ERGONOMIC ANALYSIS OF COMPANY XYZ's DE-PALLETIZING WORKSTATION

by

Michael J. Sorensen

A Research Paper

Submitted in Partial Fulfillment of the
Requirements for the
Master of Science Degree
With a Major in

Risk Control

Approved: 3 Semester Credits

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Investigation Advisor

The Graduate School

University of Wisconsin-Stout

December, 2002

The Graduate School
University of Wisconsin-Stout

Menomonie, WI 54751

Abstract

	Sorensen	Michael	J.
(Writer)	**(Last Name)**	**(First)**	**(Initial)**

Ergonomic Analysis of Company XYZ's De-palletizing Workstation
(Title)

M.S. Risk Control	Brain Finder	December, 2002	69
(Graduate Major)	**(Research Advisor)**	**(Month/Year)**	**(No. of Pages)**

APA 5th Edition
(Name of Style Manual Used in this Study)

Company XYZ is in the beverage industry producing, bottling, and distributing a variety of products. The starting point of the bottling process begins at the de-palletizing workstation where employees manually unload new cases of bottles from a pallet onto a conveyor. Workers at this station were complaining of discomfort in the shoulders/neck, elbows, hands, wrists, and lower back from excessive overhead reaching at the beginning of a new pallet and forward bending toward the end of the unloading process.

The purpose of this study was to identify, via ergonomic assessment, if workstation design and work practice risk factors were exposing employees to injuries and illnesses at XYZ Company's de-palletizing workstation. This ergonomic assessment was performed in three steps. First, the researcher began by identifying the extent of the

employees discomfort by utilizing work-related musculoskeletal disorder symptom surveys. These results indicated the severity and location of the employee's distress and informed the researcher of the extent of the problem. In the second step, the researcher video-recorded an employee's bodily postures while performing job duties at the de-palletizing workstation. The body angles and posture measurements were incorporated into three ergonomic methodologies to reveal the severity and amount of intervention required by Company XYZ. The results from the symptom surveys and products of the methodologies revealed that the de-palletizing workstation is in fact exposing the employee's to risk factors that lead to the onset of work-related musculoskeletal disorders (WMSD's). The final step in this process was to recommend suitable engineering controls that will reduce or eliminate those risk factors, while protecting and preserving Company XYZ's employees and preventing future worker compensation expenditures.

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Statement of the Problem

Introduction

In a review of loss-based data by Blaco (1993), ergonomic-related injuries are the single greatest source of lost-time in the workplace today. Currently, these injuries account for between 33% and 40% of total worker compensation spending. As the work force ages and healthcare cost continue to rise, these percentages are expected to hit 50% by the end of the century. These statistics compiled by the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and the Bureau of Labor Statistics (BLS) reflect a startling trend (Blaco, 1993).

Work-related musculoskeletal disorders (WMSD's) occur when there is a mismatch between the requirements of the job and the physical capacity of the human body. Risk factors linked with WMSD's include repetitive motion, heavy lifting, forceful exertion, awkward posture, and rapid hand and wrist motion (OSHA, 2002). These alone may cause severe injuries, while it is likely that a combination of risk factors can elevate the severity and frequency of WMSD's.

Company XYZ is in the beverage industry where it produces, bottles, and distributes a variety of products. The Bottle House Department of Company XYZ contains a de-palletizing workstation, which is the starting point of the bottling process. Employees at this workstation are complaining of physical distress that may be associated with exposure to the potential material handling-based risk factors as they manually unload pallets of new cases of bottles from a pallet to a conveyor. Consequently, employee complaints of lower back/elbow pain indicate that ergonomic risk factors may exist at the de-palletizing workstation for Company XYZ.

Purpose Statement

The purpose of this study is to identify, via ergonomic assessment, if workstation design and work practice risk factors are currently exposing employees to injuries and illnesses at XYZ Company's de-palletizing workstation.

The goals of this study include:

- Identify to what extent that employees are suffering from WMSD symptoms.
- Analyze and quantify the extent that ergonomic risk factors may be present at Company XYZ's de-palletizing workstation.

Background and Significance:

According to the National Occupational Research Agenda (NORA)(n.d.), lower back pain is one of the most common and significant musculoskeletal problems in the world. Thirty percent of American workers are employed in jobs that routinely require them to perform activities that may increase risk of developing low back disorders. The Occupational Safety and Health Administration reports over one million workers each year are affected by back pain. Economically, lower back disorders in the United States cost between $50 and $100 billion each year. An estimated $11 billion of those costs are covered by worker compensation, with an average back injury claim costing the employer $8,300, which is more than twice the average cost of all other types of compensable claims combined (NORA, n.d.).

Lower back and elbow pain complaints from Company XYZ employees have alerted upper management that ergonomic risk factors may be present. To date, Company XYZ has not yet suffered significant losses from the de-palletizing workstation, however, if ergonomic risk factors exist and active measures are not taken, it may be only a matter of time before injuries to employees may begin to accumulate. If a WMSD injury occurs, Company XYZ will have direct costs including medical and indemnity payments as well as indirect costs such as paying overtime, decreased employee morale, lost production, or missed production schedules, etc. Company XYZ has recognized that the de-palletizing workstation may pose extraordinary ergonomic risk factors. Therefore, Company XYZ prefers to reduce or eliminate the potential risk factors before the employees become symptomatic.

Assumptions

Assumptions made for this study include:

- The employees at Company XYZ are earnest in their complaints about back and elbow pain they are experiencing from the de-palletizing workstation
- The employees at Company XYZ fill out the WMSD Signs and Symptom Surveys with integrity and without bias
- The employees at Company XYZ perform consistently the methods and practices they use to de-palletize while the workstation is being videotaped

Definitions

Listed below are the definitions for common terminology used while conducting an ergonomic study. They are as follows:

1. *Abduction:* The movement of a body part away from the center plane of the body. Lifting the arm out and away from the body is an example of abduction (Friend, Kohn, Winterberger, 1996).

2. *Adduction:* The opposite of abduction. The movement of the body part toward the center plane of the body (Friend, Kohn, Winterberger, 1996).

3. *Degeneration:* Weakening of the tendon from wear and tear overtime (MMG, 2001).

4. *Ergonomics*: The science of designing the job to fit the worker than physically forcing the workers body to fit the job (OSHA 2002).

5. *Extension:* The opposite of flexion. The movement of a joint that increases the angle between the bones (Friend, Kohn, Winterberger, 1996).

6. *Flexion:* The movement of a joint that decreases the angle between the bones (Friend, Kohn, Winterberger, 1996).

7. *Ligaments:* Strong, rope-like fibers that connect one bone to another to from a joint (Putz-Anderson, 1988).

8. *Neurovascular Disorders:* Disorders that involve the nerves and adjacent blood vessels (Putz-Anderson, 1988).

9. *Nerve Disorders:* Disorders that occur when the nerves are exposed to pressure from repeated or sustained activities (Putz-Anderson, 1988).

10. *Pronation:* The opposite of supination. The turning of the forearm or wrist such that the hand rotates and the palm is facing downward (Friend, Kohn, Winterberger, 1996).

11. *Risk Factors*: Job attributes or characteristics that has potential to contribute to the onset of a CTD injury (OSHA, 2002).

12. *Rotation:* A movement in which a body part turns on its longitudinal axis. Turning the head or arm is an example of rotation (Friend, Kohn, Winterberger, 1996).

13. Static Loading or Movement: Maintaining the position of a body member in order to hold something in place (Friend, Kohn, Winterberger, 1996).

14. *Supination:* The turning of the forearm or wrist such that the hand rotates and the palm is facing upwards (Friend, Kohn, Winterberger, 1996).

15. *Tendons:* Smooth rope-like material that transfers forces and movements from the muscles to the bones (Putz-Anderson, 1988).

16. *Tendon Disorders:* Disorders that frequently occur when the tendons rub on nearby ligaments or bones (Putz-Anderson, 1988).

17. *Work-related Musculoskeletal Disorder (WMSD):* Injuries and disorders of the soft tissues (muscles, tendons, ligaments, joints, and cartilage) and nervous system (OSHA 2002).

Chapter Two

Review of literature

Introduction

As stated in Chapter 1, work-related musculoskeletal disorders are evident in today's industries. In this chapter, the researcher will be discussing the basics of the risk management process, physiology of the body and WMSD's, and methodologies to identify, analyze, and develop controls to reduce or eliminate the unexpected costs associated with such injuries.

Risk Management Process

The editor of *The Handbook of Human Factors and Ergonomics* (Salvendy, 1997, p. 989) defines risk management as "the reduction and control of the adverse effects of the risks to which an organization is exposed." Risks include all aspects of loss that leads to any capital expenditure of the organizations assets. The assets of a common organization include the employees, the products or services they produce, raw materials, the facility and equipment, work environment, and the consumers of the products or service themselves (Salvendy, 1997). Risk management is a specialized function that incorporates the basic tenets including the processes of planning, leading, organizing, and controlling (J.J. Keller, 2002d). The essence of risk management is to protect and preserve the resources of an organization by identifying and analyzing the current and past operating hazards, the potential risk factors associated with those hazards, and the existing losses the organization has already encountered (Salvendy, 1997). According to Salvendy (1997) risk management can be broken down into four strategies; risk avoidance, risk retention, risk transfer, and risk reduction. The focus of risk reduction is to identify, analyze, and develop controls to lessen the likelihood of work-related musculoskeletal disorders. The risk reduction strategy with an emphasis on ergonomics is the approach the researcher will focus on in this study.

Physiology of the Human Body and WMSDs

The U.S. Department of Labor (DOL) and OSHA (2000) support the idea that painful and disabling injuries of this magnitude generally develop over a period of weeks, months, and years. Typically, a WMSD injury does not stem from a single event or trauma such as a slip, trip, fall, collision, or entanglement. WMSD's usually result from exposure to multiple WMSD risk factors that can cause or exacerbate the disorders (DOL-OSHA, 2000). The anatomy, common causes, signs and symptoms of WMSD's affecting the lower back and upper extremities will be reviewed in this section.

Lower Back Pain

Anatomy

According to *Back.com (2002a)*, the anatomy of the spinal column is extremely well designed to serve many functions. All of the elements of the spinal column and vertebrae protect the spinal cord. The spinal cord provides communication via nerves to the brain, mobility and sensation in the body through interactions with the bones, ligaments and muscle structures of the back and the nerves that surround it. *Lowbackpain.com* (2001) breaks the spine into five components. They are the cervical spine that contains seven vertebral segments, the thoracic spine consisting of twelve thoracic vertebral bodies, the lumbar, which is composed of five lumbar vertebral bodies, the sacrum, and the coccyx. The spinal cord branches into many nerves that go into the arms, legs, hands and feet. The muscles of the low back serve to support the spine, and attach to the spinal column, pelvis, and extremities (Lowbackpain.com, 2001). These muscles may become injured, and contribute to low back pain.

Lower Back Pain Causes/Risk Factors

The specific cause of some back pain is mysterious in that health-care providers can't always say why one person gets injured and another doesn't (Intelihealth, 2002). A variety of conditions or circumstances may contribute to back pain. However, the majority of back problems result from strained or pulled muscles (Lawrence, 1990). Back strains and pulled muscles are frequently caused by working or lifting with poor posture, twisting, bending, and handling loads that are to big for an individual, or performing tasks for an extended period of time without ample rest breaks (Benton, n.d.). Other risk factors associated with back strain injuries are pushing, pulling, unexpected loads, and/or sudden slips or falls that jar the back (Lawrence, 1990). Lawrence also states that frequency, duration, and type of lifting can contribute to the likelihood of a back injury. Back strain injuries involve damage to the muscles, ligaments, tendons, and discs and usually occur when they are overstretched or muscles are overused (Lawrence, 1990).

In addition to the risk factors mentioned above, most disabling back problems result from chronic or repeated strains to the back (Benton, n.d.). The initial injury to spinal discs, muscles, ligaments, or tendons may not be noticeable on a day-to-day basis. However, once the back is injured, the muscles, discs, ligaments, and tendons can become scarred or weakened, making the person susceptible to more back injuries (Benton, n.d.). Millions of workers nation wide must lift, bend, or pull as part of their everyday job duties. Back strain injuries affect workers in a wide variety of industries

(Lawrence, 1990). Thus, it is important for employers and employees to be able to recognize the early symptoms of lower back pain before an actual back injury occurs.

