

**A COMPUTER-BASED JOB ANALYSIS SYSTEM TO REDUCE
CUMULATIVE TRAUMA DISORDERS**

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User Summary

Who Should Be Interested In This Report

The computer-based job analysis system developed during the reported effort will be useful to any organization that has jobs that involve manual assembly, packaging, and manual material handling tasks. Although the system was developed to reduce the potential for cumulative trauma disorders to the wrists, arms, shoulders and back, it is also an effective tool to evaluate the postural and motion pattern characteristics of jobs that affect the productive efficiency and product quality.

What This Report Will Do For You

The technical report provides an introduction to the research and applications literature that addresses cumulative trauma disorders. This discussion includes both the work-related and non-work-related causes of disorders, as well as the methods of analyzing jobs to document and correct those causes. The report also describes the format of the software in terms of the information to be entered by the analyst and the results and recommendations that are provided, based on the job characteristics.

In Order to Use The Results

The computer-based system is designed to be usable by operational personnel with little or no formal training in ergonomics. However, to conduct a valid analysis that results in effective recommendations, it is important that the analyst fully understand the operational aspects of the job. First-line supervisors are the intended user group for the system developed.

What It Won't Do

Although the system provides recommended modifications to the design of the workplace layout, work methods, tools and equipment, there is no substitute for operational knowledge and experience. The recommendations provided are the beginning of the problem solving process, not its completion. Although many of the recommendations can be incorporated directly, operational personnel can often develop more effective and efficient means of addressing problems, once they understand the objectives to be accomplished.

ABSTRACT

The incidence rate for cumulative trauma disorders (particularly injuries of the wrists, arms, shoulders and lower back), along with the financial and non-financial costs resulting from these disorders, is receiving an increasing amount of attention from management, labor and regulatory agencies, alike. The reported research project was conducted in two-phases. The first phase focused on manual packaging tasks, and the continuation expanded upon that base and addressed musculoskeletal disorders associated with storage and retrieval tasks in warehousing operations. A computer-based job-site analysis system has been developed that allows operational personnel with little or no training in ergonomics to: (1) analyze and document operational tasks, (2) determine the characteristics of the tasks that are associated with cumulative trauma, and (3) establish effective modifications to the workplace design, work methods, tools and equipment that reduce the risk of work-related cumulative trauma disorders. This interactive, graphical method of data collection, analysis and documentation provides a method for operational personnel to conduct valid job analysis and modification assessments of current and proposed equipment that are consistent with OSHA guidelines. The effort addressed both cumulative trauma to the wrist (e.g., carpal tunnel syndrome), as well as biomechanical stress to the arms, shoulders and back that is sometimes associated with storage and retrieval operations. There is a large potential for cost reductions that are associated with musculoskeletal disorders. These costs include workers' compensation, health insurance, and litigation, as well as absenteeism and turn-over rates. The prescriptive capability of the system, in addition to the descriptive component, provides valuable, effective assistance in achieving cost avoidance.

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I. INTRODUCTION

Cumulative Trauma Disorders (CTDs) of the upper extremities, such as tendinitis, tenosynovitis and carpal tunnel syndrome, have recently received a significant amount of attention from management of industry, as well as governmental agencies. There has been a large increase in the reported incidence of disorders in industrial operations over the past ten years. During this same ten year period, there has been a corresponding increase in the attention paid to this topic by the popular press. These musculoskeletal disorders are costing U.S. industry a large amount of money that is directly off of “the bottom line.” In 1992, “disorders associated with repeated trauma” accounted for 62% of the total occupational illnesses reported (U.S. Bureau of Labor Statistics, 1992). The costs that are most generally addressed are the direct expense of high worker's compensation insurance and the potential for OSHA fines. These costs, although high, are not the only costs associated with the characteristics of jobs that can lead to fatigue, discomfort and muscular skeletal disorders. Absenteeism and turn-over rates, as well as reductions in product quality and productivity, can also be important consequences that can have indirect costs that are much higher than the direct financial costs.

There are two general approaches to the issue of reducing the incidence of cumulative trauma disorders. The first approach is to reduce the potential for disorders by eliminating, to the extent possible, the task characteristics that can cause the disorders. If a disorder does occur, the second approach is to control the progression of a disorder to a more serious condition through early detection and effective medical management. The first, and preferred, approach involves the application of ergonomic principles to the design of workplaces, work methods, tools and equipment.

Manual packaging, storage and retrieval operations frequently involve the task characteristics that have been associated with the development of disorders of the upper extremities and lower back. When these “signal risk factors” are recognized, they can often be reduced or even eliminated with very little effort and no capital expense. By incorporating ergonomics into the original process design and installation, the costs of retrofitting the workplace are eliminated. The goal of this project is to provide operational plant personnel, who have had little or no training in ergonomics, with an analysis tool to both evaluate and improve current workstations and work

methods, as well as to avoid the hazards of poorly designed tools and equipment, prior to their purchase and installation.

The vast majority of the modifications in industry that have the potential to reduce or eliminate work related musculoskeletal disorders are not difficult to recognize or implement. Many of the solutions could be referred to as “uncommon sense.” It should seldom be necessary to employ a professional ergonomist since the personnel already in place often have both the skills and knowledge to properly design the systems if they have a means by which to identify the factors that can cause problems. The objective of this project is to develop, implement and validate an analysis tool that operational plant personnel can use to evaluate operational tasks and to suggest modifications that have the potential of significantly reducing or eliminating disorders, along with the costs to both the company and the individual.

The first phase of the project (1993-1994) addressed the area of manual packaging tasks. The term *packaging* was broadly defined in the present context to include boxing of items, casing (e.g., with dunnage), closing and securing cases, palletizing, etc. This phase of the project specifically addressed injuries to the wrist and hands that have traditionally been a large component of the costs in packaging tasks. The methodology developed during Phase I was then used as the basis for the continuation (Phase II) that addressed disorders associated with manual material handling in warehouses and manufacturing facilities (e.g., storage and retrieval operations).

Many approaches to CTD's have been directed primarily, or even solely, toward the human component in the system. The analysis tool described in this report provides an integrated approach to workplace design, work methods, tools, equipment and product characteristics that is necessary to achieve an optimally designed system. A very important aspect of this effort is that the analysis tool provided to the operational personnel be *prescriptive* rather than being only *descriptive*. Giving the plant personnel only a method of evaluating their jobs with a rating scale that indicates that a hazard exists is not sufficient. Guiding the individual to effective modifications that would eliminate the hazard is very important for a successful implementation of ergonomics. The computer-based analysis system developed during the project and described in this report provides the tools necessary for individuals with little or no direct training in ergonomics to evaluate jobs and to suggest modifications that can reduce the incidence and costs of work related musculoskeletal disorders.

2. REVIEW OF COMMON WORK-RELATED CUMULATIVE TRAUMA DISORDERS

Work-related cumulative trauma disorders are a group of musculoskeletal disorders involving injuries to the tendons, tendon sheaths, muscles, and nerves of the hands, wrists, elbows, shoulders, and lower extremities. These disorders are physical conditions that result from biomechanical stresses that occur over a period of time. Due to the temporal, cumulative aspect of the occurrence of these disorders, OSHA classifies them as illnesses rather than injuries on the occupational safety and health documentation (OSHA 200 logs). However, the term injury is commonly used in reference to these disorders which are caused or aggravated by a number of occupational activities known as *risk factors*. The result of the injury can be restricted movements, temporary or permanent tendon or nerve damage, and/or the inability of a person to perform his or her job. The symptoms of the disorders include pain, swelling, numbness and tingling. The most frequent work-related disorders include tendinitis, tenosynovitis, epicondylitis, De Quervain's disease, Raynaud's syndrome, rotator cuff tendinitis, thoracic outlet syndrome and carpal tunnel syndrome (Guidotti, 1992).

2.1 Tendinitis and Tenosynovitis

A tendon is made of tough, fibrous connective tissue in which muscle fibers end and muscles are attached to bones. A tendon may or may not be surrounded by a sheath. A sheath protects and lubricates tendons. Tendons of the wrist, shoulder, and hand are surrounded by tendon sheaths; however, tendons of the elbow and forearm are not. *Tenosynovitis* can occur when a tendon that is surrounded by a sheath becomes inflamed because of excessive or insufficient amounts of synovial fluid in the sheath. Stenosing tenosynovitis is caused by the narrowing of the tendon sheath and triggering movements of the digits which is known as *trigger finger*. *Tendinitis* occurs when a tendon becomes inflamed because the tendon has been stretched beyond its strength or when the tendon is stretched across the bone when the wrist is deviated.

2.2 Thoracic Outlet Syndrome

Thoracic Outlet Syndrome is a neurovascular condition which occurs when there is compression of the neurovascular components (nerves of the brachial plexus and the brachial artery and its branches) or compression between the muscles of the neck and shoulder. The result is

numbness and pain in the distal upper extremity. Most of the cases are attributed to poor muscle condition. The syndrome is a result of reaching above shoulder level or carrying heavy loads at the side of the body. Overhead work causes the muscles of the shoulder region to become tight or compressed (Parker, 1992).

2.3 Rotator Cuff Tendinitis

The rotator cuff consists of four tendons that fuse over the joint in the shoulder. The rotator tendons rotate the arm inward and outward, as well as move the arm away from the side of the body. Rotator cuff tendinitis is a common shoulder tendon disorder which occurs when the arm tendons push against the bony structure in the shoulder, the acromion. Pain occurs when the tendon becomes inflamed. The condition occurs in tasks that require the shoulder to be abducted (arm is away from the center of the body) and the elbow is extended.

2.4 Epicondylitis

Epicondylitis is a form of tendinitis that occurs when the tendons from the elbow tear or degenerate. These tears are a result of repeated mechanical overload. There are two forms of epicondylitis: “tennis elbow” (medial) and “golfer’s elbow” (lateral). Both result from forceful forearm rotation with a bent wrist (Guidotti, 1992) or repeated gripping, twisting, and wrist extension or flexion against resistance (Thompson, 1990). Sinclair [1965] studied the possible causes of tennis elbow. He found that almost 50% of the subjects that had tennis elbow symptoms worked on jobs involving gripping tools with contractions of the extensor muscles or forearm rotation.

2.5 De Quervain’s Disease

This disorder is a form of tenosynovitis which occurs when the extensor tendons of the thumb become inflamed due to thumb movement to the extreme of its range of motion.. According to Guidotti (1992) this disorder tends to occur in occupations which use hand tools that require deviation of the wrist either toward the thumb (radial deviation) or toward the little finger (ulnar deviation).

2.6 Carpal Tunnel Syndrome

Carpal tunnel syndrome (CTS) is the most common nerve entrapment disorder which occurs when the median nerve is compressed between the carpal ligament and structures in the narrow carpal canal. Figure 1 illustrates the basic configuration of the wrist and the “carpal tunnel” that lies between the carpal bones and the transverse ligament. Within this area are the median nerve and the flexor tendons that connect the fingers with the muscles that provide grip strength. Compression of the median nerve causes tingling, pain and numbness to the hands and fingers, and can cause loss of feeling and loss of grip. CTS is usually a result of forceful hand movements (Guidotti, 1992) or repeated grasping, pinching and gripping (Thompson, 1990).

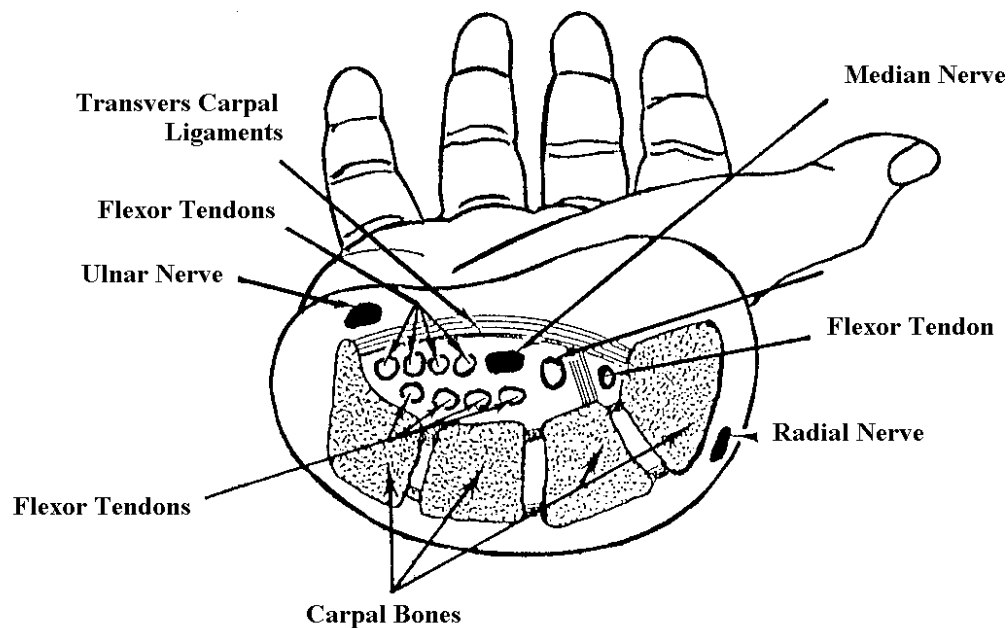


Figure 1. Diagram of the Carpal Tunnel

2.7 Raynaud's Syndrome

This disorder is associated with occupational tasks which require the handling of vibration tools and working in cold temperatures (Lahey, 1984). Vibration delivered to the hand and arm by pneumatic tools causes injury to the small blood vessels in the hand resulting in a lack of circulation. This lack of circulation results in whiteness of the fingers.

3. CAUSES OF CUMULATIVE TRAUMA DISORDERS

The causes of cumulative trauma disorders are still not fully understood. The factors can be broken down into categories which include : 1) biomechanical risk factors which are occupational or “work-related”, and 2) personal risk factors which include medical, physical and psychosocial factors.

3.1 Work-related Cumulative Trauma Disorder Risk Factors

Extensive research has been conducted on the work-related risk factors that are associated with musculoskeletal disorders. Several occupational factors which involve biomechanical stress on the job have been found to be associated with these disorders. These biomechanical stressors are referred to as occupational *risk factors*. A risk factor is defined as any attribute, experience or exposure that increases the probability of a disorder. Researchers have found that the following risk factors can contribute to musculoskeletal disorders: 1) awkward postures, 2) wrist deviations, 3) forceful exertions, 4) pinch grips, 5) cold, 6) vibration, 7) high grip forces, 8) direct mechanical impact, 9) wrist accelerations, and 10) repetitive motions. One of the research voids in this area is defining individual exposure levels that will lead to injury. Risk factors are not sufficient to cause disorders because jobs with known risk factors may or may not result in a particular individual developing a disorder. However, the risk factors will increase the probability of an injury developing. Although these are considered to be the work-related risk factors, there are no previous studies that have been able to determine the dose-response level and only a few studies that have estimated the population “attributable risk” (the proportion of persons with the disease who have the exposure or condition, adjusted for the prevalence of the exposure or condition in the population from which the patients originate) Stevens, Beard, O’Fallon, and Kurland [1992].

3.1.1 Awkward Posture

Before reviewing the literature that has been conducted on awkward postures, it is necessary to define some terminology that will be used.

Shoulder Abduction. The side-ways movement of the upper arm away from the center of the body.

Shoulder Adduction. The movement of the upper arm toward or across the center of the body.

Shoulder Flexion. The forward movement of the upper arm away from the center of the body.

Shoulder Extension. The backward movement of the upper arm (reaching behind the back).

Forearm Pronation. Rotating the forearm so that the palm is down.

Forearm Supination. Rotating the forearm so that the palm is up.

Radial Wrist Deviation. Bending the hand at the wrist in the direction of the thumb.

Ulnar Wrist Deviation. Bending the hand at the wrist in the direction of the little finger.

Wrist Flexion. Bending the hand toward the palm at the wrist.

Wrist Extension. Bending the hand backward at the wrist (dorsiflexion).

Awkward postures result in fatigue and discomfort and are usually a result of poor work station design, layout, or poor work methods that require excessive horizontal or vertical reach distances. Examples of awkward postures include shoulder elevation, awkward elbow postures (elbow above mid-torso), deviated wrist postures (flexion, extension with force, radial deviation and ulnar deviation), and pinch grips according to Sommerich, McGlothlin, and Marras [1993]. According to Tichauer [1966], tasks, such as tightening screws, are particularly harmful because the forearm is extended and turned through supination (palms-up) at the same time. In a study of 154 workers, the number of complaints of pain in the extensors of the forearm increased as the included angle between the forearm and upper arm increased. The most comfortable posture is when the arm is flexed so that the included angle between the forearm and the upper arm is 90 degrees. Armstrong and Chaffin [1979] studied two matched female populations, one with known history of carpal tunnel syndrome and one without. Both groups were employed at the same facility. The work methods of both groups were analyzed with respect to hand and wrist positions and hand force. They found that the diseased group tended to use a wrist position deviated from neutral more frequently than the non-diseased group. Furthermore, the diseased group exerted more force than the non-diseased group. Fernandez, Dahalan, and Halpern [1991] performed a study to

determine the effect of wrist posture (neutral, 1/2 of maximum extension, 1/2 of maximum flexion, maximum extension, and maximum flexion) on seven pinch grip styles (five pulp pinches, a lateral and a chuck pinch). The pulp pinches were defined by the finger that was used with the thumb to pinch. They found that as the wrist deviated from the neutral position, the pinch strength decreased by up to 34 percent for the maximum flexion using the ring finger and thumb. DeCaro, Feuerstein, and Hurwitz [1992] performed a study with educational interpreters and found that the more the hand and wrist deviated from the neutral position, the more the subjects experienced pain and fatigue. Harber, Blosswick, Beck, Pena, Baker, and Lee [1993] compared 50 supermarket checkers' motions and symptoms from questionnaires. They found relationships between wrist flexion and extension and carpal tunnel syndrome symptoms. They also found that forearm pronation showed a relationship with hand, wrist, and lower arm symptoms. Loslever and Ranaivosoa [1993] investigated both biomechanical and epidemiological data on seventeen high risk jobs. These high risk jobs were investigated by the request of the National Institute of Research and Safety because of repeated absences of workers and time off for hand surgery. They found the prevalence of carpal tunnel syndrome highly correlated with the frequency of flexion and the use of high forces. They also found that high or low flexions were a greater risk than high or low extensions. These studies indicate that having the wrist in an awkward posture is definitely a contributing factor to the incidence of CTDs.

