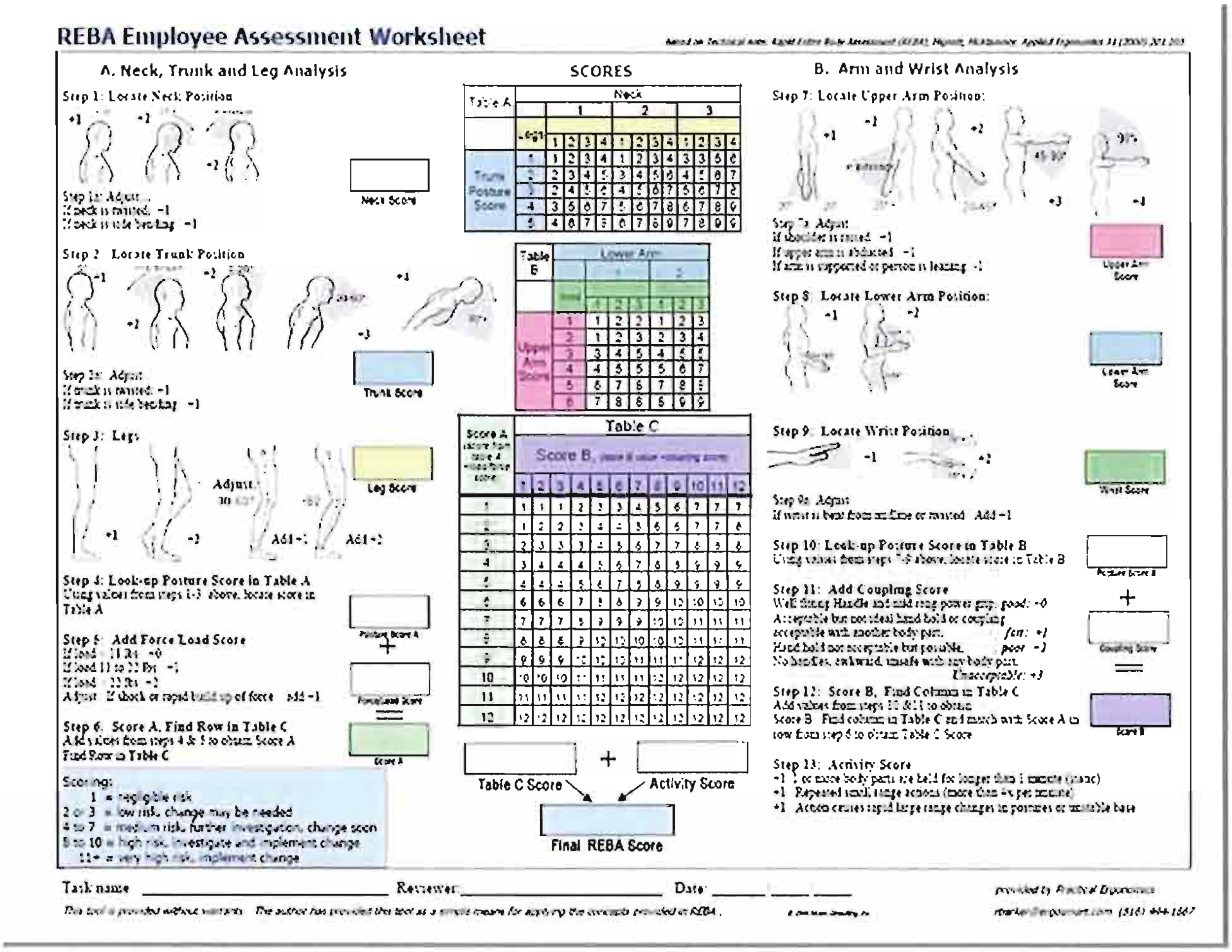
Appendix E: Blank REBA Form



REBA Employee Assessment Worksheet

[illegible] Rapid Entire Body Assessment (REBA) [illegible] Applied Ergonomics 31 (2000) 201-205

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

Step 1a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Neck Score

Step 2: Locate Trunk Position

Step 2a: Adjust:
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 3: Legs

Leg Score

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above, locate score in Table A

Posture Score A

+

Step 5: Add Force/Load Score
If load < 11 lbs: +0
If load 11 to 22 lbs: +1
If load > 22 lbs: +2
Adjust: If shock or rapid build up of force: add +1

Force/Load Score

=

Step 6: Score A, Find Row in Table C
Add values from steps 4 & 5 to obtain Score A
Find Row in Table C

Score A

Scoring:
1 = negligible risk
2 or 3 = low risk, change may be needed
4 to 7 = medium risk, further investigation, change soon
8 to 10 = high risk, investigate and implement change
11+ = very high risk, implement change