Signs and Symptoms of Lower Back Pain

According to *Back.com* (2002b), lower back pain is a reaction from signals received by the brain from the source of discomfort. The pain perceived by the brain may evolve from different sources. The origin of some back pain is either neuropathic or nociceptive. Neuropathic back pain is caused by damage to nerve tissues usually resulting from an injury or trauma that leads to acute symptoms. Acute back pain is commonly described as having a sudden onset of very sharp pain or a dull ache feeling deep in the lower back. A common example of this pain is a "pinched nerve" feeling. The pain level from an acute injury or trauma may be intermittent or constant, depending on the severity of injury. Common causes of acute back pain include contusions, torn muscles, or strained joints from lifting heavy objects, incorrect lifting techniques, or sudden bursts of back movement. People that suffer from acute back pain usually improve or completely recover in six to eight weeks (Back.com, 2002b).

The other source of pain is nociceptive and is usually caused by an injury or disease outside the nervous system. Nociceptive back pain tends to have more chronic symptoms such as deep aching, dull or burning pain in one area of the back and/or traveling down into the legs. Other symptoms include numbness, weakness, tingling, burning, or a pin-and-needles type sensation in the legs. Chronic pain tends to last for months with little relief and can have a myriad of causes. A common example of nociceptive pain is arthritis like symptoms (Back.com, 2002b). *Back.com* (2002b) reports that it's possible some people may experience both types of back pain at the same time.

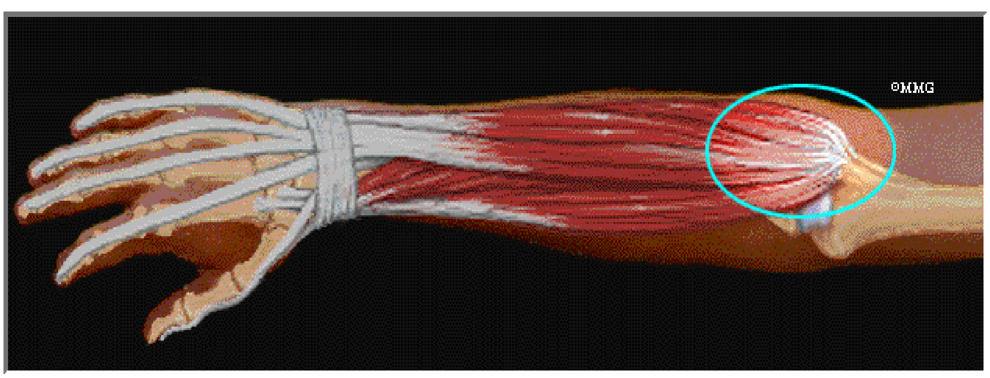
Epicondylitis

Work-related musculoskeletal disorders can affect other areas of the body including the upper extremities. A common upper extremity disorder is epicondylitis. Epicondylitis is a form of tendonitis, which involves an inflammation of the tendons in the elbow. There are two common types. Lateral epicondylitis, commonly called tennis elbow, affects the tendons on the outer side of the elbow. The other type is medial epicondylitis, which involves the tendons on the inner side of the elbow and is commonly referred to as golfer's elbow (Tayyari & Smith, 1997). The Medical MultiMedia Group (MMG) exhibits the anatomy of these diseases clearly.

Anatomy

According to MMG (2001a), lateral epicondylititis is a common condition that causes pain at the outside epicondyle of the elbow. An epicondyle is the meeting point for the forearm tendons. (See Figure 1.)

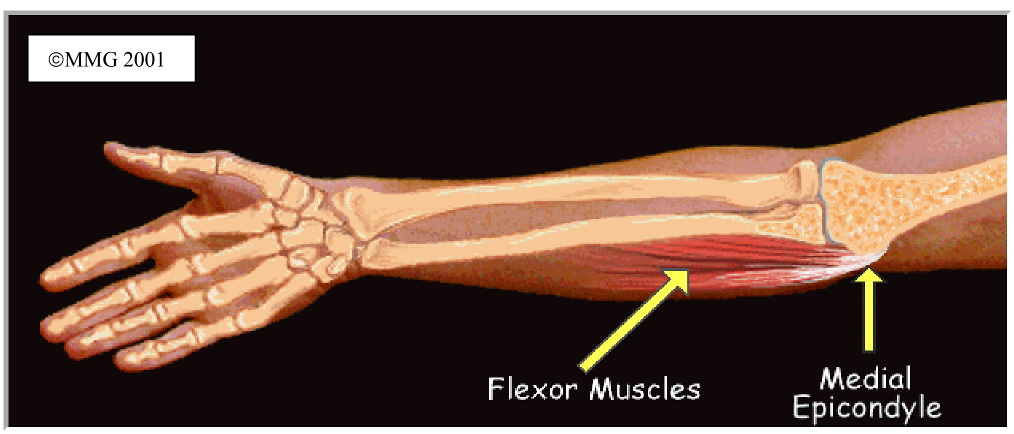
Figure 1. Lateral Epicondylitis



These are the tendons that enable a human to bend the wrist back (extension), turn the hand palm side up (supination) and reach or pick up an object with the elbow. A common motion of this nature is what affects these particular tendons (MMG, 2001a).

In addition to the potential for injury to the outside epicondyle, medial epicondylitis involves the tendons on the inner side of the elbow. The muscles of the forearm that pull the wrist down (flexion) are called wrist flexors. The wrist flexors join together and attach to one main tendon at the elbow called the flexor tendon. The flexor tendon attaches itself to the bump of the elbow called the medial epicondyle. (See Figure 2.) When the wrist is flexed or the hand is used to grip an object, the muscles contract and pull against the tendons at the medial epicondyle (MMG, 2001b). Injuries of this nature have a variety of causes that are discussed in the next section.

Figure 2. Medial Epicondylitis



Causes/Risk Factors of Epicondylitis

Some of the causes of epicondylitis are inevitable while others are induced out of necessity or extracurricular activities. As humans age, the intertwined strands of collagen which make up the tendon, are susceptible to degeneration. This degeneration leads to a condition over a period of time, where the tendon becomes weaker than normal from everyday wear and tear (MMG, 2001b). Other causes of medial and lateral epicondylitis include repeated or sustained rotation of the forearm in combination with flexions or extensions of the wrist (NC-OSHA, 1991). When the tendons are over- exerted, the individual strands of its composition get entangled, some of the strands break, and the tendon losses strength, which leads to pain and discomfort (MMG, 2001b).

Signs and Symptoms of Epicondylitis

MMG (2001b) claims the common signs and symptoms of lateral and medial epicondylitis include tenderness, swelling, pain, and weakness in the forearm and elbow. Some individuals that suffer from epicondylitis may lose a few degrees of motion, making it difficult to completely extend and flex the elbow. The symptoms may appear at night while the person is at rest, however, flare-ups usually occur during or after activities that stresses the lateral or medial epicondyle (Tayyari & Smith, 1997). The symptom location is dependent on which type of epicondylitis the individual is suffering from (MMG, 2001a).

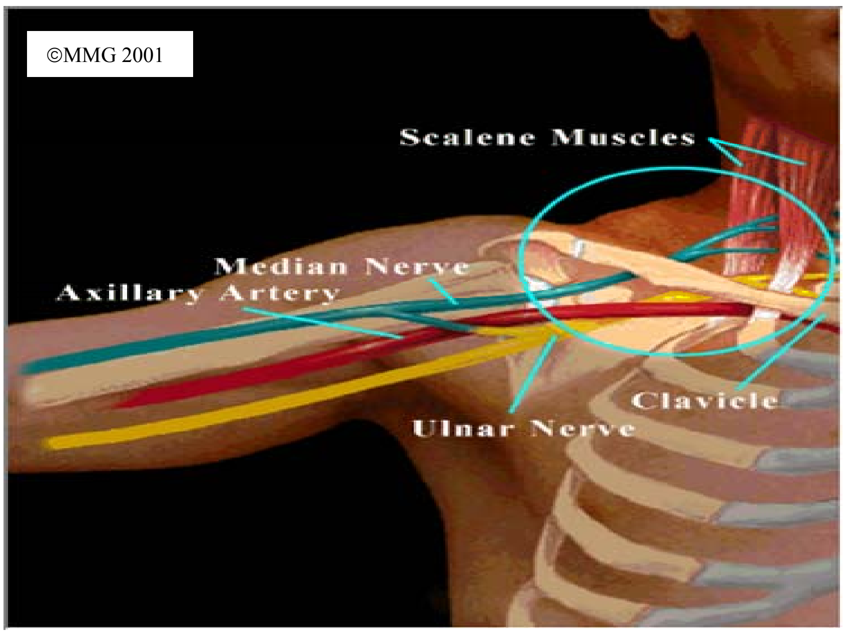
Thoracic Outlet Syndrome

Thoracic Outlet Syndrome (TOS) is a neurovascular disorder that affects the shoulders, arms, and hands (MMG, 2001c). TOS is a general term for compression of the nerves and blood vessels between the neck and shoulder (Putz-Anderson, 1988).

Anatomy

According to MMG (2001c), the nerves and blood vessels that run into the arm and hand start at the side of the neck. From there, they exit the spine through small foramen located between each vertebra. The nerves that have left the spine become the nerve roots. The individual spinal nerve roots join together to form a neurovascular bundle of large arteries and veins that run into the arm and hand. The area where the nerves and vessels leave the neck between the two scalene muscles and over the first rib is called the Thoracic Outlet (MMG, 2001c). (See Figure 3.)

Figure 3. Thoracic Outlet Syndrome



Causes/Risk Factors of TOS

In MMG's opinion, the most common underlying cause of TOS is compression of the neurovascular bundle in the thoracic outlet. Some contributing factors to the compression may be that certain people have an extra rib that limits the space for the vessels, or have suffered a violent injury, where scar tissue crowds the thoracic outlet. More commonly though, compression is caused by repetitive activities that require the arms to frequently reach overhead and extend forward repeatedly for long periods of time without a rest break. Proper posture is advantageous, while slouching and dropping the shoulders causes tension on the neck muscles and constricts the arteries and nerves which contribute to the onset of TOS (MMG, 2001c).

Signs and Symptoms of TOS

Putz-Anderson (1988) reveals the symptoms of TOS are similar to those of carpal tunnel syndrome. The similarities are numbness in the fingers, arms, and weakened pulse in the wrist. Other symptoms include loss of arm and/or shoulder strength, tingling, swelling, fatigue, or cold skin (MMG, 2001c).

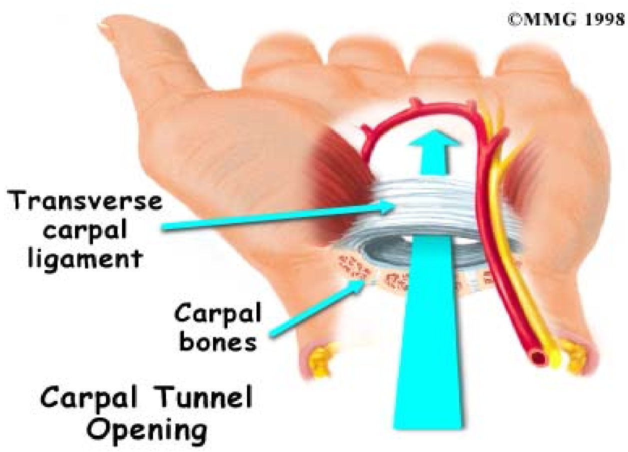
Carpal Tunnel Syndrome

Carpal Tunnel Syndrome (CTS) is a nerve disorder that affects the hands and wrists (Putz-Anderson, 1988). This particular syndrome has received increasing attention over the past several years due to the increase in cases employers face in today's industries (J.J. Keller, 2002a).

Anatomy

The nerve that provides humans with the sense of touch for the thumb, index finger, middle, and half of the fourth finger is called the median nerve. The median nerve and flexor tendons of the forearm run through the wrist into the hand (DOL-OSHA, 2000). Carpal Tunnel Syndrome transpires when there is compression and entrapment of the median nerve at the point where it passes through the wrist (DOL-OSHA, 2000). This area is known as the carpal tunnel and is comprised of wrist bones on the bottom side and transverse carpal ligaments on the topside (MMG, 2001d). (See Figure 4.) The flexor tendons are important because they allow humans to move the fingers and grasp objects with the hands. These tendons are covered with a material called tenosynovium, which is a slippery lubricant that allows the tendons to glide against each other (MMG, 2001d). Thus, in order to keep the tendons gliding smoothly, the causes of compression must be minimized or eliminated.