3.1.2 Forceful Exertions

Forceful exertions such as using knives and other tools have been associated with CTDs according to Keyserling, Armstrong, and Punnet [1991]. These forceful exertions can cause inflammation of joints, muscles, and tendons. Poorly balanced tools and poorly maintained tools (e.g., dull knives or scissors) can increase the force required by an operator. Gloves can also increase the muscular effort required to perform a gripping task because they can reduce tactile feedback, as well as reduce the friction between the hand and the object being grasped. According to Welch [1972], the use of excessive force was the cause of tenosynovitis in 30% of 500 cases studied. Kim and Fernandez [1993] conducted a study for a simulated drilling task at different applied forces and angles of wrist flexion. They found that the maximum acceptable frequency for gripping was significantly reduced as the required drilling force and the angle of wrist flexion

increased. Therefore, they concluded that the task frequency for a drilling task should be lowered as force and wrist flexion angle increase. Vanderpool, Friis, Smith, and Harris [1993] performed a study with cardiac sonographers. A questionnaire was developed to obtain possible causes of musculoskeletal disorders. Although the response rate was low, they found that high-pressure hand grip correlated significantly with carpal tunnel syndrome symptom.

3.1.3 Cold Temperatures

Extreme cold is not, by itself, considered to be a risk factor. However, working in cold temperatures and handling cold parts can reduce manual dexterity and tactile sensitivity. This creates the potential for muscle strains and sprains because of an increase of force required to perform a task and therefore have been found as a possible risk factor. Gloves can be used, however, they can also increase the force required to perform a task [Falkenburg and Shultz, 1993]. Schiefer, Kok, Lewis, and Meese [1984] studied the relationship between finger skin temperature and performance with four manual dexterity tasks. They found that cooling the finger skin temperature to 0-20 degrees Celsius affected strength and dexterity and therefore performance. If maximum strength decreases then a person is operating at a higher proportion of their maximum.

3.1.4 Vibration

Vibration is also reported to be a risk factor for CTDs. Vibration exposure results in gripping power tools, holding controls of a power machine, or percussion tools, such as hammers and chisels according to Armstrong [1992]. Armstrong, Fine, Radwin, and Silverstein [1987] claimed that vibration may actually cause a worker to use excessive force to hold the vibrating tool. Silverstein, Fine, and Armstrong [1987] performed a cross-sectional study that found a prevalence of carpal tunnel syndrome of 5.1 % for those workers performing jobs that required high forces repetitively. However, vibration was confounded in this study in that four out of the nine high force jobs involved vibration exposure. Brismar and Ekenvall [1992] performed a study using four groups of subjects: 1) vibration exposed workers, 2) unexposed workers, 3) carpal tunnel syndrome group, and 4) healthy volunteers. Motor and sensory nerve conduction velocities were measured in both hands. Nerve conduction velocity measures the speed at which the nerve impulses travel through the wrist. As the nerve is compressed, it takes longer for the impulse to travel through the carpal canal. The authors concluded that the symptoms of numbness and reduced perception in the hands of the

vibration exposed group were correlated with specific changes in the median nerve conduction similar to those of the carpal tunnel syndrome group. St. John, Tayyari, and Emanuel [1993] studied a trucking company's safety and health data (OSHA 200 logs), worker questionnaires and other data to obtain common characteristics on all of the carpal tunnel syndrome cases at the company. The data for jobs that had a high incidence of carpal tunnel syndrome was put into an information matrix that included personal factors and job-related factors. They found that excessive vibration was one of the common job characteristics. Cannon, Bernacki, and Walter [1981] performed a case study of the personal and environmental factors associated with the onset of carpal tunnel syndrome. Self-administered questionnaires and personal interviews were used to obtain information from both symptomatic and control subjects. They found that the use of vibrating tools (buffing, grinding, and other hand tools) was strongly associated with carpal tunnel syndrome. Taylor and Pelmeur [1975] also found a relationship between vibration and the development of carpal tunnel syndrome.

3.1.5 Direct Contact Stress

Localized contact stress is caused by physical contact between body tissue and an object or tool (e.g., resting the forearms on a sharp or hard work surface or using the hand like a hammer) according to Keyserling, Armstrong, and Punnet [1991]. Excessive gripping of sharp hand tools can also produce localized pressure on tendons and nerves, resulting in tenosynovitis. Tools with short handles can press on the median nerve and contribute to the development of carpal tunnel syndrome according to Tichauer [1966].

3.1.6 Repetition Rate

Repetition rate has been frequently cited as a risk factor associated with the development of occupational CTDs. Repetition rate is often easier to measure and quantify than the other risk factors. From the emphasis on repetition rate, the terms "repetitive strain injuries" and "repetitive strain motion disorders" have evolved and are often interchanged with cumulative trauma disorders. A job that requires excessive force with a deviated wrist, with or without a high repetition rate, will increase the probability of developing a disorder. Repetition increases the exposure level of a particular risk factor, thereby increasing the probability of developing the disorder. Repetition can be more accurately defined as a *quantifier*. For example, repetitive tasks that do not have biomechanical stresses can easily be done without injury. However, a task that exposes an

individual to biomechanical stress will have increased exposure that is directly proportional to the repetition rate. The increased exposure increases the “cumulativeness” of developing a disorder. Silverstein, Fine and Armstrong [1987] evaluated jobs that were characterized into four categories: 1) low force-low repetition, 2) high force-high repetition, 3) low force-high repetition, and 4) high force-low repetition. Silverstein concluded that high force-high repetition jobs were 15 times more likely to develop CTDs than those jobs with low force-low repetition. She also concluded that repetition was a stronger risk factor than force. However, force was a possible confounder because the high repetition groups included much higher force requirements although the results indicated repetition. Therefore, the development of CTDs could have been caused by the different force requirements. Hymovich and Lindholm [1966] performed a study in the electronics industry that evaluated jobs that were reported to have caused injuries to employees. The jobs performed by these employees were characterized by finger flexion, wrist motions at the extreme range of motion, and forearm rotation. However, Hymovich and Lindholm concluded that the injuries were attributed to the repetitive work performed. Hagberg, Morgenstern, and Kelsh [1992] reviewed epidemiological studies of carpal tunnel syndrome which were cross-sectional studies involving different occupational groups. They evaluated the consistency of job characteristics across the different studies. Repetition and forceful gripping were found to be common job characteristics; therefore, they concluded that repetition and forceful gripping are major risk factors for carpal tunnel syndrome in several types of work.

3.1.7 Velocity/Acceleration

Recently, some researchers have suggested that the acceleration and velocity of wrist movements can contribute to the development of CTDs. Schoenmarklin and Marris [1993] performed a study to determine which wrist motion variables were the best predictors of hand/wrist cumulative trauma disorders. Three dimensional wrist motions (position, angular velocity, and angular acceleration) were monitored in each plane of movement (radial/ulnar, flexion/extension, and pronation/supination). Twenty subjects in low-risk jobs and twenty in high-risk jobs (based on OSHA 200 logs and medical records) were studied. The high risk group had a median incidence rate of 18.4, while the low risk group had a zero incidence rate. Although very small sample sizes were used, they found that the velocity and acceleration variables significantly differentiated the low

and high-risk levels in all three planes. However, wrist position variables did not. Shealy and Latko [1992] used five subjects to study the effects of holding four different masses (9.5, 125, 250, and 500 grams) on the maximum velocities and accelerations for the wrist joint for flexion/extension and radial/ulnar deviation and forearm pronation/supination. They found that the effect of masses was not significant for forearm pronation/supination, but was for the wrist movements. They found that the velocity and acceleration was twice as great in the flexion/extension movement than in the ulnar/radial movement. According to Welch [1972], fast movements of the fingers and hands lead to tenosynovitis.

Awkward postures (e.g., pinch grips and deviated wrists), forceful exertions, cold, vibration, direct contact stress, repetition rate and wrist accelerations are the occupational characteristics that are considered to increase the probability of CTDs occurring. The research in this area is insufficient to predict jobs that will lead to injury; however, eliminating these risk factors or reducing the exposure to these risk factors can improve job performance and reduce their incidence. These risk factors are used in checklists and job analyses to reduce the number of injuries in industry.

3.2 Individual Characteristics Associated with Cumulative Trauma Disorders

There are large differences among individuals that relate to their basic skills and abilities, amount of training and experience, anatomy/physiology, and personal dispositions. Non-occupational factors often referred to as personal factors have been associated with CTDs. These non-occupational activities can be broken down into three groups: medical, physical and psychosocial. The medical factors include the development of a CTD from various conditions that predispose a person to CTDs such as acute trauma, arthritis, diabetes, gout, pregnancy, the use of oral contraceptives, age, gender, and menopause.

3.2.1 Medical Aspects

Stevens, Beard, O'Fallon, and Kurland [1992] studied subjects with carpal tunnel syndrome who were identified by a medical records-linkage system of the Mayo Clinic and the Rochester Epidemiology Program Project. The medical records of cases that were included in the study were reviewed for conditions that were present before the onset of carpal tunnel syndrome. Rheumatoid

arthritis, diabetes mellitus, and pregnancy were significantly more frequent in the CTS group than the general population. Yamaguchi, Lipscomb, and Soule [1965] found that 7.6% of carpal tunnel syndrome patients also suffered from rheumatoid arthritis. According to Phalen [1966] 16.6% of 379 carpal tunnel syndrome patients were also diabetics. Cannon, Bernacki, and Walter [1981] compared thirty workers with carpal tunnel syndrome with 90 control subjects. They found that 81.5 % of the subjects and 25.9% of the controls had a history of gynecological surgery.

3.2.2 Physical Aspects

Physical activities such as racket sports have also been associated with the development of tenosynovitis and other nerve entrapment disorders. Certain hobbies such as knitting, sewing, and playing musical instruments have also been found to be associated with the development of CTDs.

3.2.3 Psychosocial Aspects

The third group of individual factors, psychosocial, include those aspects of a worker's job that increase his/her stress while performing a job (for example: decision-making authority, task variety, and personal freedom). From the literature, it is not clear whether the psychosocial factors are a cause or a result of CTDs. Bernard, Sauter, Fine, Peterson, and Hales [1992] performed a study to identify important work organization and psychosocial risk factors for cumulative trauma disorders of the hand and wrist among keyboard operators. Subjects were randomly selected from four departments that performed different tasks. Each subject completed a self-administered questionnaire consisting of questions related to job satisfaction, job demands, worker isolation, and job security. In addition, demographics, work history, job tasks performed, and musculoskeletal discomfort information was obtained. The results showed that in the departments with a higher concentration of clerical and data entry VDT operators, psychosocial factors were important predictors of CTDs of the hands and wrists. Lim and Carayon [1993] studied 125 office workers through self-administered questionnaires and ergonomic evaluations. They found that work pressure and work pace were significantly related to awkward postures. Work pressure and work control were related to fatigue which was found to be significantly related to CTDs.

4. METHODS OF DETERMINING HIGH-RISK JOBS (SURVEILLANCE)

There are three approaches that can be taken to determine the risk of cumulative trauma disorders for a particular job: reviewing available health and safety records (passive surveillance), surveying workers (active surveillance), and analyzing jobs.

4.1 Passive Surveillance Methods

For passive surveillance, records are reviewed to identify past cases of CTDs. These records include: plant medical records, OSHA 200 logs, worker compensation records, safety and accident reports, and payroll records. The OSHA 200 log is required for most employers and must be retained for up to 5 years. The form records injuries and illnesses that have occurred during the year. Occupational illnesses are defined as "any abnormal condition or disorder, not classified as an injury, caused by exposure to environmental factors associated with employment". One of the categories listed under occupational illnesses is "disorders associated with repeated motion, vibration, or pressure". One of the problems that has been found using this log is that companies are not consistent with their descriptions of job titles under this category. Furthermore, the job that the employee was working on at the time of the occurrence of the injury may or may not be the employee's normal job. Therefore, after analyzing the data on the 200 log, the analyst might identify a job that might not have been the actual job that caused the problem.

In some companies it may be feasible to obtain information on CTDs by reviewing employee medical records. Information that may be included from these forms are the date of the visit, the occupational title at the time of the visit, the department or locations where the employee worked, and a brief description of the injury or illness. Numeric codes, such as the International Classification of Disease (ICD) system, are used.

Workers' compensation files can be used to obtain some of the costs resulting from CTDs and identifying departments and job titles where the workers' compensation costs are high. Payroll records can be used to obtain information on the number of hours worked, however, they do not tell how much time was spent on each job. More recent approaches (e.g., OSHA) include reviewing transfer requests and absenteeism in order to get an idea of problem jobs.

The information required when reviewing records is the total number of CTD cases reported, the date each case was reported, the department (or the specific job) of the injured worker, and the

number of workers on the same job or in the same department. This information is used to calculate the incidence rate or the number of CTDs per department or job for a specific time period. To compare the various jobs or departments, the percentage of workers who had CTDs must be calculated.

4.2 Active Surveillance Methods

The second approach is to conduct a survey of the workers themselves to obtain information as to the location and severity of their discomfort. By performing a survey continuously, companies can detect if they have a CTD problem early when the symptoms first develop before there is permanent and unrepairable damage done to the person. The survey should include the department and job title of the individual. Questions should include information on discomfort by body part, as well as what job activities cause the discomfort to become worse. This information is used to identify jobs that are biomechanically stressful to individuals.

Furthermore, companies sometimes prescreen potential employees for symptoms of CTDs before they are hired. In doing this, they decrease their probability of hiring a person who is not physically capable of performing the job or a person who may already have symptoms associated with CTDs.

Unfortunately there is not a method to determine whether any given individual will develop a CTD on a job that has the risk factors associated with CTDs. Prescreening tests (e.g., Tinel's and Phalen's) are often used to indicate signs of pain when the median nerve is compressed. Research has found that these tests are unreliable because they indicate a problem when there is none (high false alarm rate) or fail to indicate a problem when there is a problem (high miss rate). Furthermore, using combinations of these tests in which a sign on any of the tests indicates a problem can be too sensitive. These prescreening tests are very subjective in that individuals interpret discomfort differently, or some may not report symptoms because of job security.

4.3 Job Site Analysis

A job site analysis evaluates jobs with respect to work methods, work layout, design of equipment and tools to identify the work-related risk factors of CTDs. Furthermore, the job analysis is often used as a tool to evaluate improvements that have been made in work methods, work layout, or redesign of equipment and tools. The job analysis includes a method of measuring a worker's exposure to biomechanical risk factors. There are two types of job analysis approaches: *narrative (work-methods analysis)* and the *checklist*.

4.3.1 Narrative Approach

The narrative approach evaluates the entire work content of a job. The job analyzed must be broken down into a set of tasks. The tasks are then broken down into elements which are the fundamental elements of motion. The time duration of each task is needed to determine the exposure to particular risk factors.

Keyserling, Armstrong, and Punnett [1991] developed a structured job analysis procedure to assist safety professionals in the recognition and evaluation of exposures to risk factors. The method consisted of: basic job documentation, identification and evaluation of exposure to risk factors, and controlling exposures to risk factors. Basic job documentation included the following: identifying the job (job title), describing the worker (name, weight, height, age, hand dominance, time on job being analyzed, experience on similar jobs, and history of musculoskeletal disorders), work objective (purpose of job), work schedule, work pace, job rotation plan, work station layout, tools and equipment used, parts and materials handled, and work methods. Identification and evaluation of risk factors included examining each work element to determine if it was associated with any risk factors. The method suggested that the last phase was to control exposures to risk factors by developing control measures for eliminating or reducing the risk factors to acceptable levels.

Drury and Wick [1984] developed a program in the shoe industry to reduce cost due to cumulative trauma injuries. The method developed included a task analysis system, a system that measured performance and postural stress, and analysis of data collected to implement changes. The task analysis was developed to specifically give the posture, force and frequency of a task that could lead to injury. Jobs were video taped and broken down into task steps (elements). These task steps were recorded on a task analysis form which consisted of two pages. The first page

concentrated on the upper extremities; and the second page concentrated on the overall body posture. After the forms were completed two calculations were made. The frequency of combinations such as radial deviation and pinch grip were calculated. Each task element was counted as damaging if it required a grip with deviation, flexion, or extension of the wrist. The compressive forces on the spinal discs were also calculated from the body angles and the weight moved. Productivity was measured using weekly earnings, and postural stress was measured using a discomfort survey.