SCORES

Table A		Neck											
		1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Table B		Lower Arm					
		1			2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Score A (score from table A +load/force score)	Table C											
	Score B, (table B value +coupling score)											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score + Activity Score

Final REBA Score

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:

Step 7a: Adjust:
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 8: Locate Lower Arm Position:

Lower Arm Score

Step 9: Locate Wrist Position:

Wrist Score

Step 9a: Adjust
If wrist is bent from midline or twisted: Add +1

Step 10: Look-up Posture Score in Table B
Using values from steps 7-9 above, locate score in Table B

Posture Score B

+

Step 11: Add Coupling Score
Well fitting Handle and mid rang power grip, *good: +0*
Acceptable but not ideal hand hold or coupling acceptable with another body part, *fair: +1*
Hand hold not acceptable but possible, *poor: +2*
No handles, awkward, unsafe with any body part, *Unacceptable: +3*

Coupling Score

=

Step 12: Score B, Find Column in Table C
Add values from steps 10 & 11 to obtain Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score

Score B

Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Task name ________________ Reviewer: ________________ Date: ____ / ____ / ____

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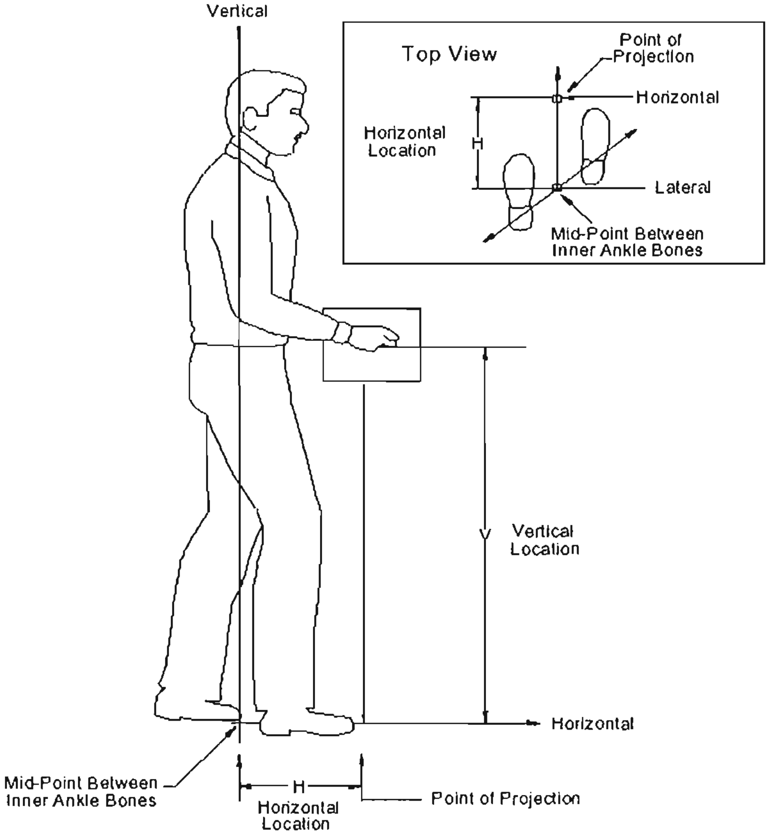
Appendix F: Explanation of Revised NIOSH Lifting Equation Calculations

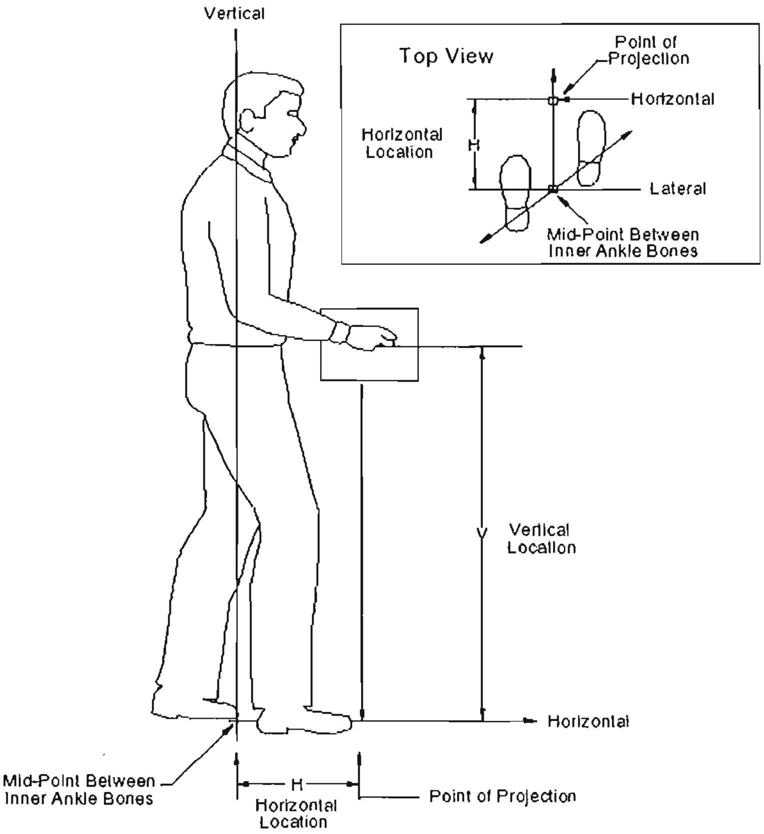
The following is EMC Insurance Companies (2010) expanded explanation of how to use the Revised Niosh Lifting Equation to determine the Recommended Weight Limit (RWL) for individual lifting tasks.