Figure 4. Carpal Tunnel Syndrome



Causes/Risk Factors of Carpal Tunnel Syndrome

Carpal Tunnel Syndrome is a growing concern in industries today for the reason that there are many causes of this particular disorder. DOL-OSHA (2000) lists CTS risk factors as excessive, forceful, repetitive motions, mechanical pressure, vibration, cold stress, and awkward postures of the hands and wrists. These common risk factors cause inflammation of the flexor tendons. This condition leads to the thickening of the tenosynovium. As the tenosynovium fluid thickens, it increases pressure in the carpal tunnel and presses the median nerve against the transverse carpal ligament. Eventually, the pressure will reach a point when the median nerve losses its function and symptoms accumulate (MMG, 2001d).

Signs and Symptoms of Carpal Tunnel Syndrome

The signs and symptoms of CTS include tingling or numb feelings in the hands and wrists. These sensations are usually felt in the area of the skin connected to the first three fingers and the base of the thumb. Another common symptom is shooting pain in the forearms that can extend up to the shoulders, neck, chest, or down to the feet (Carpal-Tunnel-Syndrome.net, n.d.). The thenar muscles of the thumb may also become weakened and loose function, thus making grasping an object difficult (MMG, 2001d). CTS symptoms are typically intensified while performing the activity that was the original source of the CTS (Carpal-Tunnel-Syndrome.net, n.d.). Even during rest times, CTS symptoms are often acute (Putz-Anderson, 1988).

The High Costs of WMSD's

The Occupational Safety and Health Administration reports on the high costs employers encounter to cover the expenses associated with work-related musculoskeletal disorders. The monetary expenditures from WMSD's roughly equals one dollar of every three spent for workers compensation, racking up a total bill of approximately $15-$20 billion in a one year time frame. WMSD's account for thirty four percent of all lost workdays, which is approximately 600,000 cases per year. On average, it takes a person twenty-eight days to recover from a CTS surgery. Amputations or fractures require less recovery time than a disorder of this nature. People with severe injuries can face permanent disabilities that prevent them from returning to their normal jobs or handling simple, everyday tasks around the home (DOL-OSHA, 2000). The number of cases and monetary expenditures make it evident that it is critical for industries to identify where the WMSD's are originating.

Identifying the Risk Factors

Identifying the potential risk factors that exist in an occupational setting can be accomplished using a variety of tools. In this section, some of the methods used to collect data to determine whether or not employees are being exposed to or on the verge of becoming symptomatic from WMSD's will be discussed. Common methods used in industry today include reviewing the OSHA Form 300, Form 301, WMSD Symptom Surveys, and Job Hazard Analysis (JHA's).

Reviewing available records

The first step in the process of evaluating the scope of WMSD's is to analyze the existing safety and health records for evidence of injuries or illnesses that are associated with WMSD's (Putz-Anderson, 1988). The Occupational Safety and Health Administration require most employers to maintain an OSHA Form 300. This form is used to record information on every work-related injury or illness that involves loss of consciousness, restricted work activity, days away from work, medical treatment beyond first aid, or injuries and illnesses that are diagnosed by a physician or licensed heath care professional (OSHA, n.d.). For further details on the WMSD's listed on the OSHA Form 300, the investigator can review the OSHA Form 301 Injuries and Illnesses Incident Report. The incident report contains more in-depth information on the nature of the injury including what the employee was doing to promote the incident, what actually happened, and the extent and time the loss causing event took place. In combination, the information can help the employer develop a picture of the extent and severity of the WMSD's (OSHA, n.d.).

Work-related Musculoskeletal Disorder Symptoms Survey

According to Putz-Anderson (1988), a symptom survey is an excellent method for identifying areas or job tasks where potential WMSD risk factors exist. The symptom survey can also assist in identifying preclinical cases of work-related musculoskeletal disorders. People that experience WMSD's almost always feel some pain and discomfort. The most direct approach for using a symptom survey is to ask the employees to what extent they are feeling discomfort and in what areas of the body they feel discomfort. The information that is received from the employee can be logged on the symptoms survey for further analysis (Putz-Anderson, 1988).

The major strength of a symptom survey is that it delineates the number of workers that may be experiencing the same indicators of WMSD's and in what department, workstation, etc. The components of a symptom survey are designed to disclose the nature and the location of the symptoms. In addition, questions can be asked to reveal the time frame of the onset, how often the symptoms appear and what triggers the flare up. A symptom survey can also reveal if the affected employee has ever been diagnosed prior to employment and/or ever received medical treatment for such symptoms (Putz-Anderson, 1988).

The results of a symptom survey must be interpreted with caution. Symptom surveys are not effective in determining pain levels, as each individual has a different level of pain tolerance. However, a positive response by an employee implies that the individual is experiencing some noticeable discomfort and that's the goal of the symptom survey (Putz-Anderson, 1988).

Job Hazard Analysis (JHA)

The authors of *Fundamentals of Occupational Safety and Health* (1996, p.216) define a job as a sequence of separate steps or activities that accomplish a work goal. An important factor when considering a JHA is selecting the best job to be analyzed to yield the greatest results. The selection process should be based on the accident history of the job. In general, the greater the number of injuries associated with a job, the greater the priority it receives. Other factors to consider during the selection process include the jobs that pose the greatest potential for severe or disabling injuries. Also, new or modified jobs in an organization become prime candidates for a JHA due to the lack of work experience at those positions (Friend, Kohn, Winterberger, 1996). JHA's may be best utilized for stationary repetitive production tasks in which the equipment and work environment change very little.

A Job Hazard Analysis is a thorough evaluation of the workstation, the tools used, and the motions employees perform while at the workstation. Putz-Anderson (1988, p.31) states the goal of a JHA is to identify the risk factors that may contribute to the onset of WMSD's. J.J. Keller's (2002c) states that a Job Hazard Analysis is based on the following ideas:

- A specific job or work assignment can be separated into a series of simple steps
- The ergonomic risk factors of those steps can be identified
- Solutions can be developed to control each of the risk factors within the steps.

See **figure 5** for a common Job Hazard Analysis form.

Figure 5. Job Hazard Analysis

Job Safety Task Steps

Job Title			
Job Description			
Date Conducted		**Completed by**	
Number of Cycles Per Minute _______ Maximum Weight Moved Per Cycle ______			
Task Step	**Task Hazards**	**Hazard Control Method**	
1.			
2.			
3.			
4.			
5.			
6.			
7.			

An advantage of performing a JHA is that each task can be evaluated visually and broken down into smaller steps. The steps can be viewed multiple times to ensure that nothing has been overlooked and that the sequence is consistent with normal operating procedures. The number of cycles and weight moved per cycle is also taken into consideration. Once the steps are noted, the potential risk factors created by the job task or operating procedures can be identified. The job observation should be repeated until all risk factors have been acknowledged. The final step in the JHA process is to develop controls to reduce and/or eliminate the risk factors that were recognized in the previous step. The goal is to make the job steps safer and more efficient (Friend, Kohn, Winterberger, 1996).

Methodologies

NIOSH Lifting Equation

In 1994, the National Institute of Occupational Safety and Health (NIOSH) issued a new revised version of the NIOSH Lifting Equation. This formula is a proactive analytical tool that evaluates manual material handling tasks. Essentially, it assesses asymmetrical lifting duties and lifts of objects with less than optimal interface with the hands of the worker. By evaluating the job-related lifting tasks and using the NIOSH equation, employers should be able to reduce the risk factors that are associated with lower back disorders and ultimately reduce the occurrences (J.J. Keller, 2002b).

The principle product of the lifting equation is the Recommended Weight Limit (RWL). NIOSH defines the RWL for a specific set of task conditions as the weight of the load that nearly all healthy workers could perform over a substantial period of time without an increased risk of developing lifting related lower back disorders. The equation has six task variables expressed as a coefficient that serves to decrease the load constant. This becomes the maximum recommended load weight to be lifted under ideal conditions (J.J. Keller, 2002b).

The Recommended Weight Limit is defined by the following equation:

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

		METRIC	U.S. CUSTOMARY
Load Constant	*LC*	23 kg	51 lb
Horizontal Multiplier	*HM*	(25 / *H*)	(10 / *H*)
Vertical Multiplier	*VM*	1–(.003 | *V*–75 |)	1–(.0075 | *V*–30 |)
Distance Multiplier	*DM*	.82 + (4.5 / *D*)	.82 + (1.8 / *D*)
Asymmetric Multiplier	*AM*	1–(.0032*A*)	1–(.0032*A*)
Frequency Multiplier	*FM*	From Table 2	From Table 2
Coupling Multiplier	*CM*	From Table 1	From Table 1

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The NIOSH equation components are the horizontal (HM), vertical (VM), distance (DM), and asymmetric values (AM). The frequency value ranges (FM) and the classification of gripping otherwise known as coupling (CM), has its own criteria. Horizontal values range from ten and twenty-five inches and equal the horizontal distance of the hands from the midpoint between the ankles. (See Figure 6.) This measurement should be taken at the origin and the destination of the lift. The vertical value equals the distance of the hands from the floor and can be measured at the origin and destination of the lift in inches or centimeters. The distance value is a measurement of the vertical travel distance between the origin and the destination of the lift. An asymmetry value is a measurement of the load from the sagittal plane and is measured at the origin and destination of the lift in degrees. (See Figure 7.) The frequency multiplier is an average frequency rate of the lifting motion measured in lifts/minute over a fifteen-minute period. The scale used for frequency value is one hour (short), two hours (moderate), or eight hours (long), depending on the work. Finally, the classification of gripping refers to the hand-to-object interface that has a rating of good, fair, and poor. A good rating refers to containers with optimal designs with handles or cutouts for gripping, while a poor rating includes containers that are hard to handle or have sharp edges and awkward shapes (J.J. Keller , 2002b).

According to NIOSH, the second part of the lifting equation is the Lifting Index (LI). The LI is a relative estimate of the level of physical stress associated with a particular manual lifting task. The estimate of physical stress is defined by the relationship of the weight of the load lifted and the recommended weight limit. The lifting index is represented by the equation:

LI = Load Weight (L) / Recommended Weight Limit (RWL).

In an explanation by J.J Keller (2002b), the RWL and LI can be used as a guide to better design manual material handling jobs. The Recommended Weight Limit can be used to redesign existing or in designing new manual lifting jobs. For example, if the task variables were fixed, the maximum weight of the new or existing load would not exceed the RWL. If the weight is fixed, then the task variables could be optimized, yet not to exceed the RWL. The Lifting Index can be utilized to estimate the relative magnitude of physical stress for a lifting task. The greater the LI score, the smaller the fraction of employees that are capable of safely sustaining that particular level of physical exertion. The LI can also help to identify and prioritize the hazardous lifting tasks within an organization. A Lifting Index score greater than 1.0 indicates a need for immediate attention, as the lifting task has the increased potential for accumulating WMSD's, especially low lower back disorders. The ultimate goal in redesigning the manual lifting jobs is to have a final LI score of less than 1.0 (J.J. Keller, 2002b).

NIOSH Lifting Equation Limitations

The lifting equation is an ergonomic tool that assesses the physical stressors of two-handed manual lifting tasks. As with any ergonomic tool, its function is limited to the circumstances for which it was designed. J.J. Keller (2002b) reports the lifting equation has several limitations for its use. First of all, the equation does not apply to manual lifting/lowering tasks with one hand or while seated or kneeling. Secondly, the equation does not apply to lifting/lowering tasks while carrying, pushing, and pulling or with a load that is unstable. The revised equation does not include task factors to account for unpredicted conditions like heavy loads, slips, and falls or environmental conditions including temperatures and humidity outside the range of 66° to 70° or 35% to 50% respectively. Finally, the equation does not apply to lifting/lowering tasks that involve high-speed motions faster than thirty inches per second or for lifting/lowering tasks that are performed for more than eight hours (J.J. Keller, 2002b). The NIOSH Lifting Equation is not applicable to all situations or organizations. Other ergonomic tools such as the Rapid Upper Limb Assessment (R.U.L.A.) may be more applicable to fulfill the limitations of the lifting equation.