Drury [1987] developed a job analysis method which was broken down into two sections: task description and task analysis. The task description section involved analyzing jobs by using video recordings of the worker from five angles: 1) front three-quarter view above operator's head, 2) direct left-side view, 3) direct right-side view, 4) direct front view, and 5) direct rear view. From the video tape, a sub-task (i.e., task element) breakdown was made and body angles, posture, grip, forces, vibration, shock, and lighting for each sub-task were recorded. The frequency of each task was estimated by taking the task working minutes over the day and dividing by the cycle time. The task analysis included breaking down the angles at each joint according to how close to the extreme value they came. The joint range-of-motion averages for the US population were taken from the Bioastronautics Data Book and divided into zones: 1) no exposure (neutral to +/- 10% of range), 2) low exposure (+/- 10% to +/- 25 % of range), 3) moderate exposure (+/- 25 % to +/- 50% of range), and 4) severe exposure (more than +/- 50 % of range). From the task description each angle was replaced with a corresponding zone number. Drury used Daily Damaging Wrist Motions (DDWM) as a metric of exposure where a damaging wrist motion was defined as the frequency of any combination of a grip or external force with any non-zero wrist exposure.

Keyserling [1986] developed a computer-aided system to evaluate postural stress. A menu of standard postures of the trunk and shoulders was developed: For a standing worker, the trunk was classified as : 1) bent forward, 2) bent backward, 3) bent sideways, and 4) twist greater than 20 degrees from vertical. Both the left and right shoulders were classified as: 1) neutral (angle from body less than 45 degrees), 2) mild flexion/abduction (angle from side of body between 45 and 90 degrees), and 3) severe flexion and abduction (angle from side of body greater than 90 degrees). Jobs were video taped and tasks were broken down into basic work motions.

A personal computer was used to assist the analyst in collecting and recording time and posture data. The data was entered into the computer while the analyst watched the video recording,

and the computer's internal clock measured the time. Each of these standard postures was assigned a key. When the posture changed, the analyst hit the key corresponding to the new posture. The value of the new posture and the time of the posture change was recorded on disk. Following the evaluation of each shoulder and the trunk, the computer analyzed and summarized the collected data and printed the results. The computer generated a posture profile for each body joint, total time spent in each standard posture during the work cycle, minimum and maximum times spent in each standard posture, and the number of times the posture was entered. The system also generated a graph which simultaneously shows the task analysis and postural activity of the trunk and both shoulders on a common time scale.

Armstrong, Chaffin, and Foulke [1979] developed a method for documenting hand positions and forces during manual work. Hand positions were documented by filming the hands of the worker with a 8mm motion camera at four frames per second. The film was then reviewed frame by frame. The positions from each frame were noted, plotted, and summarized. Hand forces were estimated using electromyography (EMG) signals. Subjects pinched the handles of a fixture with the desired hand position and the corresponding EMG level was recorded.

Armstrong, Radwin, Hansen and Kennedy [1986] further developed a methodology for analysis, identification, and elimination of cumulative trauma disorders. The method consisted of two steps: 1) a work-methods analysis to determine job content, and 2) a systematic analysis of risk factors. The work-methods analysis involved fundamental industrial engineering work-methods procedures. First, the tasks were identified. Second, the tasks were described as a series of elements or steps. Elements were defined as the fundamental movements to perform a job. After the work content was done each element was evaluated for recognized risk factors which were as follows: 1) repetitive or forceful sustained exertions, 2) shoulder posture (elbow above mid-torso reaching down and behind), forearm (inward or outward rotation with a bent wrist), wrist (palmar flexion, full extension, ulnar or radial deviation), hand (pinching), 3) mechanical stress concentrations, 4) vibration, 5) cold, and 6) the use of gloves. If any risk factor was identified it was recommended that modifications be made. Armstrong et al. [1986] provided some methods of engineering controls that could eliminate particular risk factors and showed how improvements could be made graphically using drawing-board manikins.

4.3.2 Checklist Approach

The checklist is usually customized to include a set of biomechanical risk factors. For each risk factor, specific job attributes are included to focus the effort. A point system is usually used with the checklist approach. The checklist is quick and simple to use; however, the results are not accurate. Furthermore, the checklist may restrict observations if the situation is not described by the risk factors on the list.

An example of a checklist approach is the one developed by the Occupational Safety and Health Administration (OSHA) during the development of a proposed ergonomic standard. The checklist includes a set of risk factors: shoulder position (flexion 45 to 90 degrees, flexion greater than 90 degrees), forearm position (pronation and supination), wrist position (flexion, extension, ulnar, and radial deviation), hand interface (localized mechanical stress, pinch and power grip), and neck position. Within each category of risk factors, characteristics of the velocity (static, slow, moderate, and rapid), motions per hour, total task duration per day, and force are documented and points are given according to the extent to which the risk factor is considered to be harmful. The points are totaled within each category and multiplied by a work organization factor which includes job characteristics such as whether the employees are monitored, the work pace, amount of overtime, the ability to make decisions, and whether it is monotonous work). A total score is then given within each category and compared to a trigger value. If the total score is greater than the trigger value then an in-depth analysis must be made of the job. The checklist is performed at the task level. The individual element characteristics are not documented. Therefore, when a problem has been identified, the analyst is unable to pin-point the element in which it occurred. The checklist limits the analyst to only those situations that can be documented using the risk factors selected for the checklist. This may result in analyzing jobs incorrectly. Furthermore, this approach does not allow the multiplicative effect of combining risk factors, such as force with a deviated wrist and forearm rotation of an extended forearm. Both of these conditions are associated with the development of CTDs as previously discussed in this paper.

Armstrong and Lifshitz [1986] developed a checklist where the analyst scored the job by checking only items that applied to that job. The checklist included physical stress, force, posture, work station hardware, repetitiveness, and tool design. The final score was calculated as the fraction or percentage of the responses scored by a yes. Subscores for each category of risk factors were calculated to indicate where the attention should be focused to control the problem.

Keyserling, Stetson, Silverstein, and Brower [1993] also developed a checklist for determining the presence of risk factors. The risk factors included environment, posture, metabolic rate, manual lifting, and upper extremities. Within each category, questions were asked that characterized the job. Each question was designed to evaluate the presence and/or duration of the risk factors. Some questions required simple 'yes' or 'no' responses. Others were designed to estimate the duration of exposure using *never*, *some*, or *greater than one-third* (stress present for more than one-third of the work cycle or work day) responses. In addition, each response resulted in a stress rating as follows: 1) *zero* (exposures were insignificant), 2) *check* (moderate exposures were present), and 3) *star* (substantial exposures were present). The number of elements in which the risk factor occurred was also recorded. An overall score representing the ergonomic stresses was calculated by summing the total number of checks and stars.

The checklist was used by plant personnel at four different facilities to assess the presence of CTD risk factors. The results were compared to results of ergonomic analyses performed by experts. The checklist agreed with the expert results for 34 out of 51 jobs.

4.4 Summary of the Job Site Analysis Methods

Both the narrative and the checklist methods of job site analysis have disadvantages. The checklist is relatively quick and easily performed; however, it is generally quite incomplete, does not handle the temporal aspects of the task, and requires some training on the administration of the checklist and the interpretation of the results. Most importantly, it is descriptive in that it indicates when a problem exists rather than being prescriptive in terms of providing recommended modifications to reduce the risks. The narrative method is much more complete and the analyst generally includes recommended modifications, as well as a description of the risks; however, this method requires a significant amount of training and experience in ergonomics which results in the cost being relatively high. The computer-based system developed during the reported effort provides an easily understood method of entering the analysis information, addresses the more complex temporal assessment of the risks across tasks and task elements, and provides recommendations that can be used to reduce the risks and, subsequently, the potential for work-related musculoskeletal disorders.

5. INSTALLATION OF THE SOFTWARE

To install and use the software, the following basic computer system characteristics are required: Microsoft Windows 3.0 or later operating in standard or enhanced mode, a 486 or higher microprocessor, a Windows compatible (VGA) monitor, four megabyte of random access memory (RAM), and a printer capable of printing bitmap (.bmp) images.

To install the software, the Installation Disk 1 (of two) is placed in drive "a." From the windows Program Manager, choose **File** and then **Run** from the subsequent menus. In the window, type a:\setup.exe and choose the **Run** button. The installation is menu driven from that point. When the software is installed for the first time, the **Program Registration** screen appears. The purpose of this screen is to document the name of the organization using the program (e.g. the company name) and the type of measurement units used by the organization (e.g. metric or U.S. customary). This registration screen only appears when the program is first installed. Therefore, once the measurement units have been selected, they cannot be changed without re-installing the program.

To avoid losing information due to a computer hardware failure, the program and analysis information should be periodically backed-up on a floppy disk. This procedure can be easily done with Microsoft Backup or any other file compression program. The backup should include the entire contents of the directory C:\EJA. It is recommended that a monthly backup cycle be used.

In the event that the software must be moved to another computer or copied to another computer, it is important that the entire contents of the C:\EJA directory are copied to the new computer. This copy can be done through computer links, network file exchanges, or by using the backup floppy disks. However, if the program is re-installed with the original program disks on a new computer, any analysis information entered into the program on the current computer will not exist on the new computer. The install program only installs the executable file, therefore it is important the entire directory of C:\EJA be copied from the current computer to the new computer.

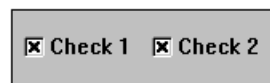
6. GENERAL ANALYSIS INFORMATION

The procedure for evaluating a job is to break down the job into tasks and, subsequently, break down each task into individual task elements. The task element level represents the detailed postures and motions. The completed job analysis addresses the postures and motions across all of the task elements and tasks that make up a particular job. This is accomplished by going to several different screens for each of these levels. The sections within which the user describes the job is referred to as the input screens. After the information is entered in the input screens, the data are given on two summary screens so that the analyst can confirm the correctness of the data entry. Following the summary screens, the results and recommendation screens are presented.

There are different ways of entering the information. *Option buttons* are used when a question has only one appropriate response. The user selects the appropriate response by clicking the left mouse button in the circle in front of the response, or using the arrow keys to move the cursor to the appropriate response position. If the user chooses the wrong response by mistake, another response can be chosen by clicking on the correct circle. *Check boxes* are used when multiple responses are appropriate simultaneously. The analyst selects the appropriate responses by clicking the left mouse button on the box in front of the inputs. If the user chooses the wrong response by mistake, the box can be deselected by clicking the left mouse button on the box again. Information, such as the operator's name, is typed in an input box. *Buttons* are used to change the screens and are activated by clicking the left mouse button or by depressing the *Alt* key and the underlined letter simultaneously. The *tab* key or *enter* moves the cursor between *input boxes*, and the arrow keys can be used to move between options in option buttons and check boxes.



Option Button




Check Box



Input Box



Buttons

The mouse buttons are used for different functions. Clicking the left mouse button selects an *option button, check box, or button*. Help screens are activated by moving the cursor to the title bar and clicking the left mouse button. The symbol  , indicates that there is a help screen for that particular selection.

All screens include three basic controls. To progress to the next screen the (➔) control is used. The (➠) control is used to go back to the previous screen. An alternative method of advancing to the next screen is to use the *alt* key in combination with the plus (+) from the keypad. Similarly, the *alt* key in combination with the minus (-) from the keypad will take the analyst to the previous screen. To leave the system, the *Exit Program* button is used. With this selection, a message screen is activated that prompts the user to confirm the choice to exit. A fourth control, which is common only to the series of summary and recommendation screens, is the *Print Page* command. This control captures the screen image and prints it according to the Windows setup.

The information entered on the screens is saved following the choice of (➔), (➠), or *Exit Program* controls. An exception occurs when an error is made in data entry (i.e., infeasible values). If an error occurs, the user will have the choice to fix the error or ignore the error and continue with the command which will not save any information on that screen.

The titles of the screens are written across the top of the forms. At the job level of the analysis, the title includes the job name. For the task level information, current task name, along with the 'number' (in sequence) of the current task and the total number of tasks involved is displayed. The titles of the screens at the element level include the current task and element names, as well as the 'number' (in sequence) of the current task, the total number of tasks involved, the 'number' of the current element, and the total number of elements listed in that particular task (e.g., Task 1 of 3: Palletizing - Element 1 of 4: Lift Box).

The maximum number of tasks allowed per job is twenty (20), and the maximum number of task elements per task is also twenty (20). The storage space is dynamically allocated so that the size of the file is dependent upon the number of tasks and task elements.

7. ENTERING JOB CHARACTERISTICS DATA

The first part of the analysis is to enter the physical, physiological and psychological characteristics of the job. Each job (e.g., packing) is broken down into the tasks that make up that job (e.g., make boxes, fill boxes, palletize) and subsequently the task elements within that task (e.g., get box, place in case, etc.). When there are changes to the products or processes, it is often the case that relatively small modifications to individual task elements are all that is necessary to maintain job documentation that is current. This documentation is not only useful for analyzing the job to reduce the risk of musculoskeletal disorders, it is also an applicable method of documenting the job and considering “reasonable accommodations” consistent with the requirements of the Americans with Disabilities Act (ADA).

The first screen that is encountered by the analyst is titled the **Department / Job Manager** (Figure 2) which lists the departments in the facility and the jobs within each department. It is important that the terminology for different jobs be consistent among different functions. That is, often the worker refers to the task by one name, the supervisors use another, and the official name in the personnel department is even different. Therefore, it is often desirable to insert the full list of departments and jobs prior to conducting the analyses. As indicated by the buttons, it is possible to add, delete or change the name of the jobs and departments. It is necessary to delete all jobs within a department before the department can be deleted. Sometimes there is a new job that is very similar to one that has previously been analyzed. The job name can be clicked and “drug” to another department. To copy the job to the same department under a different name, the job name can be drug to a department called Copy. The renamed job can then be drug back to the original department for editing. In this way, only the differences between the jobs need to be inserted during the analysis, saving a significant amount of time and effort. This frequently occurs when different products involve very similar activities, although there are slight variations. Throughout the program, help screens are available. The help symbol indicates that there is a **Help** screen associated with that particular selection (Figure 3).

The analyst can select a job to analyze or can go directly to the summary, results and recommendations for a previously analyzed job using the *View Summary* command. After activating the correct job from the list, the analyst uses *Analyze Job* control to progress to the

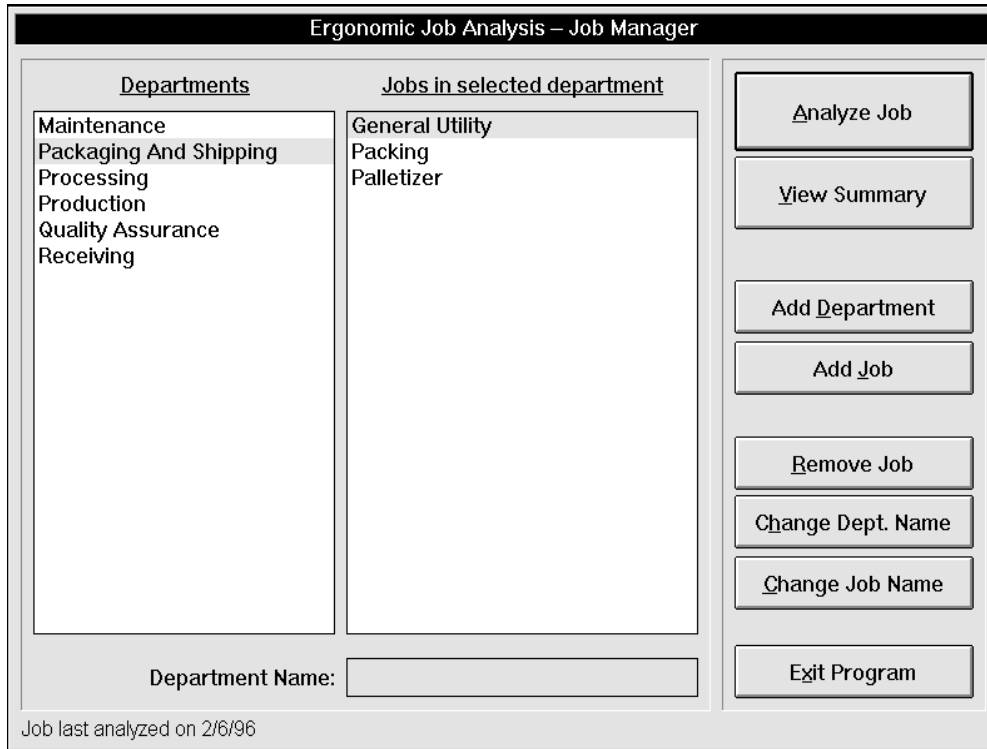


Figure 2. Department / Job Manager Screen.