Horizontal Location Origin / Destination



Graphic Representation of Hand Location

Horizontal Location is the distance of the hands (in inches) from the vertical plane of the midpoint of the ankles. The diagram below illustrates how to measure the horizontal location. Perform this measurement at the starting point (origin) and ending point (destination) of the lift.



Graphic Representation of Hand Location

Vertical Location Origin / Destination

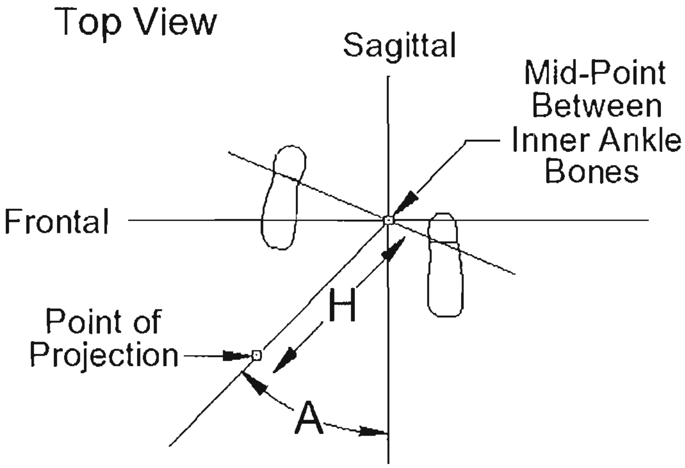
Vertical Location is the distance of the hands (in inches) from the plane of the floor. The diagram above illustrates how to measure the vertical location. Perform this measurement at the beginning (origin) and end (destination) of the lift.

Vertical Travel Distance

Vertical travel distance is the distance the hands travel between the origin and destination of the lift.

Angle of Asymmetry Origin / Destination

Angle of Asymmetry is the displacement angle of the load from the sagittal or median plane of the body. In other words, it is the number of degrees the back and body trunk must twist or rotate to accomplish the lift. The diagram below illustrates how to measure the angle of asymmetry. Perform this measurement at the beginning (origin) and end (destination) of the lift.



Frequency Rate

Frequency Rate is measured in the number of lifts performed each minute. In situations where less than one lift is performed each minute, the frequency rate will be less than 1 (e.g., one lift every five minutes = 0.2 lifts/minute).

Duration

Duration is the length of time the worker performs the lifting task. Duration is either classified as short (1 hour or less), moderate (1-2 hours), or long (2-8 hours).

Coupling

Coupling is the classification that affects how much force is required to grip the object to complete the lifting task. Coupling quality is classified as good, fair, or poor. The table below describes how to determine the coupling quality of the object being lifted.

Hand-to-Container Coupling Classification

Good	Fair	Poor
1. For containers of optimal design, such as boxes, crates, etc., a "Good" hand-to-object coupling would be defined as handles or hand-hold cutouts of optimal design.	1. For containers of optimal design, a "Fair" hand-to object coupling would be defined as handles or hand-hold cut-outs of less than optimal design.	1. Containers of less than optimal design or loose parts or irregular objects that are bulky, hard to handle, or have sharp edges.
2. For loose parts or irregular objects, which are not usually containerized, such as castings, stock, and supply materials, a "Good" hand-to-object coupling would be defined as a comfortable grip in which the hand can easily be wrapped around the object.	2. For containers of optimal design with no handles or for hand-hold cut –outs or for loose parts or irregular objects, a “fair” hand-to-object coupling is defined as a grip in which the hand can be flexed about 90 degrees.	2. Lifting non-rigid bags (i.e., bags that sag in the middle).