Table 1. Coupling multiplier

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

Note: values of *V* are in cm; 75 cm = 30 in.

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Table 2. Frequency multiplier

Frequency lifts/min	Work duration					
	≤1h		≤2h		≤8h	
	V<75	*V* ≥75	*V*<75	*V* ≥75	*V*<75	*V* ≥75
0.2	1.00	1.00	0.95	0.95	0.85	0.85
0.5	0.97	0.97	0.92	0.92	0.81	0.81
1	0.94	0.94	0.88	0.88	0.75	0.75
2	0.91	0.91	0.84	0.84	0.65	0.65
3	0.88	0.88	0.79	0.79	0.55	0.55
4	0.84	0.84	0.72	0.72	0.45	0.45
5	0.80	0.80	0.60	0.60	0.35	0.35
6	0.75	0.75	0.50	0.50	0.27	0.27
7	0.70	0.70	0.42	0.42	0.22	0.22
8	0.60	0.60	0.35	0.35	0.18	0.18
9	0.52	0.52	0.30	0.30	0.00	0.15
10	0.45	0.45	0.26	0.26	0.00	0.13
11	0.41	0.41	0.00	0.23	0.00	0.00
12	0.37	0.37	0.00	0.21	0.00	0.00
13	0.00	0.34	0.00	0.00	0.00	0.00
14	0.00	0.31	0.00	0.00	0.00	0.00
15	0.00	0.28	0.00	0.00	0.00	0.00
>15	0.00	0.00	0.00	0.00	0.00	0.00

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Figure 6. Graphic Representation of Hand Location

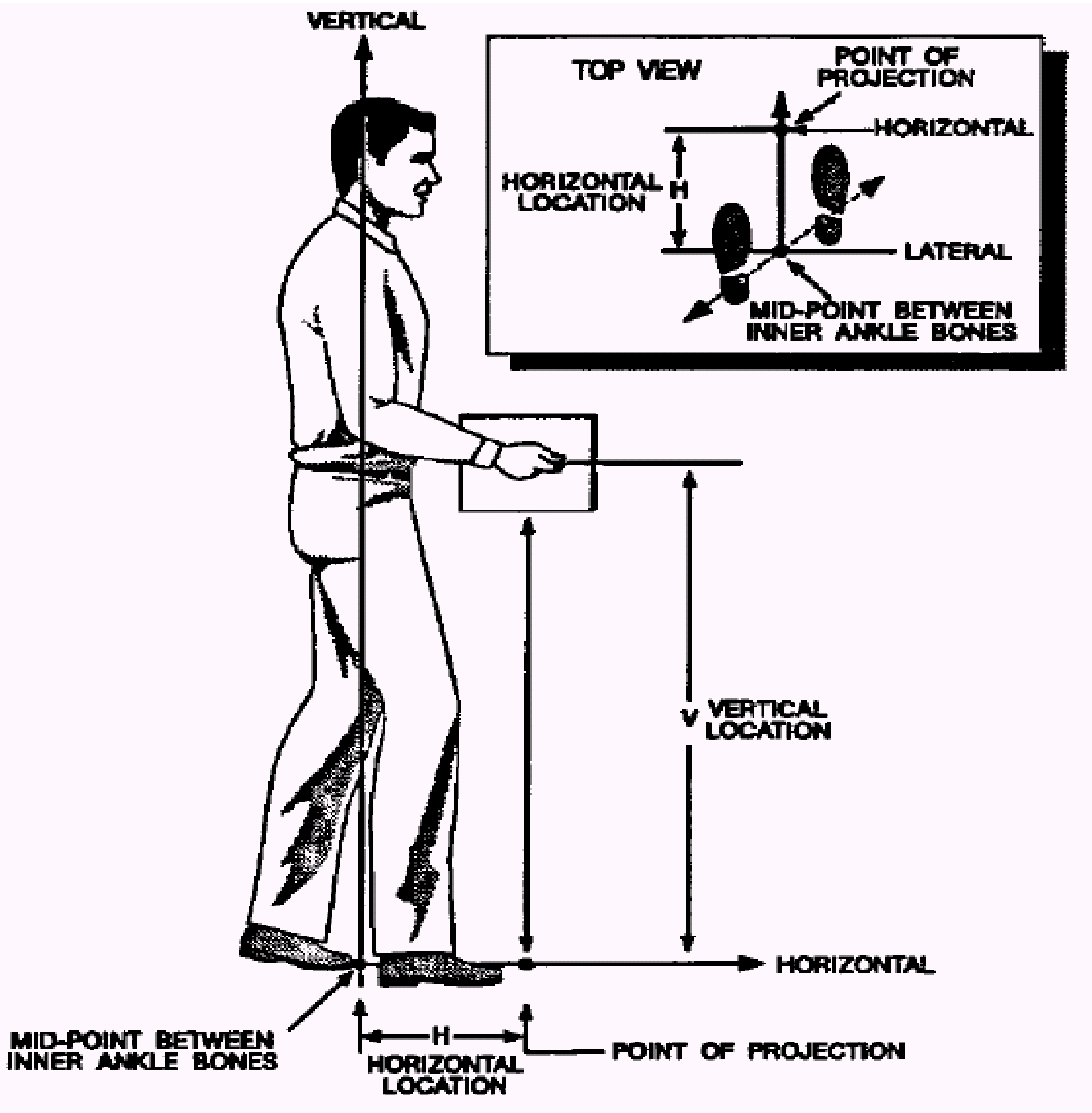
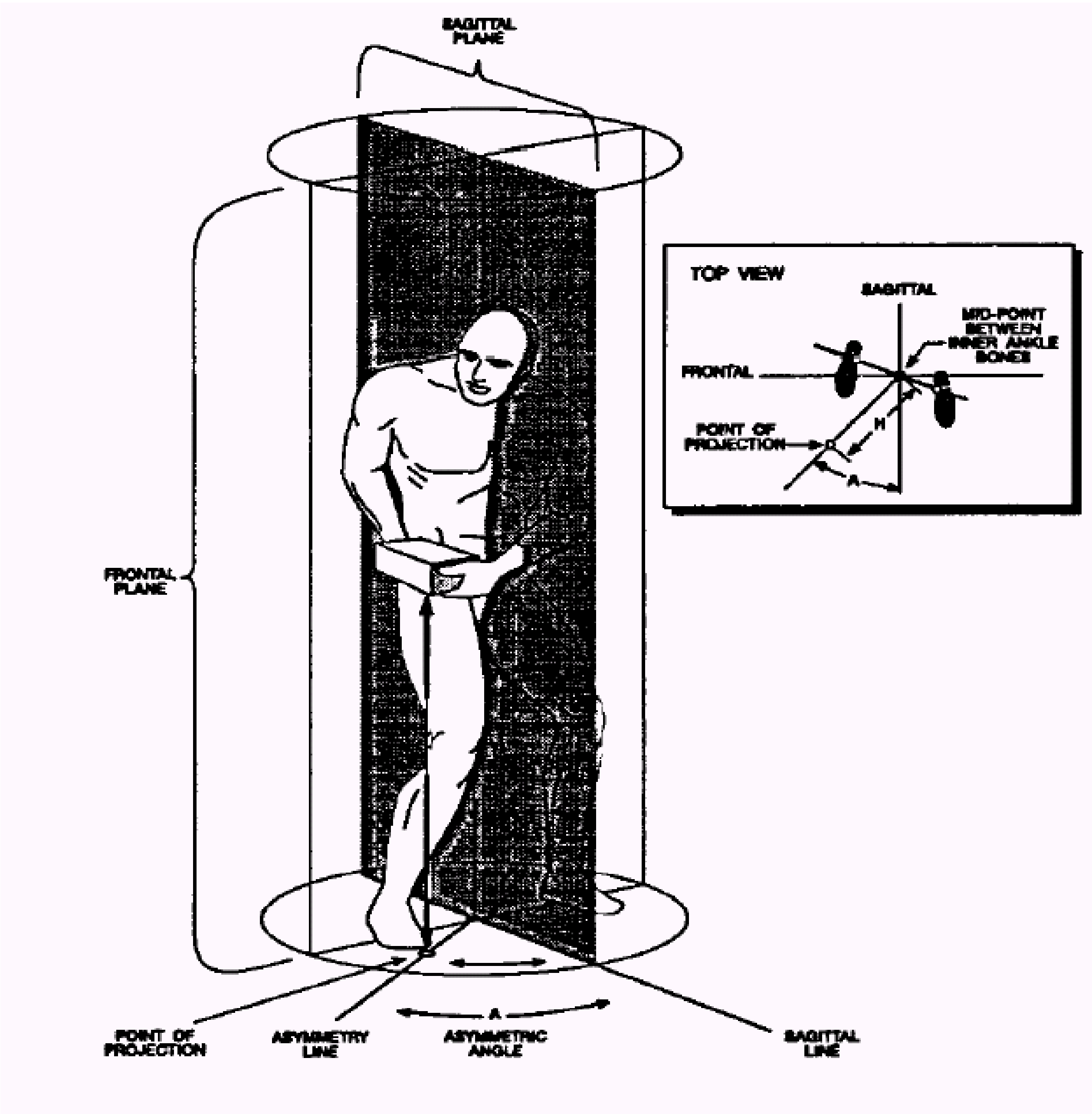


Figure 7. Graphic Representation of Angle of Asymmetry

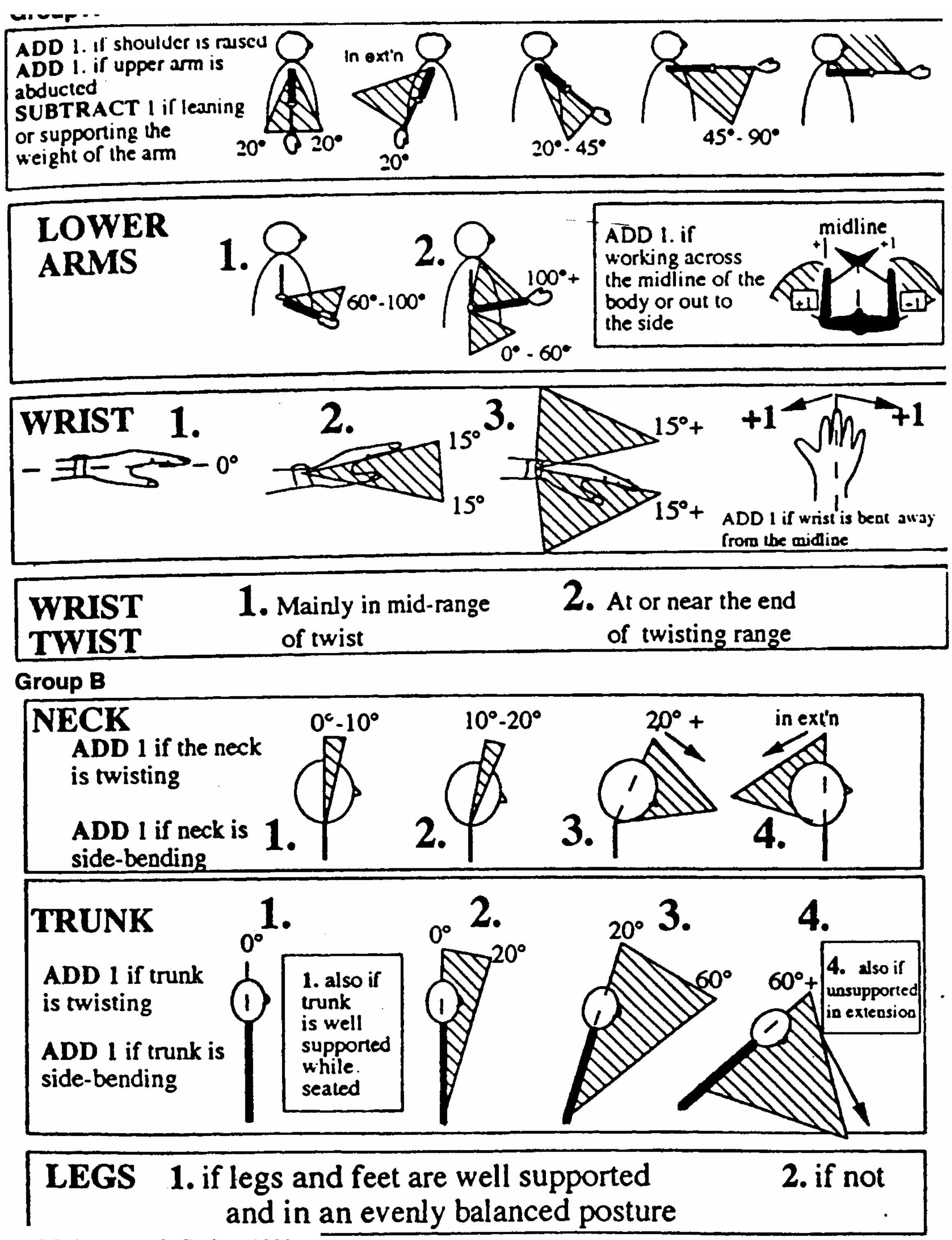


Rapid Upper Limb Assessment

Rapid Upper Limb Assessment (R.U.L.A.) is a methodology used in ergonomic analysis for work-related musculoskeletal disorders specifically related to the upper limbs, neck, and trunk. According to Karwowski & Marras (1999), performing a Rapid Upper Limb Assessment is achieved through visual observations of the workers posture, where the most repetitive use of a joint or the extreme angles are recognized. R.U.L.A. requires the segments of the body to be judged on a simple scale, producing a sequence of numbers, which are matched against a grid. The numbers and their position on the grid inform the analyst of the severity of the posture and help to determine the amount of intervention to be taken and the priority it should receive. The goal of R.U.L.A. is to identify where the most probable risk factors exist while the workers are doing the job task (Karwowski, Marras, 1999). A more in depth discussion on the R.U.L.A. is included in the next section.