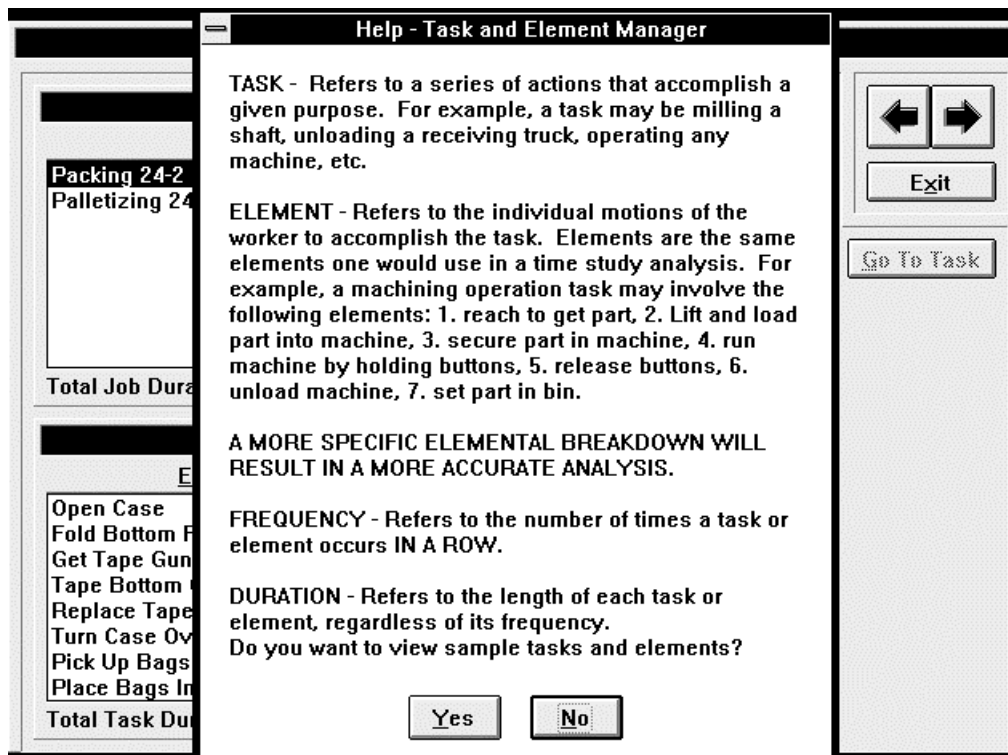


Figure 3. Example of Help Screen.

next screen which is titled **Analyst and Operator** (Figure 4). This screen is to document the name of the analyst and the operator, as well as the date of the evaluation. The amount of time that the operator has performed this particular job is documented to indicate the level of experience of the operator. For each of these options, there is a default value that is most frequently selected (e.g., > 1 year). This significantly reduces both the amount of information and time required to enter the data during the analysis procedure. One disadvantage of including default values is that the analyst must consciously ensure that they consider the appropriateness of the default value, rather than simply accepting them. Obviously, if the information entered during the analysis is not representative of the job being performed, the results will be erroneous.

Figure 4. Analyst / Operator Screen

The height, weight and gender of the operator are important in evaluating the reach distances, as well as the manual material handling portion of the analysis. At the bottom of this screen, the size of the individual, relative to the U.S. working population for males and females is provided. For example, if the operator being analyzed is very tall (e.g., 95th percentile), then the analysis may not be representative of the majority of the workers that perform that task. To the extent possible, a representative operator should be chosen. The graphical representations used later in the analysis (e.g., reach distance grid) are adapted to the particular operator's size as indicated on this screen.

After the information is placed in this screen, the analyst can advance the analysis by activating the right arrow (→). Alternatively, the combination of the *Alt* key and the plus (+) from the number pad can be used to advance to the next screen. At each of the screens, the analyst can go back one screen by activating the left arrow (←) or leave the program by activating the Exit button. If the program is exited, the information entered on previous screens will be stored. However, the information on the current screen will be lost. When the analyst chooses to exit the program, a message is displayed and a second action is required to exit.

The next screen, titled **Work Schedule** (Figure 5), includes a description of the job, as well as the shift time and break schedule. To determine the occupational exposure time, it is necessary to document the effective work time. The work time is the length of the shift, minus the scheduled breaks. If the schedule varies from day to day, a representative set of breaks should be entered. If the operator regularly rotates to one or more different jobs, the lower part of this screen is presented. The jobs can be selected from the list if they have previously been entered. If a job in the rotation has not been included in the Department / Job Manager, the operator can choose the button, *Add Future Job Rotation*, that will allow this inclusion.

Job 'General Utility' – Work Schedule

Job Description:

Responsible for a variety of tasks as needed, mostly packaging and palletizing

Total Normal Shift Length:
(Including lunch and breaks)

Break Schedule (Including Lunch)			
Break	Minutes	Break	Minutes
First	15	Fourth	
Second	15	Fifth	
Third		Sixth	

Job Rotation?

Yes
 No

Job Rotation Schedule

Job Name	Minutes
Replace Spindle	240

Available Rotation Jobs

Dept: Maintenance...
 ...Machine Testing
 ...Move Machines
 ...Replace Spindle
 ...Change Bits
 ...Check Machine Fluids

Figure 5. Work Schedule Screen.

The *Move* ↑ and *Move* ↓ buttons are used to change the sequence of jobs in the rotation schedule. Jobs can also be removed from the rotation list if they are no longer included in the rotation schedule. After the rotation list and times are entered, the *Ok* button is selected to record the sequence.

The **Tools** screen (Figure 6) provides the opportunity of documenting the handle size, tool weight and torque requirement applicable to various tools used when performing this job. Other important characteristics (e.g., vibration, balancer, etc.) as well as the fingers used to activate the tool (e.g. trigger on powered tool or grips on scissors), are also documented at this screen. This screen completes the part of the analysis that relates to the entire job. The next set of screens address the characteristics of the various tasks and task elements that make up the job.

Job 'General Utility' - Tools	
All Tools Used on this Job	Tool Specifications
Tape Gun	Handle Diameter: 2 in.
	Weight: 1 lbs.
	Torque: 0 lb.ft.
Tool Characteristics	Activation Fingers
<input type="checkbox"/> Power Operated	<input type="checkbox"/> Thumb
<input type="checkbox"/> Exhaust Air	<input type="checkbox"/> Index
<input type="checkbox"/> Vibration	<input type="checkbox"/> Second
<input type="checkbox"/> Trigger Used	<input type="checkbox"/> Third
<input type="checkbox"/> Balancer Used	<input type="checkbox"/> Fourth

Figure 6. Tools Screen

The **Task / Element Manager** screen (Figure 7) is used to document the duration and frequency of each of the tasks in the job and, subsequently, the task elements within each task. The frequency and duration of the task elements within a task determine the total duration of the task, itself. In the center of this screen, the total work time, minus job rotation and break times, is indicated as well as the total time derived from the duration and frequency of the tasks and task elements previously entered. If the analyst attempts to advance to the next screen with the total

task and task element times more than 15 percent higher or lower than the total job duration, the

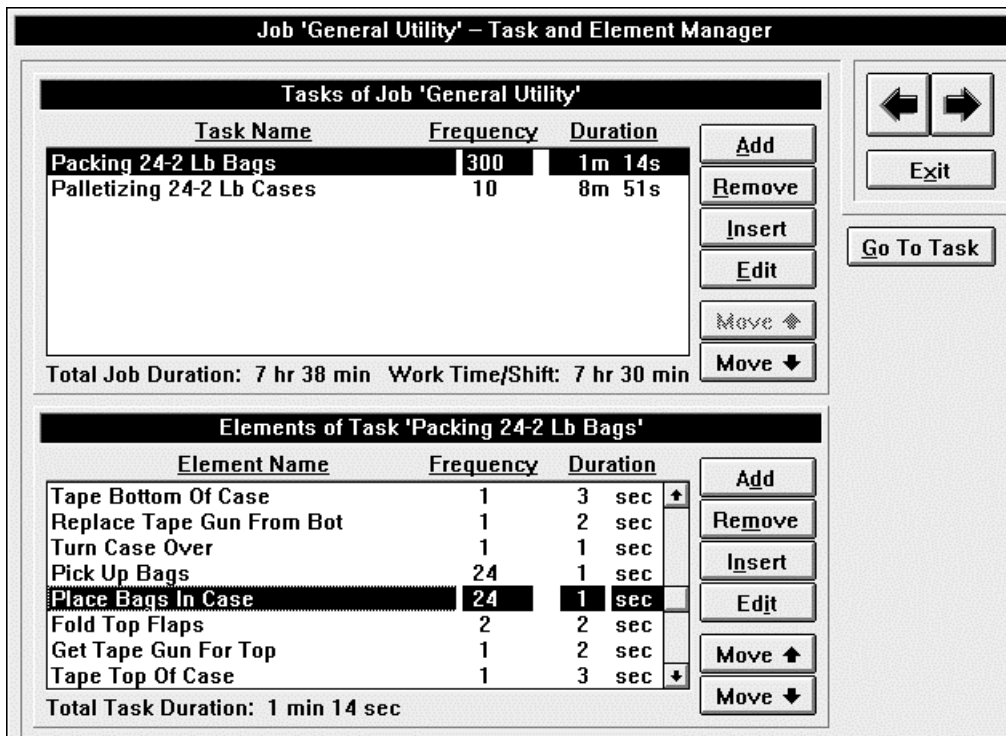




Figure 7. Task Element Manager.

times must be corrected by adjusting the duration and/or the frequency of the tasks and/or task elements (see Figure 8). If the discrepancy is less than five percent of the specified working time, a message is given that signals the analyst of the magnitude of the discrepancy (see Figure 9). It is important to understand that the unaccounted difference in times will result in incorrect exposure times and the results and recommendations will not be correct. For this reason, the analyst must actively choose to continue, in spite of the time discrepancy.

Tasks and task elements can be inserted or removed. In addition, it is possible to edit the name, frequency or duration of the tasks and task elements. To change the order of the tasks or task elements in the sequence, the *Move*  and *Move*  buttons are used. It is important that the sequence of the tasks and task elements be correct.

If the task characteristics (e.g., postures, motions, etc.) for a previously analyzed task element are to be edited, the *Go To Task* button is activated after the particular task and task element are selected. After the particular changes to the chosen task and task element have been made, the analyst can return to the Task /Element Manager screen to continue the analysis.

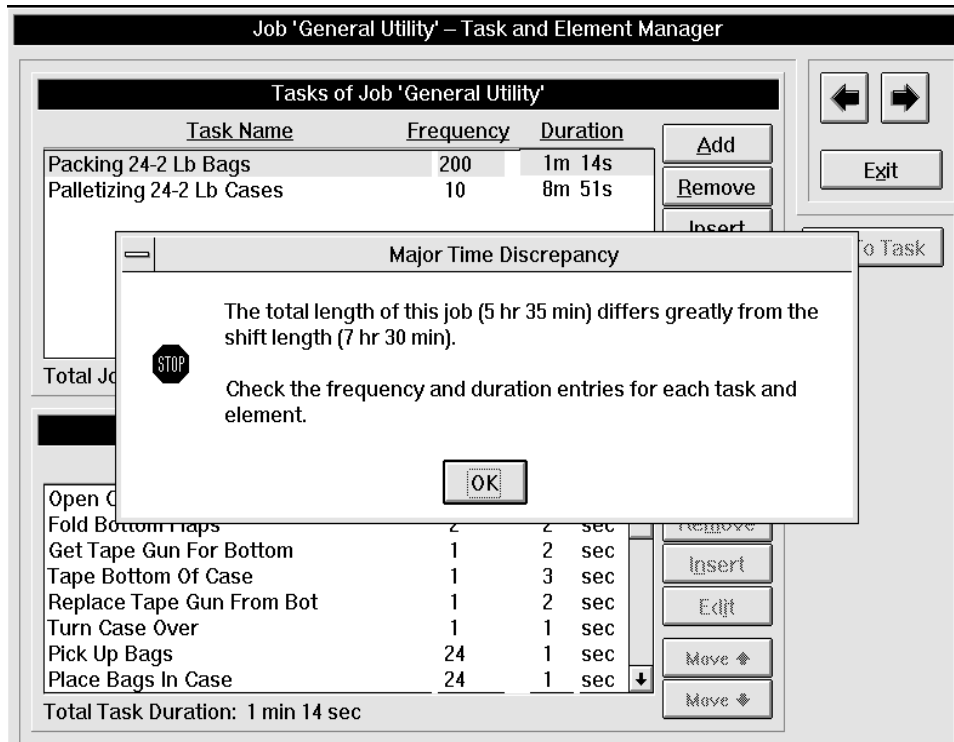


Figure 8. Job Duration Error Screen

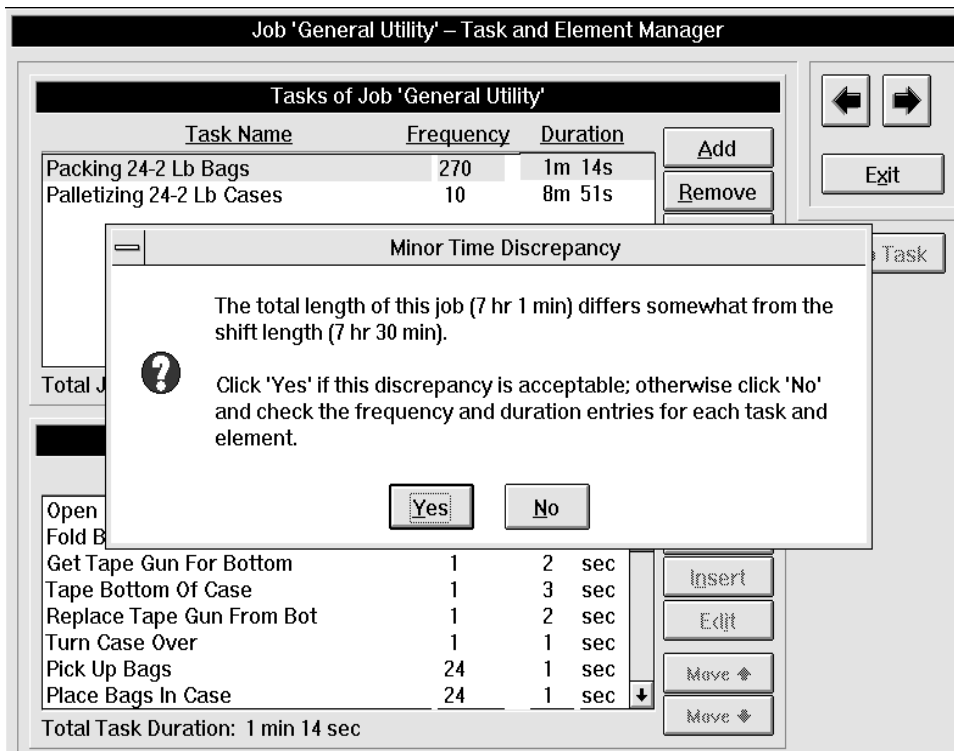


Figure 9. Job Duration Warning

After the job schedule has been documented, the **Task Information** screen (Figure 10) is used to give a short description of the task. One characteristic that generally applies to the entire task is whole body vibration. The next screen is used to document the **Work Environment** (Figure 11). This information also characterizes the entire task (e.g., room and part temperature, control over work pace and personal protective equipment). If gloves are indicated, the right side of the screen is shown and used to document the type of glove. The glove characteristics can have an affect on the grip force requirements. Each of these factors has been associated with the risk of experiencing cumulative trauma disorders.

The screenshot shows a software interface titled "Task 1 of 2: 'Packing'". The main section is "Task Information". It contains a "Description:" field with the text "Form, pack, and close case of 24-2 lbs bags of product". Below this are two input fields: "Duration per Cycle:" with the value "1 min 14 sec" and "Frequency per Job:" with the value "300". At the bottom, there is a question: "Operator Exposed to Whole-Body Vibration (i.e., as in when driving a forklift)?" with radio buttons for "Yes" and "No", where "No" is selected. On the right side, there are navigation arrows and an "Exit" button.

Figure 10. Task Information Screen

The screenshot shows a software interface titled "Task 1 of 2: 'Packing' - Work Environment". It is divided into several sections:

- Room Temperature:** Radio buttons for Normal (selected), Hot, and Cold.
- Part Temperature:** Radio buttons for Normal (selected), Hot, and Cold.
- Control Over Work Pace:** Checkboxes for Machine-Paced, Piece Rate, Constant Monitoring, and Daily Deadlines.
- Personal Protective Equipment (PPE) Used:** Checkboxes for Eye Wear, Ear Plug, Gloves (checked), Respirator, Head Wear, and Other.
- Gloves:** A table with columns for Type and Hand (Left, Right).

Type	Left	Right
Cotton	<input type="checkbox"/>	<input type="checkbox"/>
Cut-Resist	<input type="checkbox"/>	<input type="checkbox"/>
Leather	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Linen	<input type="checkbox"/>	<input type="checkbox"/>
Vinyl	<input type="checkbox"/>	<input type="checkbox"/>
Liners	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>

On the right side, there are navigation arrows and an "Exit" button.