As stated by McAtamney & Corlett (1993), R.U.L.A. has three phases. The first phase records the postures, the second is the scoring system, and the third is a grand score table. The first phase is broken into group A and B. Group A includes the upper arm, lower arm and wrist, while group B consists of the neck, trunk, and legs. The ranges of motion for the upper extremities are assessed and scored according to the amount of flexion, extension, pronation and supination of the arms and hands, the radial and ulnar deviations of the wrist, and abduction of the shoulders. Group B components are scored on the amount of twisting or bending of the neck and trunk, while the legs are scored according to how well the feet are placed on the floor and amount of support they provide. (See Figure 8.) The postures from group A and B is ranked on a scale of 1-9, where 1 is a minimal amount of postural loading and 9 is the maximum.

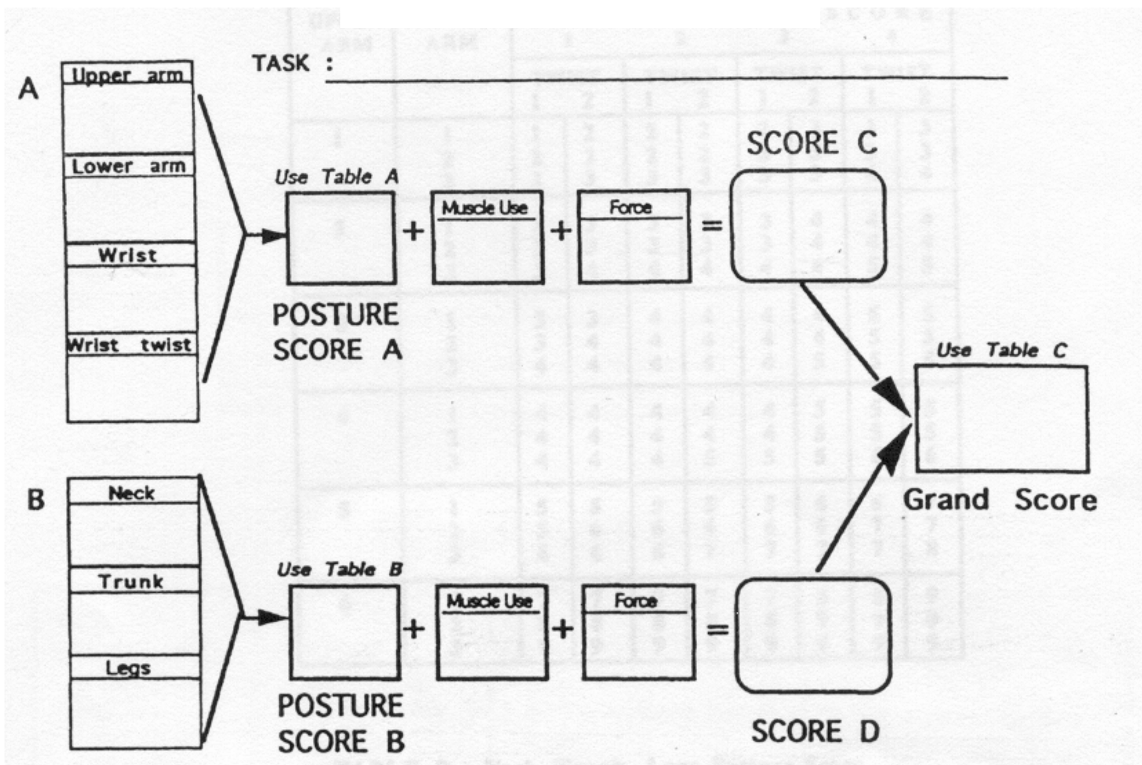
Figure 8. R.U.L.A. Criteria



McAtamney & Corlett, 1993

The second phase is the scoring grid. (See Figure 9.) Posture scores A and B are individually combined with the muscle use score and force/load score. A muscle use score of one indicates static postures for more than one minute, or if the work cycle is 4 or more repetitions per minute. The force/load factor indicates the weight of the object being handled which places a high score of three, on objects exceeding 10kg (22 pounds) (McAtamney, Corlett, 1993).

Figure 9. R.U.L.A. Final Score Table



McAtamney & Corlett, 1993

The final results of group A and B are combined in the third phase that represents the grand score. The final score for the R.U.L.A. determines the severity and amount of intervention needed to reduce the WMSD risk factors. According to McAtamney & Corlett (1993), a final score of 1-2 indicates an acceptable level, 3-4 indicates that there may be a need for further investigation, 5-6 means investigate further and change soon, and 7-9 indicates that an immediate change is necessary (McAtamney, Corlett, 1993).

Rapid Upper Limb Assessment Limitations

As with the NIOSH Lifting Equation, RULA has its limitations. First of all, the neck and trunk criterion in group B does not receive more than 1 point if bent or twisted sideways. There is no more value put on a neck or trunk that's bent forward or twisted down or to the side 3 degrees verses 23 degrees, the later being more severe. Secondly, part of the muscle use score criteria is static loading. An employee would have to hold a static position for one minute or more before a point would be allotted. One minute of static loading is a significant amount of time for an employee to hold. Finally, the scoring system for R.U.L.A. is rather vague. The time frames for intervention are not clearly defined.

R.U.L.A. was developed as a quick and easy guide to determine if WMSD risk factors exist. The assessment is better used to prioritize job tasks under suspicion of WMSD risk factors and assist in determining if further investigation is needed. For further analysis, the researcher may want to follow up with the Baseline Risk Identification of Ergonomic Factors.

Baseline Risk Identification of Ergonomic Factors

The Baseline Risk Identification of Ergonomic Factors (BRIEF Survey) is a screening tool that uses a structured and formalized rating system to identify improper postures and the ergonomic risk factors. The BRIEF Survey is similar to R.U.L.A. as it analyzes the same nine body parts including the left and right shoulders, elbows, hands and wrists, and the neck, back, and legs on an individual basis (Humantech, 1995).

According to Humantech (1995) the components of the BRIEF Survey measure posture, force, duration, and frequency for each of the body parts. To measure force, a grip dynameter can be used to accurately measure the amount of strength exerted by the hands of an employee to grasp an object. Forces range from 2-20 pounds depending on the body part and grip. Frequency is determined by counting the number of like postures during a work cycle, while duration is measured as any posture sustained for ten seconds of longer. Frequency ranges from 2-30 repetitions per minute and duration are expressed as a percentage for the legs or in seconds for the remaining body parts.

The posture measurements required for the BRIEF Survey have different criteria for each of the body parts. (See Figure 10.) Both left or right hands and wrists are evaluated for several postures. The first is the type of grip used, which is either a pinch grip or power grip. Other motions include ulnar/radial deviations and flexion/extensions of more than 45 degrees. The elbows are assessed for full extension and pronation/supination (rotation) of the forearms, while the abduction of more than 45 degrees is evaluated for the shoulders. The neck and back are evaluated for forward or backward postures in excess of 20 degrees either way. Other criteria for the neck and back include twisting, sideway bends, or combinations of both. The legs are assessed for postures that include squatting, standing on one leg, or in a kneeling position (Humantech, 1995).

Circling all the appropriate choices for posture, force, duration, and frequency does the scoring for the BRIEF Survey. The numbers for each category are then tallied. For the body areas with a total of 2 or more, the analyst would mark the body area in the

High Risk Summary box. The High Risk Summary box is the final score and indicates the need of for further investigation or intervention with some type of controls.

Figure 10. BRIEF Survey

BRIEF™ Survey BASELINE RISK IDENTIFICATION OF ERGONOMIC FACTORS

Identification

Job Name:
Dept: Date:
Zone: Analyst:
Station: **Record:**

Directions

- Mark all appropriate Posture, Force, Duration, and Frequency boxes.
- Total the number of marked boxes.
- For body areas with a total of 2 or more, mark the body area in the High Risk Summary box.

High Risk Summary	
Left	**Right**
Hand/Wrist	Hand/Wrist
Elbow	Elbow
Shoulder	Shoulder
Neck	
Back	
Legs	

	Left				**Right**						
	Hand and Wrist		**Elbow**	**Shoulder**	**Hand and Wrist**		**Elbow**	**Shoulder**	**Neck**	**Back**	**Legs**
Posture	Pinch Grip	Radial Dev	Forearm Rotation	≥ 45°	Pinch Grip	Radial Dev	Forearm Rotation	≥ 45°	≥ 20°	≥ 20°	Squat
	Finger Press	Ulnar Dev			Finger Press	Ulnar Dev			Sideways	Twisted	Stand on 1 leg
		Flex ≥ 45°	Full Extension	Arm Behind Body		Flex ≥ 45°	Full Extension	Arm Behind Body	Backwards	Sideways	Kneel
		Ext ≥ 45°				Ext ≥ 45°			Twisted		
Force	Pinch Grip ≥ 2 lbs Power Grip ≥ 10 lbs		≥ 10 lbs	≥ 10 lbs	Pinch Grip ≥ 2 lbs Power Grip ≥ 10 lbs		≥ 10 lbs	≥ 10 lbs	+ Weight	≥ 20 lbs	Foot ≥ 10 lbs
Duration	≥ 10 secs			≥ 10 secs	≥ 10 secs			≥ 10 secs	≥ 10 secs	≥ 10 secs	≥ 30% of Day
Frequency	≥ 30/min		≥ 2/min	≥ 2/min	≥ 30/min		≥ 2/min	≥ 2/min	≥ 2/min	≥ 2/min	≥ 2/min
Total											

Physical Stressors

Check the type of stressor present and shade the area of the body affected.

- ❑ Vibration (V)
- ❑ Mechanical Stress (M)
- ❑ Low Temperatures (L)

Comments / Observations

- ❑
- ❑
- ❑
- ❑
- ❑
- ❑
- ❑

Humantech, 1995

BRIEF Survey Limitations

The researcher observed only two limitations for using the BRIEF Survey. The first is the degree allowance for the flexion and extension of 45 degrees for the wrists. R.U.L.A. had a considerably lower allowance at 15 degrees. The other is the scoring system is similar to R.U.L.A. It's not at all defined on the scoring sheet, however, it is an indicator that controls need to be implemented or further investigation is necessary.

Super-8 Video Recorder, Jog Shuttle VCR and Goniometer

The researcher of this study has observed and experienced the benefits of utilizing the super-8 video recorder, jog shuttle VCR, and goniometer (protractor) to assist in the data collection necessary to complete the NIOSH Lifting Equation, R.U.L.A., and the BRIEF Survey. Following is a review of the methodologies.

A super-8 video recorder allows the researcher to videotape the subject throughout the entire work cycle from a 90-degree angle of the side, head on, overhead or close-up. The tape can be analyzed in slow motion or on a frame-by-frame basis with a jog shuttle VCR to identify the awkward postures that exist. Measuring the awkward posture angles of the back, shoulders, elbows, hands and wrists can be performed on the TV screen with the manual goniometer and a water-based felt tip marker. Also, the tape can be analyzed numerous times to ensure that all steps, postures, and angles have been measured and nothing has been overlooked. A thorough analysis of the job tasks allows for better selections of controls to reduce or eliminate WMSD's in the workplace.

Controls

The State of Wisconsin Department of Administration (DOA) confirms that an effective safety and health program relies on the risk reduction technique that emphasizes preventing, controlling, or eliminating the risk factors that contribute to WMSD's. There are four basic control methods recommended by OSHA (DOA, n.d.). The methods include engineering and administrative controls, safe work practices, and the use of personal protective equipment (PPE's).

Engineering Controls

According to *Ergonext.com* (2001b), the most effective means for controlling and eliminating WMSD risk factors is through engineering controls. Engineering controls focus on the complete production system layout, the workstation dimensions and arrangement, and the tools and equipment used by the employees. The objective of using these controls is to better fit the task, workspace, and tools to the employees (Ergonext.com, 2001b).

Proven engineering controls utilized in today's industry include re-designing works stations and processes to reduce human exposures to potential WMSD risk factors. This can be achieved by altering the way materials are handled with the use of mechanical devices, modification of container handles, or adjusting workstation heights to accommodate all sizes of users. Other controls used include re-designing hand tool grips to reduce awkward hand and wrist postures or suspending the tools to reduce weight and decrease the reach distance allowing easier access (Ergonext.com, 2001b). Engineering controls can also be uses for isolating or enclosing hazardous processes or noisy equipment by machine guarding and barriers, booths to reduce toxic material exposures, or automating with new machines that meet or exceed the safety standards (DOA, n.d.). An added benefit of engineering controls is that they can result in permanent fixes that usually require minimal training. In addition, engineering methodologies are less likely to fail than administrative or personal protective equipment (PPE) controls because an employee can visually inspect a tool or piece of equipment to ensure all guards are in place. Guards can also be designed to isolate electrical equipment if not properly replaced after service or maintenance (Ergonext.com, 2001b). However, disadvantages of engineering controls are higher cost expended in the short term and may not be feasible to fit in all individual operations. If this is the case, then alternate solutions should be reviewed.

Safe Work Practices

When engineering controls are not feasible or affordable, safe work practices can be used to reduce the likelihood of WMSD exposures. This technique focuses on procedural alterations and relies on the behaviors of the managers, supervisors, and the employees to follow proper working procedures (Ergonext.com, 2001d). Safe work practices include work rules, general work habits, and specific safe operating procedures. A common safe work practice used in industries today is safe lifting practices (DOA, n.d.).

Safe work practices are a proven method of preventing WMSD’s with minimal cost input compared to engineering controls. This technique requires more employee training on WMSD recognition, standard operating procedures, and safe work habits. However, the biggest disadvantage of safe work practices is that they are only as effective as the management systems ability to ensure the compliance by all employees (DOA, n.d.).

Personal Protective Equipment (PPE)

Personal protective equipment can be used to reduce the intensity, frequency, and durations of WMSD risk factors. Common PPE's used in industry include safety glasses, goggles, face shields, protective clothing, hard hats, gloves, various styles of respirators, footwear, noise protection, to name a few. The State of Wisconsin Department of Administration lists the key elements to an effective PPE program as:

1. Proper selection of PPE's to protect against applicable risk factors
2. Proper fit of PPE's for all employees
3. Training on the PPE's and there uses
4. Replacement procedures
5. Consistency of enforcement needed

An advantage of personal protective equipment is that they are a quick, short-term fix. PPE's can readily be utilized and come in a wide variety of colors, shapes, and sizes. However, PPE's may be more expensive in the long-term and degrade with use and may not maintain the protective functions without proper inspection and maintenance (Ergonext.com, 2001c). In the article *Loss Prevention and Control Techniques*, DOA states that personal protective equipment should only be used when engineering controls are not feasible or as an interim measure while engineering controls are being implemented. An effective PPE program also relies heavily on consistent employee participation and continual enforcement by management (DOA, n.d.).

Administrative Controls

Administrative controls refer to the actions taken by management to limit the potentially harmful effects of a physically stressful job on individual workers.

Administrative control is achieved by modifying existing personnel functions by controlling actions that are focused on the employee (Putz-Anderson, 1988). Proven administrative controls that have been effective in reducing employee exposure to WMSD's risk factors include employee rotation among workstations, job task enlargement that expands the employee's job duties, and adjustment of work pace. Alternative tasks and increased rest breaks can also relieve employees from the highly repetitive workstations (Ergonext.com, 2001a).

The State of Wisconsin Department of Administration claims that administrative controls should only be used when no other method is feasible (DOA, n.d.). Administrative controls can be effective with the proper on-going training and enforcement by management. However, this type of control tends to be more costly from a monetary and time standpoint. It may also increase the workload at the supervisory level. Because of these limitations, administrative controls should only be used in conjunction with other controls and replaced when feasible with more effective controls (DOA, n.d).

Summary

Many industries suffer from the economic and social costs of WMSD's. In this chapter, the researcher discussed how the risk factors could be acknowledged through the risk reduction strategy that focuses on identifying, analyzing, and developing controls to reduce or eliminate employee exposures. With a better knowledge of the anatomy and physiology of the human body and WMSD's, the job tasks in question can more efficiently be identified with past records, symptoms surveys, and a job hazard analysis. This information and an enhanced background of the NIOSH Lifting Equation, RULA, and BRIEF Survey, should make the methodologies more effective. The results can be use to prioritize and quantify the extent of the problem and assist in developing most suitable controls that will alleviate some of the economic and social burdens WMSD's induce.

Chapter 3

Methodology

Introduction

The intent of this chapter is to provide the reader a recap of the purpose of this study, an explanation as to how the subjects were selected and the instrumentation used. In conclusion, the data collection and analysis procedures will be explained in greater detail.

Purpose

The purpose of this study was to identify, via ergonomic assessment, if workstation design and work practice risk factors are currently exposing employees to work-related musculoskeletal injuries and illnesses at XYZ Company's de-palletizing workstation. Although Company XYZ has not yet suffered significant losses from work-related musculoskeletal disorders (WMSD's), employee complaints of lower back pain and discomfort in the elbows and shoulders are present. However, before the study can begin, the researcher must select the participants and discuss with them, the legal aspects regarding human subjects in research.

Subject Selection and Description

Prior to data collection, the researcher will host a meeting with all the full-time employees that currently work or have worked at the de-palletizing station. At this time, the researcher will discuss the purpose and objectives of the study and the procedures that will be used to collect the data needed. The researcher will ask for one volunteer to perform their normal job task at the de-palletizing workstation while the Super-8 video recorder tapes them unloading one full pallet of cases. The remainder of the employees will be asked to fill out the symptom survey to the best of their knowledge. The researcher will then discuss the voluntary consent forms applicable to this study to ensure the participants absolute confidentiality of any information submitted by them.

Instrumentation

The instrumentation required to perform this study includes the Super-8 video recorder, which will be placed on a tri-pod and positioned at a 90° angle of the de-palletizing workstation. This angle will capture the subject's full range of motion as he/she unloads the cases onto the conveyor system. Other instruments necessary for this study include a goniometer for measuring body and joint angles, a jog-shuttle VCR for frame-by-frame analysis, and a water-based felt tip marker to assist in the on screen analysis.

Data Collection

Once the Super-8 video recorder is positioned, the researcher will count the number of individual cases, measure its height, width, and weight and then determine the overall dimensions of one full pallet. The researcher and subject can begin video recording.

During the taping session, some data needs to be collected on-site to complete the NIOSH Lifting Equation that's outlined on pages 16-17 of Chapter 2. Measurements for the horizontal, vertical, and distance multipliers will be made with a conventional tape measure, while the asymmetric value will be projected with the goniometer. The hand-to-object interface (coupling) of the cases and subject will be rated according to the NIOSH Lifting Equation criteria (Chapter 2, page 20, table 1). The researcher will also be timing the lifts per minute for the frequency multiplier of the NIOSH Lifting Equation and the repetition criteria for the R.U.L.A. and BRIEF Survey. Another component of the NIIOSH Lifting Equation is the conveyor (destination) height which will be measured and documented. Any additional observations made regarding workstation design, safe work practices, and environmental concerns will be documented and taken into consideration while analyzing the data.

Data Analysis

Data analysis will be completed in several steps. First, the researcher will review the symptom surveys to reveal if the employees are indeed experiencing any pain or discomfort from working at the de-palletizing station. The surveys will identify the symptom locations and to what extent the employees are feeling distress from potential WMSD risk factors. The main areas of concern are the lower back, the elbows (Epicondylitis), shoulders (TOS), and the wrists (CTS). This information will be charted in table form and expressed as a percentage of the population surveyed.

The second step will be to complete the R.U.L.A. and Brief Survey by utilizing the jog shuttle VCR, goniometer, and a water-based felt tip marker. This instrumentation will allow the researcher to analyze the subject's postures frame-by-frame as they unload the pallet of cases. The felt tip marker will allow the researcher to draw lines on the television screen to assist in measuring the body postures and joint angles with the goniometer. Specifically, the researcher will be looking for the most severe instances of flexions/extensions and ulnar/radial deviations of the hands and wrists, pronation/supination of the forearms and elbows, shoulder abduction/adduction, trunk twisting, forward bending, and feet location and support. Observations for the more severe postures and joint angles will be made while the employee is unloading the top, middle, and bottom layers of the pallet. For example, the first section of group A in the R.U.L.A. examines as to what degree the shoulders are raised and/or abducted. The researcher will be able to extract those measurements needed through a thorough examination of the video recording and correlate the results with the criteria in the R.U.L.A. or the Brief Survey. The product of the R.U.L.A. is a grand score, while the results of the BRIEF Survey are in the form of a high-risk summary.

The NIOSH Lifting Equation is the third step in this analysis. All the data that was collected during the taping session will be incorporated into the Recommended Wight Limit (RWL) equation yielding the RWL. Furthermore, the RWL will be included in the Lifting Index (LI) equation to calculate the LI score that will be used to determine the severity and the amount of intervention required to reduce the risk factors that contribute to the onset of WMSD's.

At the conclusion of the data collection process, the information extracted from methodologies and symptom surveys will be used by the researcher to compare and contrast the similarities, dissimilarities, and interpret the final results. In combination, these ergonomic assessment tools will assist the researcher in determining whether or not the employees at Company XYZ are being exposed to WMSD risk factors at the de-palletizing workstation. A discussion of the results will be discussed in Chapter 4.

Chapter 4

Results

Introduction

This chapter will present the results from the data collection and analysis as outlined in Chapter 3. The researcher will begin with a description of the materials the employees are manually handling, demographic information about the participants in this study, subject's symptom survey results, and conclude with a final discussion of the video analysis. The combined information will be used to determine to what extent that the employees at Company XYZ are being exposed to the risk factors that may lead to the onset of work-related musculoskeletal disorders (WMSD's).

Material Description

The employees at Company XYZ's de-palletizing workstation are unloading pallets of beverage cases that contain 24 new bottles per case at an average rate of 18 cases per minute. One pallet consists of one hundred and eight cases that weigh 12.02 pounds each. The dimensions for an individual case (figure 11) and the overall dimensions of one full pallet is illustrated in Figure 12.