Figure 11. Work Environment Screen

After entering the information for the task, the detailed analysis of the individual task elements is begun using the **Task Element Information** screen (Figures 12 and 13). In addition to a short description of the task element, in operational terms, the general movement speed

Task 2 of 2: 'Palletizing 24-2 Lb Cases' – Element 15 of 18: 'Lift Case To Layer 3 Mid'

Element Information

Description:

Lift case from chute to layer 3 middle

Duration per Cycle:

Frequency per Task:

Material Handling

None Pull Lower
 Push Lift Carry

Movement Speed

Normal Static
 Slow Fast

Tool Used

None ↓

Load Characteristics

Normal Weight: lbs.
Maximum Weight: lbs.

Figure 12. Task Element Information Screen - Lift/Lower Activity

Task 1 of 2: 'Packing' – Element 13 of 13: 'Push Case To Conveyor'

Element Information

Description:

Push case to conveyor belt (with both hands)

Duration per Cycle:

Frequency per Task:

Material Handling

None Pull Lower
 Push Lift Carry

Movement Speed

Normal Static
 Slow Fast

Tool Used

None ↓

Force Direction

Up Right Forward
 Down Left Backward

Figure 13. Task Element Information Screen - Push/Pull Activity during the element is characterized. In particular, it is important to document whether the task is performed at a pace that is comfortable for most operators (i.e., normal pace) or at a pace that would be considered faster than comfortable (over a period of time) for most operators (i.e., due to machine or incentive pacing). Alternatively, some task elements are performed at a slow pace from the perspective of the operator (e.g., machine pacing with operator idle time). Another temporal characteristic of the task element is the existence of static postures such as prolonged holding of objects in a particular position or orientation. If lifting is indicated, the normal and maximum weight lifted is documented on the lower portion of the screen. This is subsequently used in the material handling section of the program. If push or pull is indicated then the lower portion of the screen is used to indicate the direction of the force application. Both the speed and the force application relate to only the task element being analyzed, not to other elements or the task, as a whole. The tools that are used during the task element, if any, are selected from the list provided. If the analyst did not previously enter the tool, it must be done at this point (e.g., by using the ← button to go back to the Tool screen).

The next set of screens provide the biomechanical analysis of the task element. The first screen titled, **Shoulder / Upper Arm** (Figure 14), gives a graphical method of entering the posture of the right side upper arm and shoulder at both the beginning and end of the

Task 1 of 2: 'Packing 24-2 Lb Bags' – Element 8 of 13: 'Place Bags In Case' – Right Upper Arm

Upper Arm Positions

Top View Front View Side View

Motions

	Top View	Front View	Side View
Beginning:	<input type="radio"/> 0 <input checked="" type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4	<input checked="" type="radio"/> 0 <input type="radio"/> 1 <input type="radio"/> 2	<input type="radio"/> 0 <input type="radio"/> 1 <input checked="" type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4
Ending:	<input checked="" type="radio"/> 0 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4	<input checked="" type="radio"/> 0 <input type="radio"/> 1 <input type="radio"/> 2	<input type="radio"/> 0 <input checked="" type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4

Left Upper Arm

Same
 Different
 Not Used

Static for Duration of Element
 Yes No

Upper Arm Supported?
 Yes No

Repetitive?
 Yes No

Figure 14. Shoulder / Upper Arm Screen

element. The ending position for this element is the default beginning position for subsequent elements. Depending upon the choice of the top view, either the front or side view is activated. For example, top view positions of **2** or **3** result in the front view; whereas top view positions of **0**, **1** or **4** result in the side view being activated. Graphical entries provide a relatively quick and easy method of entering information, particularly for operational personnel with little or no experience in job documentation.

If the upper arm is held in a static position for the duration of the element, this is indicated. If the posture is static and the arm is not supported, significant fatigue to the shoulder and arm can occur. The other end of the temporal continuum is when the action occurs repetitively. If the posture is static, the repetitiveness part of the panel is deactivated on the screen.

When the information for the right arm is completed, the analyst then indicates whether left arm posture and motion are the *Same* as the right, *Not Used* during the element, or *Different*. If the left arm is used, but with a different posture or motion, *Different* is chosen and the next screen is used to enter the appropriate information for the left upper arm.

When the postures and motions of the upper arms are documented, the analyst progresses to the **Elbow / Forearm** screen (Figure 15). The analyst documents the rotation of the forearm as well as the bend of the elbow at the beginning and end of the task element. Although this motion is often described as a rotation of the wrist, it is actually a forearm rotation. As with the other biomechanical analysis screens, the ending position of one element is the default beginning position of the subsequent element. If the position of the forearm is the same at the beginning as at the end, although there is rotation, this is indicated on the lower portion of the screen. Of particular concern is repetitive rotation of the forearm with the arm extended (e.g., position 1). The information is entered for the right elbow first and then, as with the previous screen, the left arm is indicated as being the *same*, *different* or *not used*. If the motions are not performed repetitively, the lower portion of the screen is used to indicate if the lower arm is held in a static posture during the task element.

The **Hand / Wrist** screen (Figure 16) is used to document the characteristics of the wrist position (e.g., deviation) and the type of grip used. The wrist can be in a *neutral* posture during the element or it can be deviated. The deviations can be singular (*radial / ulnar* or *flexion / extension*) or they can be a combination of the four.

Task 1 of 2: 'Packing 24-2 Lb Bags' – Element 13 of 13: 'Push Case To Conveyor' – Right

Elbow Positions

Rotation

Position

Motions

Beginning: 0 1 2

Ending: 0 1 2

Rotation

Beginning: 0 1 2

Ending: 0 1 2

Position

Beginning: 0 1 2

Ending: 0 1 2

Repetitive?

Yes No

Forearm Rotation?

Yes No

Elbow Supported?

Yes No

Static for the Duration of the Element

Yes No

← →

Exit

Left Elbow

Same

Different

Not Used

Figure 15. Elbow / Forearm Screen

Task 1 of 2: 'Packing 24-2 Lb Bags' – Element 8 of 13: 'Place Bags In Case' – Right Hand/Wrist

Hand/Wrist Positions

Neutral

Radial

Ulnar

Flexion

Extension

Motions

Beginning: Neutral Radial Ulnar Flexion Extension

Ending: Neutral Radial Ulnar Flexion Extension

Wrist Deviations

Beginning: Neutral Radial Ulnar Flexion Extension

Ending: Neutral Radial Ulnar Flexion Extension

Grip

Power - Grip Push - Passive

Pinch - Low Pinch - High None

Contact Stress

Tool Grip

Work Surface

Using Hand As Hammer

Static for the Duration of the Element

Yes No

Wrist Flicking Action?

Yes No

← →

Exit

Left Hand/Wrist

Same

Different

Not Used

Repetitive?

Yes

No

Figure 16. Hand / Wrist Screen

The power grip, with the wrist in a neutral posture is the preferred method of gripping tools or parts. As discussed in the Literature Review, a wrist deviation in combination with a grip force has been associated with cumulative trauma to the wrist (i.e., carpal tunnel syndrome).

Exerting finger forces with a pinch grip is problematic, even when the wrist is in a neutral posture. An example of a passive push is pushing a box on a conveyor, away from the operator. Although the wrist is extended, the stress is less than that of an active push. Other important factors include a wrist flick motion (i.e., high hand acceleration) and contact forces that can put direct pressure on the median nerve in the palm and wrist. The other controls on this screen (*Static, Left Hand / Wrist, Repetitive*) operate as they do on the previous screens.

The posture of the upper torso is documented on the **Back Posture** screen (Figure 17). The top view is used to indicate whether a twist is required during the element. If an operator can side step instead of twisting, this is documented. The front and side views indicate bending postures. As with the other screens, the ending position of one element is the beginning position for the next element. If the operator bends to reach and then stands erect, this should be divided into two elements to accurately describe the activity.

Task 2 of 2: 'Palletizing' – Element 1 of 18: 'Lower Case To Layer 1 Far' – Back

Back Position

Top View/Twist

Front View/Tilt

Side View/Bend

← →

Exit

Can Operator Use Either a Sidestep or a Twist?

Yes

No

Motions	Top View			Front View		Side View					
Beginning:	<input checked="" type="radio"/> 0	<input type="radio"/> 1	<input type="radio"/> 2	<input checked="" type="radio"/> 0	<input type="radio"/> 1	<input checked="" type="radio"/> 0	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3		
Ending:	<input type="radio"/> 0	<input checked="" type="radio"/> 1	<input type="radio"/> 2	<input checked="" type="radio"/> 0	<input type="radio"/> 1	<input type="radio"/> 0	<input type="radio"/> 1	<input checked="" type="radio"/> 2	<input type="radio"/> 3		

Figure 17. Back Posture Screen

After the biomechanics of the upper extremities and back have been documented, the information pertaining to the overall body posture is entered in the **Leg and Seating Posture** screen (Figure 18). The analyst enters whether the operator must sit, stand or can choose to sit or

stand at their discretion. If the operator performs the task element in a seated posture, the adjustability of the workstation (i.e., chair height, back support and foot rests) is documented. For standing workstations, the surface characteristics are also entered. Two factors that affect the amount of postural fatigue are the requirement for standing stationary and the use of foot pedals (whether sitting or standing). If the element involves kneeling or squatting, it is indicated at this screen.

Task 1 of 2: 'Packing 24-2 Lb Bags' – Element 8 of 13: 'Place Bags In Case' – Legs

<p>Sit/Stand</p> <p>Operator...</p> <p><input type="radio"/> Must Always Sit</p> <p><input type="radio"/> Must Always Stand</p> <p><input checked="" type="radio"/> Can Alt Sit/Stand</p> <hr/> <p>Foot Pedal Used?</p> <p><input type="radio"/> Yes</p> <p><input checked="" type="radio"/> No</p> <hr/> <p>Kneeling or Squatting?</p> <p><input type="radio"/> Yes</p> <p><input checked="" type="radio"/> No</p>	<p>Sitting</p> <p>Foot Rests</p> <p>Available?</p> <p><input type="radio"/> Yes</p> <p><input checked="" type="radio"/> No</p> <p>Adjustable?</p> <p><input checked="" type="radio"/> Yes</p> <p><input type="radio"/> No</p> <hr/> <p>Chair Height Adjustable?</p> <p><input checked="" type="radio"/> Yes <input type="radio"/> No</p> <hr/> <p>Room for Legs Under Equipment?</p> <p><input type="radio"/> Yes <input checked="" type="radio"/> No</p> <hr/> <p>Back Support</p> <p>Provided?</p> <p><input checked="" type="radio"/> Yes <input type="radio"/> No</p> <p>Adjustable?</p> <p><input checked="" type="radio"/> Yes <input type="radio"/> No</p> <hr/> <p>Contact Stress</p> <p><input checked="" type="checkbox"/> Hard/Sharp Objects Press Into Skin</p> <p><input type="checkbox"/> Using Knee As Hammer or Kicker</p>	<p>Standing</p> <p>Anti-Fatigue Pad Used?</p> <p><input type="radio"/> Yes</p> <p><input checked="" type="radio"/> No</p> <hr/> <p>Slippery Standing Surface?</p> <p><input type="radio"/> Yes</p> <p><input checked="" type="radio"/> No</p> <hr/> <p>Stand Stationary for Duration of Element?</p> <p><input type="radio"/> Yes</p> <p><input checked="" type="radio"/> No</p>	<p>← →</p> <p>Exit</p>
--	--	--	------------------------

Figure 18. Leg and Seating Posture Screen

If lifting or lowering an object was indicated on the Task Element Description screen, the **Lifting / Lowering** screen (Figure 19) is shown next. If no material handling was indicated for the task element, the corresponding screens are not activated. The information entered is used by both the National Institute for Occupational Safety and Health (NIOSH) lifting guidelines, as well as material handling guidelines developed by Liberty Mutual Insurance Company. Both the physical geometry and the temporal aspects of the lifting task are entered. The grid is used to

Task 2 of 2: 'Palletizing 24-2 Lb Cases' – Element 15 of 18: 'Lift Case To Layer 3 Mid' – Lifting

Recovery Time (between lifts) <input type="text" value="10"/> sec.	Horizontal Distance (between hands) <input type="text" value="12"/> Inches	Coupling Quality <input type="radio"/> Good <input checked="" type="radio"/> Fair <input type="radio"/> Poor	Hands Used <input type="radio"/> One <input checked="" type="radio"/> Both	<input type="button" value="←"/> <input type="button" value="→"/> <input type="button" value="Exit"/>																																										
Stability of Load <input checked="" type="radio"/> Rigid <input type="radio"/> Compliant	Initial and Final Hand/Load Locations																																													
Significant Control <input type="radio"/> Beginning <input checked="" type="radio"/> Ending <input type="radio"/> Both	<table border="1"> <thead> <tr> <th></th> <th>Against Body</th> <th>Straight Arm</th> <th>Back Bend min.</th> <th>Back Bend max.</th> <th></th> </tr> </thead> <tbody> <tr> <td>OverHead</td> <td></td> <td></td> <td></td> <td></td> <td>84</td> </tr> <tr> <td>Shoulder</td> <td></td> <td></td> <td></td> <td></td> <td>57</td> </tr> <tr> <td>Waist</td> <td></td> <td></td> <td></td> <td></td> <td>44</td> </tr> <tr> <td>Knee</td> <td></td> <td></td> <td></td> <td></td> <td>23</td> </tr> <tr> <td>Floor</td> <td></td> <td></td> <td></td> <td></td> <td>0</td> </tr> <tr> <td></td> <td>0</td> <td>15</td> <td>32</td> <td>38</td> <td>45</td> </tr> </tbody> </table>				Against Body	Straight Arm	Back Bend min.	Back Bend max.		OverHead					84	Shoulder					57	Waist					44	Knee					23	Floor					0		0	15	32	38	45	Initial Position Vertical: <input type="text" value="36"/> in. Horizontal: <input type="text" value="10"/> in.
	Against Body	Straight Arm	Back Bend min.	Back Bend max.																																										
OverHead					84																																									
Shoulder					57																																									
Waist					44																																									
Knee					23																																									
Floor					0																																									
	0	15	32	38	45																																									
Asymmetry Angle <input type="text" value="45"/> Degrees				Final Position Vertical: <input type="text" value="46"/> in. Horizontal: <input type="text" value="20"/> in.																																										
				This grid represents the 75th percentile of the female population.																																										

Figure 19. Lifting Data Screen

help the analyst determine the geometry from body landmarks (i.e., knee, waist, etc.). This method of determining the heights and distances has been found to be very easily used by operational personnel. Obviously, the height of the landmarks is different for different height operators. The height of the operator that was included in the Analyst / Operator screen is used to scale the grid. The relative size of the operator (i.e., percentile stature) is indicated in the lower corner of the screen. Each of the data categories is accompanied by a help screen that is accessed by clicking on the category label (e.g., *Stability of Load*).

The **Push / Pull / Carry** screen (Figure 20) is activated next if one of these activities was indicated on the Task Element Description screen. This information is used in conjunction with the Liberty Mutual Insurance Company's guidelines that indicate the proportion of the population capable of performing the task, without being at risk. Only the activities that were previously indicated (e.g., *Push*) are activated. For push and pull, it is important to enter both the initial force necessary to get the item moving and the sustained force. Force measuring equipment is

Task 1 of 2: 'Packing 24-2 Lb Bags' – Element 13 of 13: 'Push Case To Conveyor' –

Push	Pull	Carry
Duration of Push <input type="text" value="2"/> <input type="text" value="sec."/> <input type="text" value="↓"/> /push	Duration of Pull <input type="text" value=""/> <input type="text" value="sec."/> <input type="text" value="↓"/> /pull	<input type="text" value=""/> <input type="text" value="sec."/> <input type="text" value="↓"/> /carry
Distance of Push <input type="text" value="24"/> <input type="text" value="in."/> <input type="text" value="↓"/>	Distance of Pull <input type="text" value=""/> <input type="text" value="in."/> <input type="text" value="↓"/>	Duration of Carry <input type="text" value=""/> <input type="text" value="sec."/> <input type="text" value="↓"/> /carry
Height of Hands <input type="text" value="42"/> <input type="text" value="in."/> <input type="text" value="↓"/>	Height of Hands <input type="text" value=""/> <input type="text" value="in."/> <input type="text" value="↓"/>	Distance of Carry <input type="text" value=""/> <input type="text" value="ft."/> <input type="text" value="↓"/>
Force Initial: <input type="text" value="75"/> lbs. Sustained: <input type="text" value="48"/> lbs.	Force Initial: <input type="text" value=""/> lbs. Sustained: <input type="text" value=""/> lbs.	Height of Hands <input type="text" value=""/> <input type="text" value="in."/> <input type="text" value="↓"/>

Figure 20. Push / Pull / Carry Data Screen

necessary for this part of the analysis. Although electronic force gauges are easy to use and are readily available, a simple fish scale is sufficient for these purposes.

When the biomechanical and postural information has been entered to the previous screens, the data are abstracted on two **Summary** screens (Figures 21 and 22). The first summary screen shows the shoulder/upper arm, elbow/forearm and hand/wrist motion characteristics and the second screen represents the postural characteristics of the back, legs, upper and lower extremities. These screens, as well as all subsequent screens, can be printed using the **Print Screen** buttons. This summary information, along with the date of the analysis, can be filed in hard copy form, if necessary. The information entered is saved as each screen is left so the analyst can leave the program or progress to an evaluation of the results and recommendations based on the job characteristics.