Figure 11. Case Dimensions

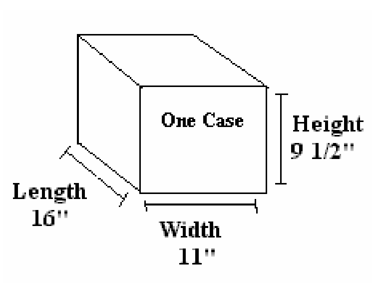
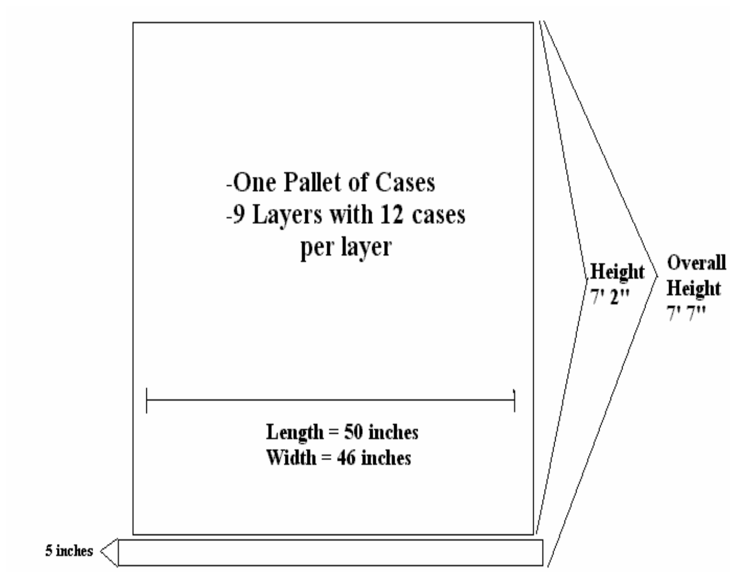


Figure 12. Pallet Dimensions



The employees at this workstation have to extend their reach over seven feet to remove the top layer of cases from a pallet. As the pallet is unloaded, the employees at this station have to bend forward and reach down to pick up the last row of cases and place them on a conveyor that's approximately 32 1/2 inches off the ground. The repetitive and awkward postures of this nature are what the employees at the de-palletizing workstation have to deal with on a daily basis. More information on the employees who work at the de-palletizing workstation and the results of the symptom surveys are in the next sections.

Demographic Information

Company XYZ has on average has 10 employees on two shifts that rotate in and out of the de-palletizing workstation every half hour. Of those, six people agreed to participate in the study by filling out the symptom surveys, therefore representing 60% of the total possible participants. Of the six, two (33.3%) were female and the remaining 4 (66.7%) were male. Four (66.7%) of the six employees have been working at the de-palletizing workstation for one year or more, while the remaining 2 (33.3%) have less than one year at this position. The overall results of the symptom survey these employees filled out are discussed in the next section.

Symptom Survey Analysis

The symptom surveys revealed that all 6 employees participating in this study have in the last year experienced some type of discomfort from working at the de-palletizing station. Specifically, the areas of concern for this study included the lower back, elbows/forearms, shoulders/neck, hands and wrists. The areas of discomfort for each of the six employees are charted in Table 3.

Table 3. Discomfort Locations

Employee #	Shoulders/Neck	Lower Back	Elbows/Forearms	Hands/ Wrists
1	X	---	X	---
2	X	X	X	X
3	X	---	---	---
4	X	X	---	---
5	X	X	X	---
6	---	X	---	X
Totals	**5**	**4**	**3**	**2**
Percentage (%)	**83.3**	**66.6**	**50**	**33.3**

As indicated in Table 3, nearly 84% of the participants have encountered or are currently experiencing discomfort in the shoulder and neck region. Almost 67% have encountered lower back pain during their employment at this workstation. Discomfort in the elbows and forearms have affected or are currently inflicting pain on 50% of the employees, while 33% claim distress in the hands and wrists. Nearly all of the employees have attributed their aches and pains from the excessive amount of overhead reaching at the beginning of a new pallet and bending down to remove the last row of cases at the end of a pallet.

The signs and locations of discomfort the participants specified in the symptom surveys are the same types of work-related musculoskeletal disorders that were discussed in Chapter 2. Several of the employee's claim that their discomfort includes pain, tingling, and numbness when sleeping, while the remainder of the participants state their discomfort arises in the form of stiffness, swelling, and a burning sensation in the affected areas. Evidence from the symptom surveys reveal that the de-palletizing workstation is exposing the employees to the potential risk factors that lead to the onset of WMSD's. In the next section the researcher will evaluate the results of the ergonomic analysis to better determine the causes of the problem.

Methodology Analysis

In conjunction with the symptom surveys, the researcher will use the results from the ergonomic methodologies to better determine the extent of the problem at Company XYZ's de-palletizing workstation. The data extracted from the NIOSH Lifting Equation, Rapid Upper Limb Assessment (R.U.L.A.), and the Baseline Risk Identification of Ergonomic Factors (BRIEF Survey) will help the researcher determine the severity and amount of intervention required to eliminate the risk factors that lead to the onset of WMSD's.

NIOSH Lifting Equation

The NIOSH Lifting Equation is a methodology the researcher used in this study to help determine to what extent the employees are being exposed to WMSD risk factors. As discussed in Chapter 2, the lifting equation is comprised of two parts. The first is the Recommended Weight Limit (RWL) and the other is the Lifting Index (LI). The researcher will calculate and discuss the two components in the next section.

Results

The NIOSH Lifting equation is expressed as:

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

The measurements required to complete this equation were taken during the data collection process that was discussed in Chapter 3. The measurements are documented in table 4.

Table 4. NIOSH Equation Components

Components	On-site Measurements	Calculations
Load Constant (LC)	51 pounds	51 pounds
Horizontal Multiplier (HM)	12”	.83
Vertical Multiplier (VM)	14.5”	.891
Distance Multiplier (DM)	18”	.92
Asymmetric Multiplier (AM)	45°	.856
Frequency Multiplier (FM)	Less than 1 hour	---
*Coupling Multiplier (CM)	Poor	.90

*The employees have no formal handles to grip, therefore a pinch or press style grip is necessary. (To increase the coupling score, the manufacturer would have to change the case design.)

The RWL was calculated using the following equation of numbers.

RWL = 51 * .83 * .891 * .92 * .856 * .90 = 26.73 pounds

RWL = 26.73 pounds

In Chapter 2, NIOSH defines the RWL for a specific set of task conditions as the weight of the load that nearly all healthy workers could perform over a substantial period of time without an increased risk of developing lifting related lower back disorders. The RWL is then required to complete the LI equation, which can be utilized to estimate the relative magnitude of physical stress for a lifting task. The greater the LI score, the smaller the fraction of employees that are capable of safely sustaining that particular level of physical exertion. A Lifting Index score greater than 1.0 indicates a need for immediate attention, as the lifting task has the increased potential for accumulating WMSD’s, especially lower back disorders. The Lifting Index formula is:

LI = Load Weight (L) / RWL

LI = 12.02 pounds (L) / 26.73 pounds (RWL)

LI = .45

The Lifting Index for the de-palletizing workstation is .45, which indicates there is very little need to intervene with the workstation. However, the results from this equation are not consistent with the symptom surveys and employee complaints. To obtain a better understanding of the extent the problem, the researcher will complete the Rapid Upper Limb Assessment.

Rapid Upper Limb Assessment

R.U.L.A. is an ergonomic methodology that examines the postures of the upper extremities, trunk, and legs. The researcher used this methodology to capture the upper extremity angles on the subject as they unloaded one full pallet of cases. The next section will reveal the step-by-step results and the grand score.

Results

The Rapid Upper Limb Assessment is divided into three sections, group A, group B, and a grand score table. The results for each of the groups and the grand score are presented in Table 5.

Table 5. R.U.L.A. Score Sheet

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

Group B: ***Neck, Trunk, and Leg Analysis***	Score
Step 9: Neck Position	4
Step 10: Trunk Position	5
Step 11: Legs	2
Step 12: Posture Score B	**7**
Step 13: *Add* Muscle Use Score	1
Step 14: *Add* Force/Load Score	2
Step 15: Final Neck, Trunk, and Leg Score	**10**

(Table 5 continued)

Grand Score Table

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

Final Arm and Wrist Score = 8

Final Neck, Trunk, and Leg Score = 10

Grand Score = 7

Group A of the R.U.L.A. analyzed the arms and wrist postures. The angle criteria for each of the steps were scored according to the subject's postures on screen. Steps one and two located the degrees of upper and lower arm extensions, while three and four identified the amount of wrist flexion and twisting. The scores combined are utilized in table A of the R.U.L.A. to yield a posture score of five. The muscle use and force/load numbers are then added to the posture score to result in a final wrist and arm score of eight. The final wrist and arm score (8) is inputted into the grand score table.

Group B of the R.U.L.A. analyzed the neck, trunk, and leg positions. Steps nine, ten, and eleven measured the degrees of neck extension, bending and twisting of the trunk, and support from the legs, which yielded a posture B score of seven. Added to the seven, is the muscle use and force/load score to result in the final neck, trunk, and leg score of ten. The ten is incorporated into the grand score table to result in a final overall score of seven. According to McAtamney and Corlett (1993) a seven indicates the need for further investigation and immediate intervention at the workstation. Seven is the highest score allotted for this assessment therefore the results are significant.

Baseline Risk Identification of Ergonomic Factors

The BRIEF Survey is another ergonomic methodology that examines the postures of the upper extremities, neck, back, and legs. This assessment process is similar to the R.U.L.A. method as it assists in determining the severity and amount of intervention required to reduce/eliminate the risk factors associated with WMSD's. The results of the BRIEF Survey will be discussed in the next section.

Results

The BRIEF Survey analyzes the posture, force, duration, and frequency for the left and right hands, wrists, elbows, and shoulders. It also examines the posture, force, duration, and frequency for the neck, back, and legs. The results for the applicable criteria for the BRIEF Survey are illustrated in Table 6.

The posture analysis for the left and right hands and wrists indicated that the subject was using a pinch grip to grasp the cases and their wrist flexion was greater than 45 degrees. The force of the pinch grip was estimated at greater than two pounds, therefore scoring a two for the hand and wrist category. The posture rating for the elbows include

Table 6. BRIEF Survey Score Sheet

	Left Side			Right Side					
	Hand and Wrist	**Elbow**	**Shoulder**	**Hand and Wrist**	**Elbow**	**Shoulder**	**Neck**	**Back**	**Legs**
Posture	Pinch Grip Flex ≥45°	Full Extension	≥45°	Pinch Grip Flex ≥45°	Full Extension	≥45°	Backwards	≥20° Twisted	Stand on 1 leg
Force	Pinch Grip ≥2 lbs.	---	≥10 lbs.	Pinch Grip ≥2 lbs.	---	≥10 lbs.	---	---	--
Duration	---	---	---	---	---		---	---	--
Frequency	---	≥2/min.	≥2/min.	---	≥2/min.	≥2/min.	≥2/min.	≥2/min.	≥2/min.
Total	**2**	**2**	**3**	**2**	**2**	**3**	**2**	**2**	**2**

Note: for the body areas with a total of 2 or more, mark the body area in the High

Table 7. High Risk Summary

High Risk Summary	
Left	**Right**
◀Hand/Wrist	◀Hand/Wrist
◀Elbow	◀Elbow
◀Shoulder	◀Shoulder
◀Neck	
◀Back	
◀Legs	

full extensions at a rate greater than two repetitions per minute. This combination scores a two for elbow category. The video revealed that the left and right shoulders of the subject were being raised and abducted greater than 45 degrees while reaching overhead to remove the upper layers of the pallet. The force is greater than ten pounds with a frequency of more than 2 repetitions per minute. This category scores a three for both left and right shoulders. The neck category scored a two from the backward bending of the head in excess of 20° and for more than two repetitions per minute. The back category also scored a two from the extreme repetitions per minute. Other criteria for the back include bending forward greater than twenty degrees and twisting to the side to place the case on the conveyor. The legs were unstable as the subject was often standing on one leg to reach the top or very bottom layers of the pallet. This occurrence was also greater than two repetitions per minute, for an overall score of two for the leg category.

Each grouping has a total number score. If the number is two or greater, then the area of the body that's affected gets marked in the High Risk Summary Box. (Table 7.) All of the body parts in this survey have been marked with a red triangle in the High Risk Summary Box. These results indicate the need for intervention with some type of controls to reduce/eliminate the WMSD risk factors.