Task 1 of 2: 'Packing 24-2 Lb Bags' – Element 1 of 13: 'Open Case'–Element Summary					
Element Information					
<u>Upperarm</u>			<u>Hand/Wrist</u>		
	<u>Right</u>	<u>Left</u>		<u>Right</u>	<u>Left</u>
	<u>No</u>	<u>Yes</u>	<u>No</u>	<u>No</u>	<u>Yes</u>
Static for Entire Element	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Upperarm Supported	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Repetitive	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
<u>Elbow</u>			Tool Grip Contact		
	<u>Right</u>	<u>Left</u>	Work Surface Contact		
	<u>No</u>	<u>Yes</u>	<input checked="" type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>		
Static for Entire Element	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Use Hand as Hammer		
Upperarm Supported	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>		
Repetitive	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<u>Type of Grip:</u>		
Forearm Rotation	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Right Hand <input type="text" value="Pinch-Low"/>		
			Left Hand <input type="text" value="Pinch-Low"/>		
Duration	<input type="text" value="1 sec"/>	Frequency	<input type="text" value="1"/>	Material Handling	<input type="text" value="None"/>

Date Last Analyzed
 1/5/96

Figure 21. Summary 1 Screen.

Task 1 of 2: 'Packing 24-2 Lb Bags' – Element 8 of 13: 'Place Bags In Case'–Element Summary					
<u>Back/Legs Information</u>		<u>Body Positions</u>			
	<u>No</u>	<u>Yes</u>	<u>Beginning</u>	<u>Ending</u>	
Operator Seated	<input type="checkbox"/>	<input type="checkbox"/>	Back Side Position	<input type="text" value="1"/>	<input type="text" value="0"/>
Operator Stands	<input type="checkbox"/>	<input type="checkbox"/>	Back Top Position	<input type="text" value="1"/>	<input type="text" value="0"/>
Operator Can Sit or Stand	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Back Front Position	<input type="text" value="0"/>	<input type="text" value="0"/>
Foot Pedal Used	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Right Arm Top Position	<input type="text" value="1"/>	<input type="text" value="0"/>
Kneel or Squat	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Right Arm Front Position	<input type="text" value="0"/>	<input type="text" value="0"/>
Anti-Fatigue Pad	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Right Arm Side Position	<input type="text" value="2"/>	<input type="text" value="1"/>
Slippery Surface	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Left Arm Top Position	<input type="text" value="0"/>	<input type="text" value="0"/>
Foot Rest Avail.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Left Arm Front Position	<input type="text" value="0"/>	<input type="text" value="0"/>
Foot Rest Adjust.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Left Arm Side Position	<input type="text" value="2"/>	<input type="text" value="1"/>
Back Support	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Right Elbow Rotation	<input type="text" value="1"/>	<input type="text" value="2"/>
Back Support Adjustable	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Right Elbow Position	<input type="text" value="0"/>	<input type="text" value="1"/>
Chair Height Adjustable	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Left Elbow Rotation	<input type="text" value="2"/>	<input type="text" value="2"/>
Static for Entire Element	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Left Elbow Position	<input type="text" value="0"/>	<input type="text" value="0"/>
			Right Hand Position	<input type="text" value="Neutral"/>	<input type="text" value="Extension"/>
			Left Hand Position	<input type="text" value="Extension"/>	<input type="text" value="Neutral"/>

Date Last Analyzed
 12/4/95

Figure 22. Summary 2 Screen.

8. RESULTS AND RECOMMENDATIONS OF THE ANALYSIS

The results of the biomechanical analysis of the job, across the tasks and task elements, are presented separately for the left and right side of the body. There are many combinations of risk factors with some being more serious than others. For example, wrist deviation is a risk factor and the posture can often be improved with different workspace design, tool design or changes in the work methods. However, if the wrist deviation is combined with a high grip force and, particularly if it is performed repetitively, the risk of a disorder is much greater. Although the latter situation is more of a concern from the standpoint of occupational safety and health, improving the conditions that involve less risk can often lead to less fatigue, better manual efficiency and improved product quality. In general, the more serious combinations are listed higher in the order to indicate that they should probably have priority in being addressed.

8.1 Results Screens

The first screen presented in this section, **Shoulder/Upper Arm Results** (Figure 23), lists the characteristics that decrease biomechanical efficiency, along with the task elements that involve those characteristics. The number of motions per day and the total exposure time are also indicated on the results screens. Obviously, even if an awkward motion or posture is experienced, if it occurs very rarely or for only a brief period, it is of much less concern than more severe exposures. Poor postures that do not have prolonged exposure are listed but are indicated as being of less concern. In addition, although there are not specific levels that can be considered *acceptable* or *damaging*, by making modifications that reduce the amount of exposure the potential for fatigue, discomfort and disorders is reduced. The result screen also indicates the task elements that do not pose a potential risk, as well as the total number of motions and postural exposure time for the shoulder/upper arm, across the entire job. The shoulder/upper arm results screen for the left side is then presented.

The **Elbow/Forearm Results** (Figure 24) and **Hand/Wrist Results** (Figure 25) screens provide the same information and format as the Shoulder/Upper Arm screen. As the research and applications literature develop with respect to specific dose-response levels, they will be easily updated in the software to represent the regions of significant risk of injury. Even at that point,

Job 'General Utility' – Right Side Upper Arm Motion Count and Exposure Time		
Upper Arm Risk Factor Combinations (with Affecting Tasks-Elements)	Motions per Day	Exposure Time per Day (min)
1. Upper Arm Between 45 and 90 Degrees in Front of Body and Repetitive Motion (1-2; 1-8; 1-9)	8400	160
2. Upper Arm Between 90 and 180 Degrees to Side of Body (1-3; 1-5; 1-10; 1-12)	1200	40
3. Upper Arm Between 90 and 180 Degrees in Front of Body (1-7)	7200	120
4. Upper Arm Between 45 and 90 Degrees to Side of Body (1-13)*	300	10
5. Upper Arm Between 45 and 90 Degrees in Front of Body (1-1; 1-4; 1-6; 1-11; 2-4; 2-6; 2-8; 2-10; 2-12; 2-14; 2-16; 2-18)	1440	80
6. No Risk Factors Identified (2-1; 2-2; 2-3; 2-5; 2-7; 2-9; 2-11; 2-13; 2-15; 2-17)	N/A	49
* Denotes poor posture but not prolonged exposure. Concentrate on listed items with no asterisks first.		

← →

Print Page

Exit

Date Last Analyzed
12/4/95

Overall Job Motions per Day
18840

Overall Job Exposure Time (min) per Day
459

Figure 23. Shoulder/Upper Arm Results Screen

Job 'General Utility' – Right Side Elbow Motion Count and Exposure Time		
Elbow Risk Factor Combinations (with Affecting Tasks-Elements)	Motions per Day	Exposure Time per Day (min)
1. Forearm Rotation, Extended, Repetitive Motion (1-8)	7200	120
2. Forearm Rotation, Repetitive Motion (1-9)*	600	20
3. Forearm Rotation, Extended (1-4; 1-5; 1-11; 1-12)	1200	50
4. Forearm Rotation (1-1)*	300	5
5. Extended (1-3; 1-10; 1-13)	900	30
6. Static (1-7)	7200	120
7. No Risk Factors Identified (1-2; 1-6; 2-1; 2-2; 2-3; 2-4; 2-5; 2-6; 2-7; 2-8; 2-9; 2-10; 2-11; 2-12; 2-13; 2-14; 2-15; 2-16; 2-17; 2-18)	N/A	114
* Denotes poor posture but not prolonged exposure. Concentrate on listed items with no asterisks first.		

← →

Print Page

Exit

Date Last Analyzed
12/4/95

Overall Job Motions per Day
18840

Overall Job Exposure Time (min) per Day
459

Figure 24. Elbow/Forearm Results Screen

Job 'General Utility' – Right Side Hand/Wrist Motion Count and Exposure Time		
Hand/Wrist Risk Factor Combinations (with Affecting Tasks-Elements)	Motions per Day	Exposure Time per Day (min)
1. Deviations, High Pinch Grip, Repetitive Motion (1-8)	7200	120
2. Wrist Flick, Repetitive Motion (1-8)	7200	120
3. Deviations, Power Grip (1-3; 1-4; 1-5; 1-10; 1-11; 1-12; 2-1; 2-3; 2-5; 2-7; 2-9; 2-11; 2-13; 2-15; 2-17)	2070	114
4. Deviations, Tool Grip Contact Stress (1-4; 1-11)*	600	30
5. Deviations, Repetitive Motion (1-2; 1-9)	1200	40
6. Deviations, Low Pinch Grip (1-1)*	300	5
7. Deviations, Force (1-13)*	300	10
8. Deviations (1-6)*	300	5
9. No Risk Factors Identified (1-7; 2-2; 2-4; 2-6; 2-8; 2-10; 2-12; 2-14; 2-16; 2-18)	N/A	165
* Denotes poor posture but not prolonged exposure. Concentrate on listed items with no asterisks first		

← →

Print Page

Exit

Date Last Analyzed
12/4/95

Overall Job Motions per Day
18840

Overall Job Exposure Time (min) per Day
459

Figure 25. Hand/Wrist Results Screen

due to the differences in susceptibility of different workers, it will still be the case that a high risk task for one operator will pose no risk for others. Therefore, it will always be necessary to apply engineering and management judgment to establish where modifications to the workplace design and work methods are justified

The **Back Exposure** (Figure 26) and **Leg Exposure** (Figure 27) screens list the activities or postures that can cause unnecessary fatigue and discomfort, along with the exposure time for each. As with the other result screens, the image can be printed and filed, if necessary. The **Other Exposure** (Figure 28) screen is used to indicate the conditions related to the work environment or tools that can affect the effectiveness of the manual operation. As with the previous two screens, it lists the conditions and the exposure time.

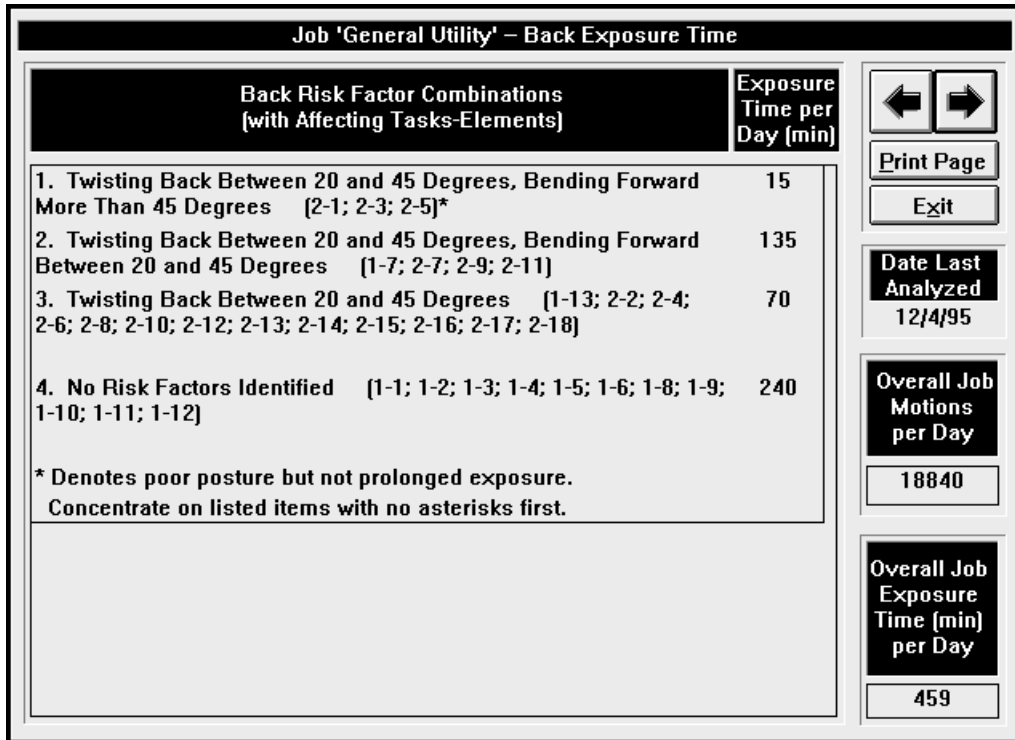


Figure 26. Back Exposure Screen

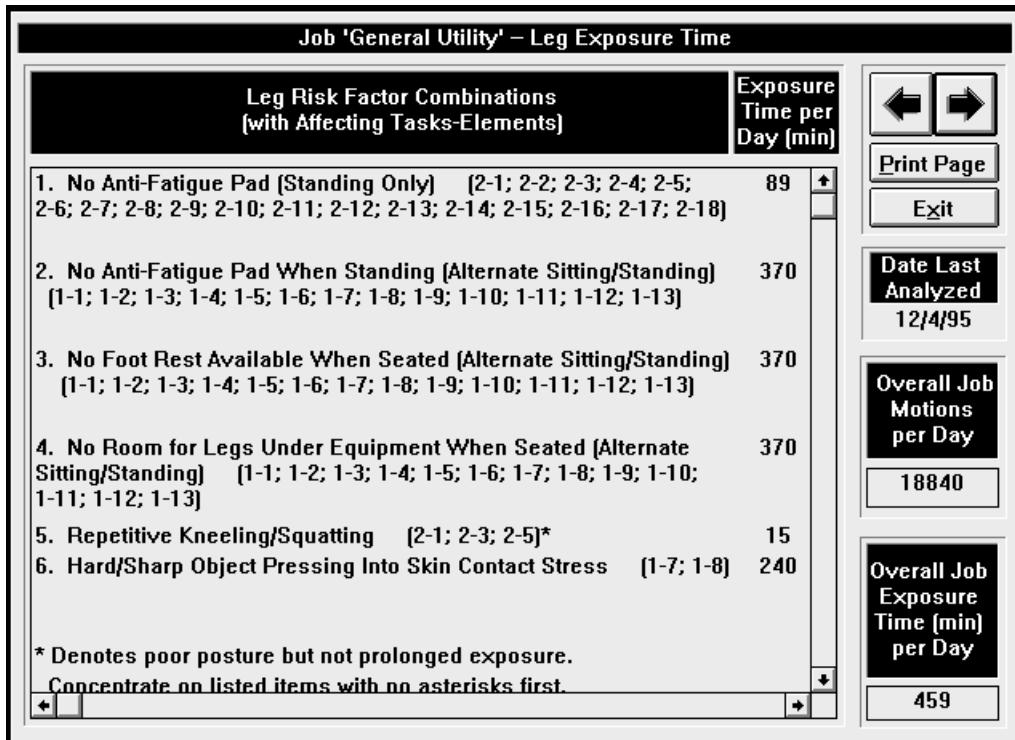


Figure 27. Leg Exposure Screen.

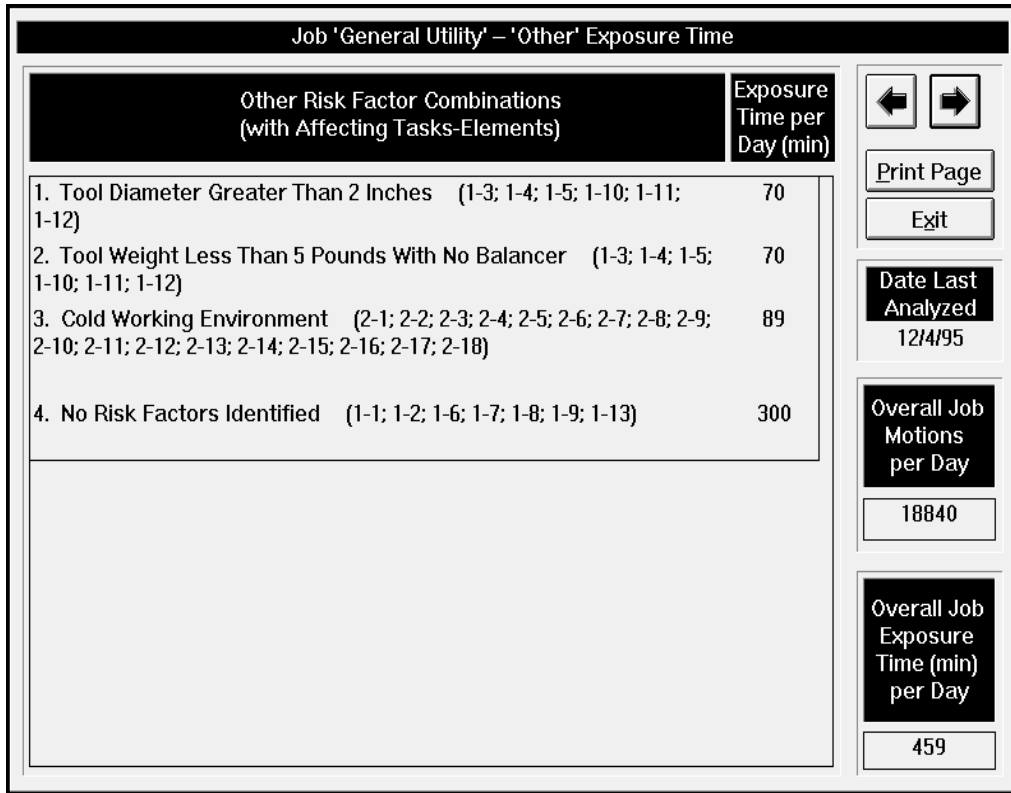


Figure 28. Other Exposures Screen.

8.2 Recommendations Based on the Results

The next set of screens (Figures 29 -34) provides recommendations that have the potential of reducing the effects of the risk factors identified on the results screens. Along with the description of the risk factor is the number of daily motions and the exposure time associated with that factor. The suggested modifications are intended to be the initiation of the problem solving process, rather than its completion. That is, it is often the case that the personnel with a complete understanding of the operational capabilities and constraints can determine more effective alternatives, if they understand the objective.

The next two screens (Figure 35) provide a summary of the results for each task element, separated by body part. The first screen presents a summary for the right side of the body and the second screen presents a summary for the left side. Whereas the previous screens provide information that encompasses the whole job (tasks and task elements), these provide complete summaries for each task element. The **Risk Factor Summary** screens can be printed to provide a hard copy of the results for filing purposes.

Job 'General Utility' – Right Side Upper Arm Job Risk Factors and Recommendations	
Upper Arm Risk Factors (Motions; Exposure Time)	Recommendations (with Affecting Tasks-Elements)
Upper Arm Between 45 and 90 Degrees in Front of Body and Repetitive Motion (8400; 160)	<p>Raise the body, lower the location of the work, adjust the equipment, or change the work method so that the upper arm is at an angle with the body of less than 45 degrees.</p> <p>Change work method to reduce or eliminate repetition. For example, this can be accomplished by modifying the job (i.e., adding elements to work cycle), changing the process (i.e., using two screws instead of four nails), and/or using mechanical devices.</p> <p>[1-2; 1-8; 1-9]</p>
Upper Arm Between 90 and 180 Degrees to Side of Body	<p>Raise the body, lower the location of the work, adjust the equipment, or change the work method so that the upper arm is at an angle with the body of less than 45 degrees.</p>

← →

Print Page

Exit

Date Last Analyzed
12/4/95

Overall Job Motions per Day
18840

Overall Job Exposure Time (min) per Day
459

Figure 29. Shoulder / Upper Arm Recommendations Screen.

Job 'General Utility' – Right Side Elbow Job Risk Factors and Recommendations	
Elbow Risk Factors (Motions; Exposure Time per Day)	Recommendations (with Affecting Tasks-Elements)
Forearm Rotation, Extended, Repetitive Motion (7200; 120)	<p>Change the work and/or body location, layout, methods, tools, or equipment so that the elbow is in a neutral position.</p> <p>Change the work and/or body position or the work methods so that the work is closer to the body and the elbow is not completely straightened (extended) when working.</p> <p>Change work method to reduce or eliminate repetition. For example, this can be accomplished by modifying the job (i.e., adding elements to work cycle), changing the process (i.e., using two screws instead of four nails), and/or using mechanical devices.</p> <p>[1-8]</p>

← →

Print Page

Exit

Date Last Analyzed
12/4/95

Overall Job Motions per Day
18840

Overall Job Exposure Time (min) per Day
459

Figure 30. Elbow / Forearm Recommendations Screen.

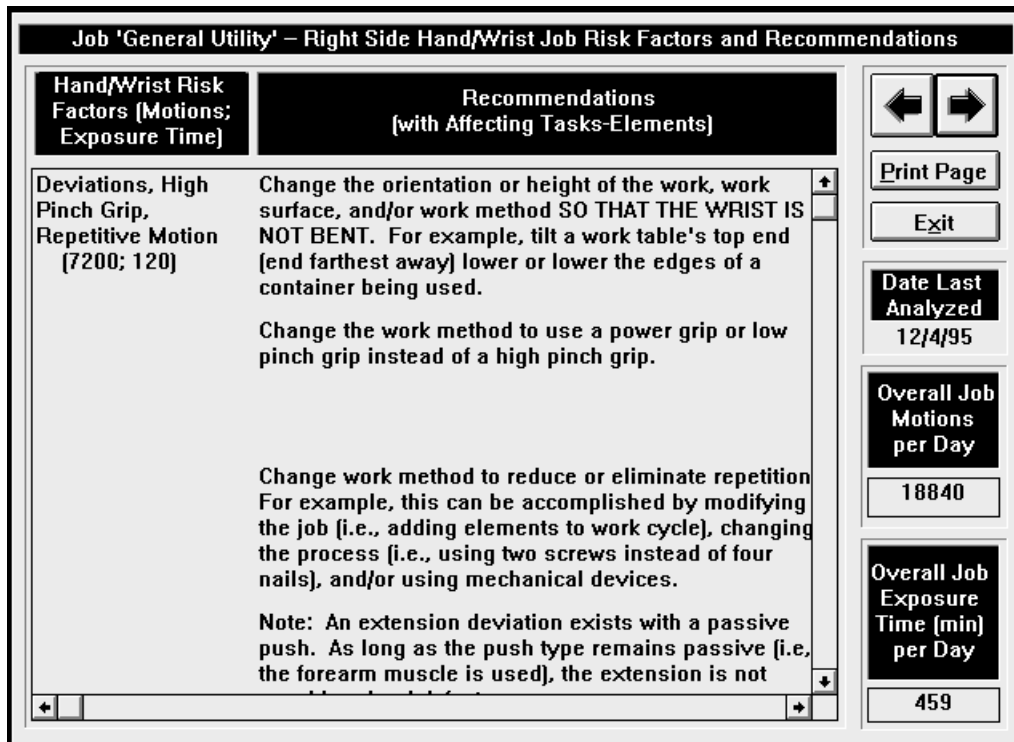


Figure 31. Hand / Wrist Recommendations Screen.

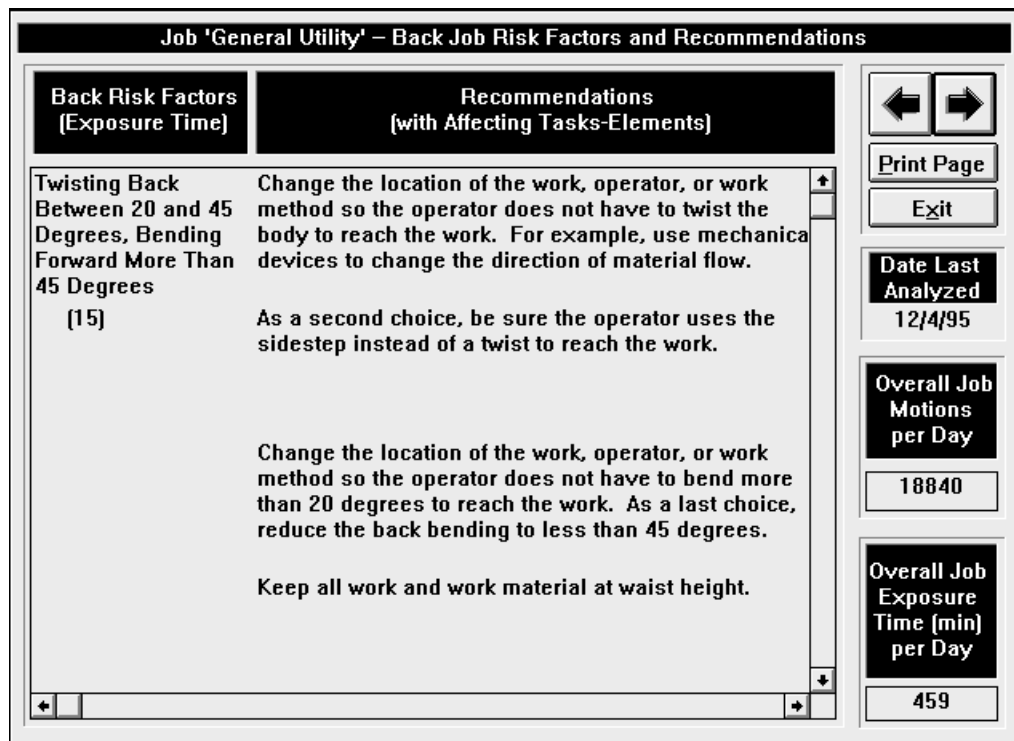


Figure 32. Back Recommendations Screen.

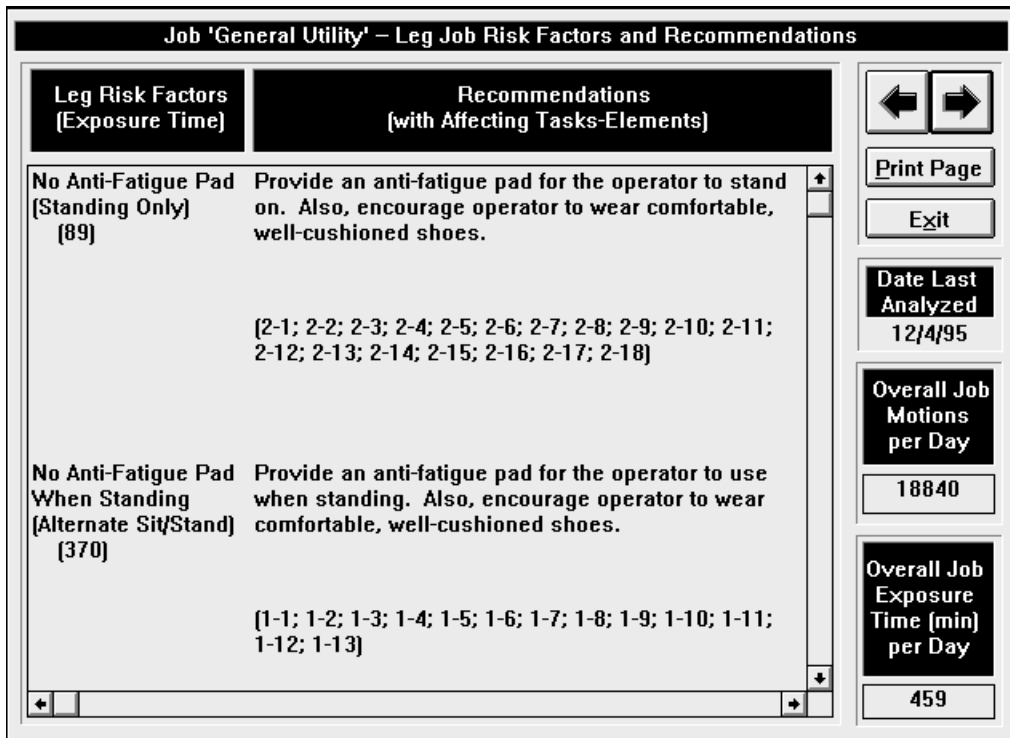


Figure 33. Lower Extremity Recommendations Screen.

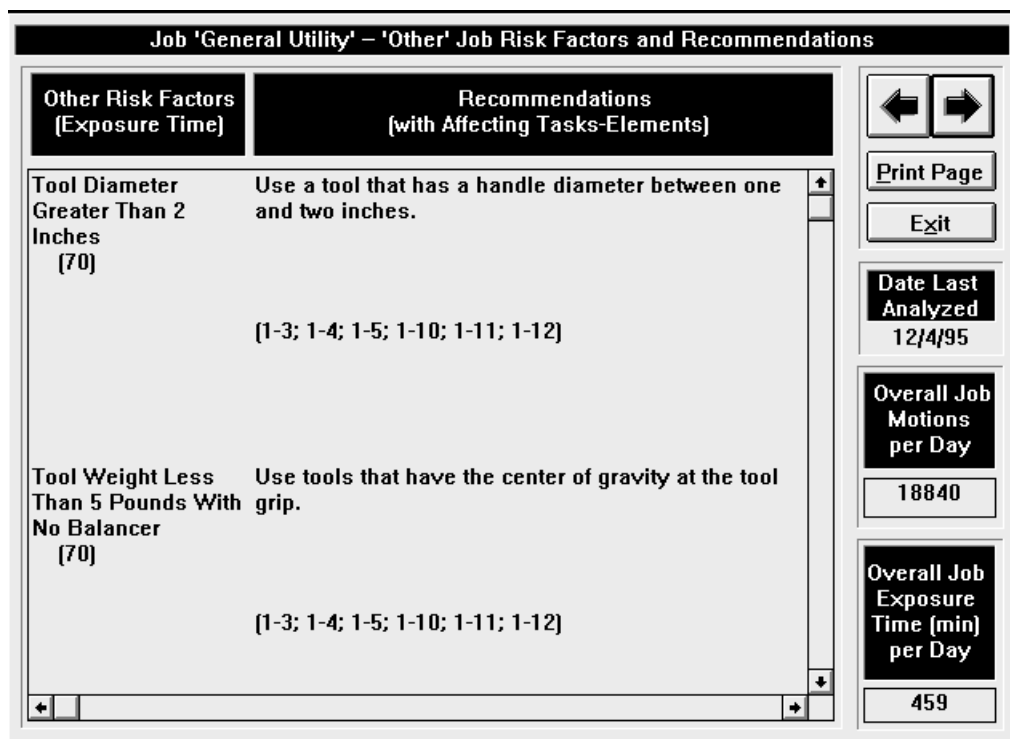


Figure 34. Other Recommendations Screen.

Task 1 of 2: 'Packing 24-2 Lb Bags' – Element 1 of 13: 'Open Case'	
Left Side Upper Body Risk Factors	
Upper Arm	Upper Arm Between 45 and 90 Degrees in Front of Body
Elbow	No Risk Factors Identified
Hand/Wrist	Ulnar, Flexion Deviations, Low Pinch Grip
Left Side Lower Body Risk Factors	
Back	No Risk Factors Identified
Legs	No Anti-Fatigue Pad When Standing; No Foot Rest Available When Seated; No Room for Legs Under Equipment When Seated (Alternate Sitting/Standing)
Other	No Risk Factors Identified
<input type="button" value="←"/> <input type="button" value="→"/>	
<input type="button" value="Print Page"/>	
<input type="button" value="Exit"/>	
Date Last Analyzed 12/4/95	
Element Motions per Day 300	
Element Exposure Time (min) per Day 5	

Figure 35. Risk Factor Summary Screen

8.3 Manual Material Handling Analysis, Results and Recommendations.

The manual material handling results and recommendations are divided into task elements that involve lifting and those that involve lowering, pushing, pulling, and carrying. The analysis of the lifting tasks utilizes the National Institute of Occupational Safety and Health (NIOSH) lifting guidelines. These guidelines are used to calculate what NIOSH refers to as a *recommended weight limit (RWL)* that can be handled without risk by the vast majority workers for the geometry and pacing of the lifting task. The actual weight lifted is compared to the RWL to establish the acceptability of the task. A more usable measure of the lifting task is what NIOSH refers to as the **Lifting Index**. Although an index of one or less is preferable (i.e., task weight is equal to or less than the RWL), an index of above one is generally acceptable, depending upon the capabilities of the workers performing the task. It is generally recognized that a lifting index of above three should be avoided in that it poses a risk for a significant proportion of the workers. Another source of information pertaining to lifting tasks is the set of tables developed over a number of years by the Liberty Mutual Insurance Company. For the specific lift geometry and pacing, the proportion of workers capable of performing the task

without being at risk is estimated. The methodology divides the results into the proportion of males and of females capable of performing the task. **The Lifting Results and Recommendations** screen (Figure 36) presents the Recommended Weight Limit, Lifting Index, and the proportion of males and females capable of performing the task. The results portion of the screen indicates the characteristics of the task that significantly reduce the RWL. The recommendations section of the screen presents some possible modifications that would increase the RWL and the proportion of workers that would be able to perform the task without being at risk.

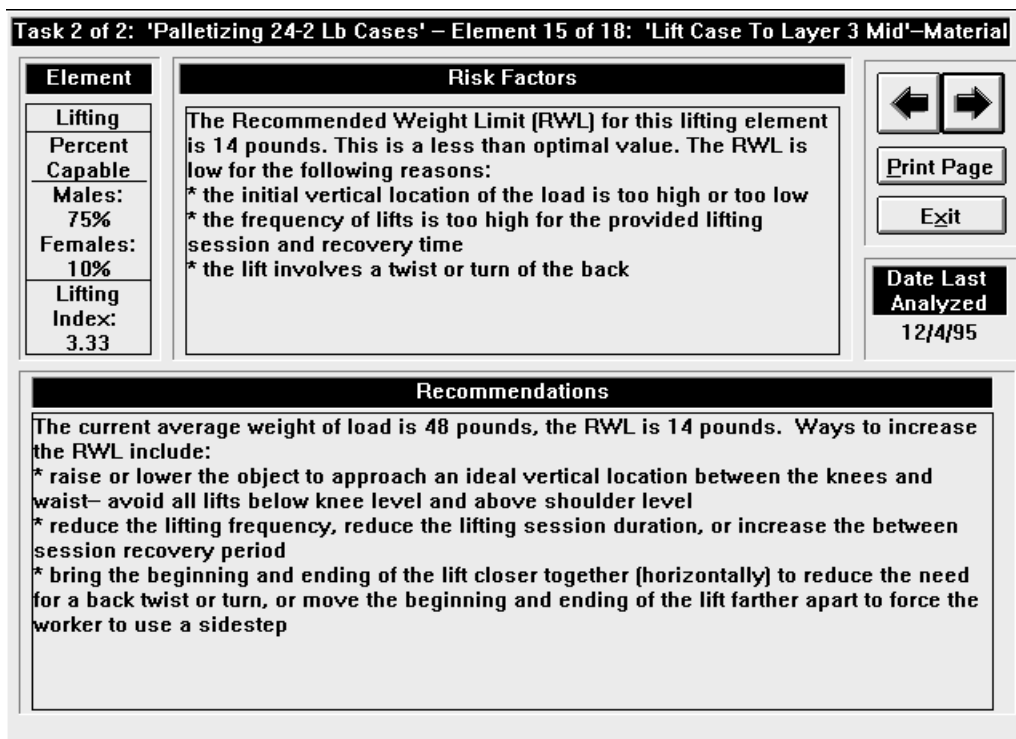


Figure 36. Lifting Results and Recommendation Screens

The next screen, **Lifting Modification Test** screen (Figure 37), allows the analyst to evaluate the effect of possible changes to the geometry and pacing characteristics of the task. Entries to this screen do not change the task documentation; rather it is to allow the analyst to conduct a “*what if*” type of sensitivity analysis. For the new conditions, a modified RWL and lifting index are calculated, as well as determining the new proportion of males and females capable.