The R.U.L.A., BRIEF, and symptom surveys indicated significant potential for WMSD's at Company XYZ's de-palletizing workstation. These results are consistent with the employee complaints that the excessive overhead reaching and awkward bending to pick up cases is the overall cause of their distress. In contrast, however, the NIOSH Lifting Equation did not indicate substantial problems in that the product of this methodology yielded a Lifting Index Score of only .45. A disadvantage of this equation is that it only accounts for the perfect lifting tasks that are directly from the pallet or floor to the destination spot. The lifting tasks at this workstation often require employees to shuffle their feet or walk around the pallet to gain access to all sides of the pallet of cases. The NIOSH Lifting Equation is not applicable to those types of conditions. Whereas, the R.U.L.A. and Brief Survey measure the full body including the upper extremities, back, legs, and trunk. A further discussion on the results and recommendations will be in Chapter 5.

Chapter 5

Discussion, Conclusions, and Recommendations

Introduction

The function of this chapter is to discuss the results revealed in Chapter 4 and relate the conclusions made by the researcher. This chapter will also provide recommendations and conclude with errors noted by the researcher during this study.

Purpose Statement and Goals

The purpose of this study was to identify, via ergonomic assessment, if workstation design and work practice risk factors are currently exposing employees to injuries and illnesses at XYZ Company's de-palletizing workstation. The goals developed for this study include identifying to what extent the employees are suffering from work-related musculoskeletal disorders (WMSD's) and quantifying the degree of ergonomic risk factors that may be present at the de-palletizing workstation. The next section of this chapter will discuss the results of the analysis.

Discussion

Company XYZ is currently practicing job rotation, which is an administrative control that was discussed in Chapter 2. The employees that perform this job task are alternating in and out of this position every half an hour. Therefore, each employee involved in this rotation is at the de-palletizing workstation for an average of two hours per day, five days a week. However, this administrative control technique is insufficient for the reason that the employees at the de-palletizing workstation are still feeling distress in the shoulders/neck, lower back, elbows, arms, hands, and wrists as suggested by the WMSD symptom surveys. The results of the symptom surveys assisted the researcher in quantifying the outcome of the Rapid Upper Limb Assessment (R.U.L.A.) and Baseline Risk Identification of Ergonomic Factors (BRIEF Survey), which are discussed in the next section.

As stated in Chapter 4, the results of the R.U.L.A. and BRIEF Survey are consistent with the complaints from Company XYZ's de-palletizing workstation operators. The employees at this workstation are repeatedly suffering distress from the excessive overhead reaching and bending throughout the unloading process. However, the results of the NIOSH Lifting Equation do not indicate the need for immediate intervention. The Lifting Index for the de-palletizing workstation was calculated to be .45, which is less than the intervention benchmark of 1.0. Company XYZ could improve the Lifting Index even more if the coupling score could be raised from a current status of "poor" to the rating of "good". This would lower the current LI from .45 to a .40. The conclusions drawn for this study will be discussed in the next section.

Conclusions

The combined results of the R.U.L.A., BRIEF, and symptom surveys reveal that Company XYZ's de-palletizing workstation does expose the employees to the risk factors that lead to the onset of work-related musculoskeletal disorders. The scores for the R.U.L.A. and BRIEF Survey were as high as the methodologies would allow, which indicates the need for immediate intervention. The researcher has concluded the best way to reduce or eliminate the risk factors is by utilizing some form of engineering controls. The current workstation is inadequately designed, rendering safe work practices, personal protective equipment, and administrative controls that were discussed in chapter 2 non-applicable. Consequently, the best practice to eliminate the excessive overhead reaching at the beginning of a new pallet and the forward bending when the pallet is nearly empty is to engineer the risk factors out of the workstation. In the next section, the researcher will provide some possible engineering controls to reduce or eliminate the risk factors that lead to the employee's distress.

Recommendations

The researcher's first recommendation is to fully automate the de-palletizing workstation. Alvey Systems, Inc. (Packexpo.com, 2002) manufactures the Accu-Flow De-palletizer, which removes cases from the pallets and unscrambles them onto a single conveyor line. The Accu-Flow is capable of handling 3000 pounds with an output rate of up to seventy cases per minute. The benefits of this system are that it is 3-4 times faster than manual de-palletizing, reduces product damage, and eliminates the WMSD risk factors that currently cause the employees discomfort. Other benefits of the Accu-Flow De-palletizer include built-in control functions such as oversized load protection and a complete diagnostics system in the event of a malfunction (Packexpo.com, 2002).

If the fore-mentioned recommendation is not feasible due to cost, space limitations, or applicability to the current process at Company XYZ, the researcher has provided a second recommendation.

This option for engineering the risk factors out of the workstation involves a hydraulic lift table provided by Advance Lifts, Inc. (Avancelifts.com, 2002). This lift table has a fifteen hundred pound capacity and a travel distance of 96 inches. Currently, the overall pallet height at Company XYZ is 91 inches. This lift table can be utilized by submerging it into the floor where the workstation currently exists. The de-palletizer operator would be able to place the pallet on the lift table at floor level and then lower it until the top layer is at roughly waist height on the employee. An additional option is adding an Advance Lift's work positioner (turn-table) to the hydraulic table. The benefit of adding the turn-table is that as employee unloads the layers of cases, the table can be raised and then rotated to keep the cases directly in front of them. The overall benefits of this system would include relieving the amount of awkward postures such as excessive overhead reaching and forward bending that is currently causing the distress the employee's are experiencing. Also, once the operators are familiar with using the lift table, this control could possibly reduce the amount of product loss and increase product output per minute.

Overall, the goal of utilizing the engineering controls is to reduce or eliminate the excessive reaching and bending associated with working at the current manual de-palletizing workstation. The employees are currently and will continue in the future to suffer discomfort in the upper extremities and lower back if the workstation design is not automated. The net affect of the above options would be to relieve the workers from risk factors that lead to the onset of WMSD's which plague the nation's industries today.

Summary

Although Company XYZ has not sustained any losses associated with the de-palletizing workstation, the symptom surveys identified injury pre-cursors that have the potential to result in substantial human and subsequent financial loss. The use of either of the proposed engineering controls will significantly reduce the probability of losses occurring in the future. Given the current condition of the labor as well as the insurance market, the prevention of occupational injuries at this de-palletizing station may be a key factor in ensuring the company's future profitability.

Opportunities to Improve Analysis Process

It should be noted that the researcher could have selected a more applicable employee work analysis methodology to use. For example, two of the six employees that filled out the symptom surveys are experiencing pain in the lower extremities from working at this station. None of the work analysis methodologies used in this study addressed lower extremity stressors/postures. Consequently, instead of using the NIOSH Lifting Equation, the researcher could have selected the Rapid Entire Body Assessment, which would have better addressed the lower extremities.

REFERENCES

Advance Lifts, Inc. (2002). *Hydraulic lift table.* Retrieved on December 6, 2002 from: http://www.advancelifts.com

Alvey Systems, Inc. (2002). *Accu-flow de-palletizer.* Retrieved on December 6, 2002 from: http://www.packexpo.com/std/32940/pdt/5770.html

Back.com (2002a). *Anatomy*. Retrieved on October 17, 2002 from: http://www.back.com

Back.com (2002b). *Pain: Symptoms.* Retrieved on October 17, 2002 from: http://www.back.com

Benton, M.L. (n.d.). Ergonomics: Adapting the job to fit the person. *Job Safety and Health Quarterly,* 4-8.

Blaco, C.E. (1993, February). *Ergonomic-related injuries: Compliance in the workplace.* Retrieved on October 09, 2002 from: www.trsa.org/members/tr/0293/ergo.htm

Carpal-Tunnel-Syndrome.net. (n.d.). *Carpal tunnel syndrome symptoms.* Retrieved on October 18, 2002 from: http://www.carpal-tunnel-syndrome.net

Ergonext.com (2001a). *Administrative controls.* Retrieved on October 20, 2002 from: http://www.ergonext.com/aa-prevention/admin-control.htm

Ergonext.com (2001b). *Engineering controls.* Retrieved on October 20, 2002 from: http://www.ergonext.com/aa-prevention/engineering.htm

Ergonext.com (2001c). *PPE controls.* Retrieved on October 20, 2002 from: http://www.ergonext.com/aa-prevention/ppe-controls.htm

Ergonext.com (2001d). *Work practice controls.* Retrieved on October 20, 2002 from: http://www.ergonext.com/aa-prevention/work-practice.htm

Friend, M.A., Kohn, J.P., & Winterberger, C.A. (1996). *Fundamentals of occupational safety and health.* Rockville, MD: Government Institutes.

Humantech Inc. Consultants in Occupational Ergonomics. (1995) *Applied ergonomics manual*: Author. 55-78.

Intelihealth Inc. (2002, March 6). *Low back pain: Knowing your risk factors.* Retrieved on October 14, 2002 from: www.intelihealth.com

J.J. Keller & Associates, Inc. (2002a). *Carpal tunnel syndrome.* Retrieved on October 12, 2002 from: www.kelleronline.com/reference

J.J. Keller & Associates, Inc. (2002b). *NIOSH lifting equation: Safe lifting to prevent back injuries.* Retrieved on October 13, 2002 from: www.kelleronline.com/reference

J.J. Keller & Associates, Inc. (2002c). *Job safety analysis.* Retrieved on October 13, 2002 from: www.kelleronline.com/reference

J.J. Keller & Associates, Inc. (2002d). *Risk management/loss control.* Retrieved on October 13, 2002 from: www.kelleronline.com/reference

Karwowski, W., & Marras, W.S. (Eds.). (1999). *The occupational ergonomics handbook.* Boca Raton: CRC Press LLC.

Lawrence, K.L. (1990, Fall). Your aching back: A look at back strain in the workplace. *Job Safety and Health Quarterly,* 25-27.

Lowbackpain.com (2001). *Understanding back pain-anatomy.* Retrieved on October 14, 2002 from: http://www.lowbackpain.com/anatomy.htm

McAtamney, L., & Corlett, E.N. (1993). R.U.L.A.: A survey method for the investigations of work-related upper limb disorders, *Applied Ergonomics*, 24, 91-99.

Medical MultiMedia Group, LLC (MMG). (2001a). *A patient's guide to lateral epicondylitis.* Retrieved on October 19, 2002 from: http://www.medicalmultimediagroup.com/pated/ctd/lepi

Medical MultiMedia Group, LLC (MMG). (2001b). *A patient's guide to medial epicondylitis.* Retrieved on October 19, 2002 from: http://www.medicalmultimediagroup.com/pated/ctd/mepi

Medical MultiMedia Group, LLC (MMG). (2001c). *A patient's guide to thoracic outlet syndrome.* Retrieved on October 19, 2002 from: http://www.medicalmultimediagroup.com/pated/ctd/tos

Medical MultiMedia Group, LLC (MMG). (2001d). *A patient's guide to carpal tunnel syndrome.* Retrieved on October 19, 2002 from: http://www.medicalmultimediagroup.com/pated/ctd/cts

National Occupational Research Agenda (NORA). (n.d.). *Low back disorders.* Retrieved on October 10, 2002 from: www.cdc.gov/niosh/nrlowbck.html

NC-OSHA. (1991). *Cumulative trauma disorders*. *Industry guide no.16*. Raleigh, NC: Author.

National Institute of Occupational Health and Safety (2002). *NIOSH lifting equation components.* Retrieved on October 16, 2002 from: http://www.cdc.gov/niosh

Occupational Safety and Health (OSHA). (2002). *Safety and health: Ergonomics: Problem recognition.* Retrieved September 24, 2002 from: www.osha-slc.gov.SLTC/ergonomics/recognition.html

Occupational Safety and Health (OSHA) (n.d.). *OSHA form 300, from 301 injuries and illnesses incident report.* Retrieved on October 21, 2002 from: http://www.osha.gov/recordkeeping/RKform.html

Putz-Anderson, V. (Ed.). (1988). *Cumulative trauma disorders: A manual for musculoskeletal diseases of the upper limbs.* Bristol, PA: Taylor & Francis, Ltd.

Salvendy, G. (Eds). (1997). *Handbook of human factors and ergonomics.* New York: John Wiley and Sons, Inc.

State of Wisconsin Department of Administration (DOA). (n.d.). *Loss prevention and control techniques.* Retrieved on October 24, 2002 from: http://www.doa.state.wi.us

Tayyari, F., & Smith, J.L. (1997). *Occupational ergonomics.* Great Britain: T.J. Press, Ltd.

U.S. Department of Labor (DOL) & Occupational Safety and Health Administration (OSHA). (2000). *Ergonomics: The study of work.* Washington, DC: Author.