Material Handling: Lifting Modification Test Screen	
Evaluate	Print Page
Initial Horizontal Location	10 in.
Initial Vertical Location	36 in.
Final Horizontal Location	20 in.
Final Vertical Location	40 in.
Object Weight	48 lbs.
Recovery Time (between lifts)	10 sec. ↓
Horizontal Distance Between Hands	12 in.
Asymmetry Angle	45 Degrees
Initial and Final Hand/Load Locations 	
Significant Control <input type="radio"/> Beginning <input checked="" type="radio"/> Ending <input type="radio"/> Both	
Coupling Quality <input type="radio"/> Good <input checked="" type="radio"/> Fair <input type="radio"/> Poor	
Stability of Load <input checked="" type="radio"/> Rigid <input type="radio"/> Compliant	
Hands Used <input type="radio"/> One <input checked="" type="radio"/> Both	
← → Exit	
Current RWL 14 pounds <hr/> Current Lifting Index 3.33 <hr/> Percent Capable Males: 75% Females: 10%	
Modified RWL 19 pounds <hr/> Modified Lifting Index 2.50 <hr/> Percent Capable Males: 75% Females: 10%	

Figure 37. Lifting Modification Test Screen.

For the other manual material handling activities (lower, push, pull and carry) the Liberty Mutual Insurance Company's data are used to estimate the percentage of workers capable of performing the task. As with the lifting data, the assessment is divided into separate percentiles capable for males and females (Figure 38).

Task 1 of 2: 'Packing 24-2 Lb Bags' – Element 13 of 13: 'Push Case To Conveyor'–Material	
Percentile Evaluation	
Element Type: Push Element Description: Push Case To Conveyor Characteristics of this pushing element include: * the initial pushing force for the load is: 75 pounds * the sustained pushing force for the load is: 48 pounds * the distance of the push is: 24 inches * the frequency of the push is: 2 seconds per push * the height of the hands for the push is: 42 inches Due to these pushing characteristics, this pushing element can be performed by the following percentages of the male and female population: -based on initial force required -based on sustained force required Males: 75 Males: 50 Females: 10 Females: 10	
← → Exit	
Print Page	
Date Last Analyzed 12/4/95	

Figure 38. Example of Push/Pull Percentile Evaluation Screen.

8.4 OSHA Checklist Results Based on the Analysis Information

One of the methods of evaluating workstations promoted by the Occupational Safety and Health Administration (OSHA) involves the use of checklists. The advantage of a checklist is that it has the appearance of simplicity. However, one of the primary disadvantages of a checklist is that it is difficult to evaluate a task across task elements or even tasks, considering the recovery times, to determine the effective exposure. The checklist is divided into three parts. The first portion of the checklist (A) is concerned with the upper extremities (Figure 39). When risk factors are observed, different scores are attached, depending upon the relative severity of the risk. The score also depends upon whether the exposure is estimated to occur for 2 to 4 hours, 4 to 8 hours or more than 8 hours. The score for each of the risk factor categories is then summed. If the total score is more than a criterion value (e.g., 5), the job is a candidate for analysis and modifications to reduce the risk.

OSHA UPPER EXTREMITY CHECKLIST A – Job 'General Utility'					
Column A Risk Factor Category	Column B Risk Factor	Column			F Score
		C 2 to 4 Hours	D 4 to 8 Hours	E + .5 Ea Hr > 8	
Repetition (Finger/Wrist/ Elbow/ Shoulder/Neck Motions)	1. Identical/Similar Motion(s) Performed Every Few Seconds	1	3		3.
	2. Intensive Keying	1	3		
	3. Intermittent Keying	0	1		
Hand Force (Repetitive or Static)	1. Grip More Than 10 Pound Load	1	3		.
	2. Pinch Grip More Than 2 Pounds	2	3		3.
Awkward Postures (Repetitive or Static)	1. Neck: Twist/Bend	1	2		
	2. Shoulder: Unsupported Arm or Elbow Above Mid Torso Height	2	3		2.
	3. Rapid Forearm: Rotation	1	2		2.
	4. Wrist: Bend/Deviate	2	3		3.
	5. Fingers	0	1		1.
Contact Stress	1. Hard/Sharp Objects Press Into Skin	1	2		1.
	2. Using the Palm of the Hand as a Hammer	2	3		.
Vibration (No Dampening)	1. Localized Vibration	1	2		.
	2. Sitting/Standing on Vibrating Surface	1	2		.
Environment	1. Lighting (Poor Illumination/Glare)	0	1		
	2. Cold Temperature	0	1		.
Control Over Work Pace	Machine-Paced, Piece Rate, Constant Monitoring, and/or Daily Deadlines	1 or 2			

TOTAL
UPPER
EXTREMITY
SCORE FOR
CHECKLIST A

15.

WARNING!!
According to the OSHA checklist, this job is potentially high risk for Upper Extremity CTDs.

Figure 39. OSHA Checklist A Screen.

The second portion of the checklist (Figure 40) is concerned with the back posture and the lower extremities. In addition, the total score (after entering the results from the third portion of the checklist) is included in this portion of the checklist.

OSHA UPPER EXTREMITY CHECKLIST B – Job 'General Utility'					
Column A	Column B	Column			
		C	D	E	F
Risk Factor Category	Risk Factor	2 to 4 Hours	4 to 8 Hours	+ .5 Ea Hr > 8	Score
Awkward Postures (Repetitive or Static)	1. Mild Forward or Side Bending of Torso More Than 20 Degrees But Less Than 45 Degrees	1	2		2.
	2. Severe Forward Bending of Torso More Than 45 Degrees	2	3		.
	3. Backward Bending of Torso	1	2		.
	4. Twisting Torso	2	3		3.
	5. Prolonged Sitting Without Adequate Back Support	1	2		.
	6. Standing Stationary or Inadequate Foot Support While Seated	0	1		1.
	7. Kneeling/Squatting	2	3		.
	8. Repetitive Ankle Extension/Flexion	1	2		.
Contact Stress	1. Hard/Sharp Objects Press Into Skin	1	2		.
	2. Using the Knee as a Hammer or Kicker	2	3		.
Vibration	1. Sitting/Standing on Vibrating Surface (Without Vibration Dampening)	1	2		.
Push/Pull	1. Moderate Load	1	2		.
	2. Heavy Load	2	3		.
Control Over Work Pace	Machine-Paced, Piece Rate, Constant Monitoring, and/or Daily Deadlines	1 or 2			

Manual Handling Score (from Checklist C)

10

TOTAL BACK AND LOWER EXTREMITY SCORE FOR CHECKLIST B

16.

Figure 40. OSHA Checklist B Screen.

The third part of the checklist (C) addresses lifting tasks (Figure 41). It is based on the NIOSH lifting guidelines, previously discussed. As with other analysis systems, the OSHA checklist can be used to accentuate the problem areas and evaluate the different modifications to the workplace design and work methods. That is, independent of the use of a specific criterion value, it is generally better to have jobs that involve a lower score on the OSHA checklist.

8.5 Summary of Results and Recommendations Section

As with any analysis process, the quality of the results and recommendations are highly dependent upon the validity of the information entered by the analyst. That is, if the descriptions of the task and task elements do not accurately represent the true job characteristics (physically or temporally), the results of the analysis will not be valid. Subsequently, the recommendations could be very inappropriate. It is also important to note that the results of the analysis provided by this system constitute the beginning of the problem solving process, not its completion. That is, there is no substitute for the knowledge and experience of operational personnel in the

OSHA UPPER EXTREMITY CHECKLIST C – Job 'General Utility'

STEP 1: STEP 2: Score: <input style="width: 30px; text-align: center;" type="text" value="6"/> * 6 Points if lift more than 15 times/shift	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 33%;">Near Lift: Horizontal Distance Toes to Mid-Knuckle (0-4 in)</th> <th style="width: 33%;">Middle Lift: Horizontal Distance Toes to Mid-Knuckle (4-10 in)</th> <th style="width: 33%;">Far Lift: Horizontal Distance Toes to Mid-Knuckle (>10 in)</th> </tr> <tr> <td>Danger Zone More Than 51 lb 5* Points</td> <td>Danger Zone More Than 35 lb 6 Points</td> <td>Danger Zone More Than 28 lb 6 Points</td> </tr> <tr> <td>Caution Zone 17 to 51 lb 3 Points</td> <td>Caution Zone 12 to 35 lb 3 Points</td> <td>Caution Zone 10 to 28 lb 3 Points</td> </tr> <tr> <td>Safe Zone Less Than 17 lb 0 Points</td> <td>Safe Zone Less Than 12 lb 0 Points</td> <td>Safe Zone Less Than 10 lb 0 Points</td> </tr> </table>	Near Lift: Horizontal Distance Toes to Mid-Knuckle (0-4 in)	Middle Lift: Horizontal Distance Toes to Mid-Knuckle (4-10 in)	Far Lift: Horizontal Distance Toes to Mid-Knuckle (>10 in)	Danger Zone More Than 51 lb 5* Points	Danger Zone More Than 35 lb 6 Points	Danger Zone More Than 28 lb 6 Points	Caution Zone 17 to 51 lb 3 Points	Caution Zone 12 to 35 lb 3 Points	Caution Zone 10 to 28 lb 3 Points	Safe Zone Less Than 17 lb 0 Points	Safe Zone Less Than 12 lb 0 Points	Safe Zone Less Than 10 lb 0 Points	<input type="button" value="←"/> <input type="button" value="→"/> <input type="button" value="Exit"/>																																
Near Lift: Horizontal Distance Toes to Mid-Knuckle (0-4 in)	Middle Lift: Horizontal Distance Toes to Mid-Knuckle (4-10 in)	Far Lift: Horizontal Distance Toes to Mid-Knuckle (>10 in)																																												
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Caution Zone 17 to 51 lb 3 Points	Caution Zone 12 to 35 lb 3 Points	Caution Zone 10 to 28 lb 3 Points																																												
Safe Zone Less Than 17 lb 0 Points	Safe Zone Less Than 12 lb 0 Points	Safe Zone Less Than 10 lb 0 Points																																												
STEP 3: Score: <input style="width: 30px; text-align: center;" type="text" value="4"/>	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%;">Risk Factor</th> <th style="width: 15%;">Lifts: <= 1 Hr in Total/Shift</th> <th style="width: 15%;">Lifts: > 1 Hr in Total/Shift</th> <th style="width: 20%;">Score</th> </tr> </thead> <tbody> <tr><td>Twist Torso During Lift</td><td style="text-align: center;">1</td><td style="text-align: center;">1</td><td style="text-align: center;">1</td></tr> <tr><td>Lift One-Handed</td><td style="text-align: center;">1</td><td style="text-align: center;">2</td><td></td></tr> <tr><td>Lift Unstable Loads</td><td style="text-align: center;">1</td><td style="text-align: center;">2</td><td style="text-align: center;">1</td></tr> <tr><td>Lift Between 1 to 5 Times per Minute</td><td style="text-align: center;">1</td><td style="text-align: center;">1</td><td></td></tr> <tr><td>Lift 5 or More Times per Minute</td><td style="text-align: center;">2</td><td style="text-align: center;">3</td><td style="text-align: center;">2</td></tr> <tr><td>Lift Above the Shoulder</td><td style="text-align: center;">1</td><td style="text-align: center;">2</td><td></td></tr> <tr><td>Lift Below the Knuckle</td><td style="text-align: center;">1</td><td style="text-align: center;">2</td><td></td></tr> <tr><td>Carry Objects 10 to 30 Feet</td><td style="text-align: center;">1</td><td style="text-align: center;">2</td><td></td></tr> <tr><td>Carry Objects Farther Than 30 Feet</td><td style="text-align: center;">2</td><td style="text-align: center;">3</td><td></td></tr> <tr><td>Lift While Seated or Kneeling</td><td style="text-align: center;">1</td><td style="text-align: center;">2</td><td></td></tr> </tbody> </table>	Risk Factor	Lifts: <= 1 Hr in Total/Shift	Lifts: > 1 Hr in Total/Shift	Score	Twist Torso During Lift	1	1	1	Lift One-Handed	1	2		Lift Unstable Loads	1	2	1	Lift Between 1 to 5 Times per Minute	1	1		Lift 5 or More Times per Minute	2	3	2	Lift Above the Shoulder	1	2		Lift Below the Knuckle	1	2		Carry Objects 10 to 30 Feet	1	2		Carry Objects Farther Than 30 Feet	2	3		Lift While Seated or Kneeling	1	2		TOTAL MANUAL HANDLING CHECKLIST C <input style="width: 50px; text-align: center;" type="text" value="10"/>
Risk Factor	Lifts: <= 1 Hr in Total/Shift	Lifts: > 1 Hr in Total/Shift	Score																																											
Twist Torso During Lift	1	1	1																																											
Lift One-Handed	1	2																																												
Lift Unstable Loads	1	2	1																																											
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Lift Above the Shoulder	1	2																																												
Lift Below the Knuckle	1	2																																												
Carry Objects 10 to 30 Feet	1	2																																												
Carry Objects Farther Than 30 Feet	2	3																																												
Lift While Seated or Kneeling	1	2																																												

Figure 41. OSHA Checklist C Screen.

process of establishing effective and efficient methods of modifying the workplace design, work methods, tools and equipment. In general, the operational personnel can usually develop applicable solutions to the problems, give that the problems are recognized in the first place. That is the goal of this analysis system. In addition, this system can be very useful in evaluating alternative designs before they are installed, thus reducing both the time and cost involved with retrofitting. By using the system to evaluate alternative configurations, the relative effects can both be documented and communicated in the decision making process.

9. PRELIMINARY EVALUATION AND FUTURE WORK

A preliminary evaluation of the computer-based job analysis system has been performed at operational facilities by first-line supervisors who have received no formal ergonomics training. One consideration that was illuminated by the preliminary study is that a complete understanding of the operational task characteristics is essential for a valid analysis. That is, a person with extensive training in ergonomics that does not fully understand the requirements of the job is much less capable of performing a valid analysis than a person who fully understands the job, even if they have little or no formal knowledge of ergonomics. Obviously, a person who has had at least an orientation to ergonomic principles, and is also very familiar with the job, is the preferred analyst.

Another observation was that there is a tendency for operational personnel to describe the “way it is supposed to be done,” rather than the methods actually used by the operator. It is important that the analysis characterizes the actual job characteristics if effective modifications are to be implemented. Training the workers to perform their jobs correctly is one obvious solution, particularly with respect to operator controlled equipment adjustments and motion patterns. This need for training is illuminated by the analysis.

When compared to the use of a checklist, the operational personnel found the computer-based system to provide a much more complete assessment of the jobs. In particular, the computer-based evaluation of both individual and combinations of risk factors (e.g., wrist deviation with a grip force), across the task elements and tasks that make up a job, was found to be much more representative of the actual exposure than could be derived from the checklist approach. The prescriptive aspect of the recommendations that are provided by the system is also well received by operational personnel. Most of the recommendations can be considered directly, although others serve as the basis for more effective and/or efficient modifications that are developed by the plant personnel, once they recognize the problem and understand the objectives.

The use of the job analysis tool has been found to be very effective in evaluating current operations; however, another advantage of this type of system is that it can be used to evaluate potential changes and even future task and facility designs. Although the dose-response relationships for the risk factors associated with musculoskeletal disorders are not totally understood; it is evident that a reduction in poor postures and motion patterns is beneficial to both the operator and the process as a whole (i.e., product quality and process efficiency). The

operational personnel that utilize the computer-based job analysis system understand and appreciate the continuous improvement potential of the analysis, as well as its potential for reducing work-related disorders.

To complete the process of developing a valid, user-friendly computer-based job analysis system, a more formal evaluation must be conducted to determine where modifications must be made (e.g., rewording help screens, etc.) and to ensure that the results and recommendations of the system are both correct and feasible in an operational setting. That is, it is important for a system such as the one developed during this project to have face validity for the users, as well as technical validity with respect to the analysis of job characteristics that are associated with musculoskeletal disorders. Operational personnel who find the job analysis tool easy to use and have confidence in the results and recommendations of the system will have a much higher probability of implementing the system as part of their normal job analysis operations.

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