Photo: UW Department of Environmental Health Archives

Musculoskeletal Risks in Washington State Apple Packing Companies

Nancy Simcox, Mary Ellen Flanagan, Janice Camp,
Peregrin Spielholz, Karen Synder

Field Research & Consultation Group, University of Washington
Department of Envrionmental Health, Seattle, WA 98195

2001

©2001, University of Washington Department of Environmental Health

MUSCULOSKELETAL RISKS IN WASHINGTON STATE APPLE PACKING COMPANIES

2001

Nancy Simcox, Mary Ellen Flanagan, Janice Camp, Peregrin Spielholz, Karen Snyder

Field Research and Consultation Group, University of Washington Department of Environmental Health, Seattle WA 98195

ACKNOWLEDGEMENTS

We would like to extend our appreciation to the Washington Growers League, the Shippers and Growers Association, and to the management and workers of all participating companies without whom this study would not have been possible.

We would also like to thank Claire Olsovsky, Yolanda Gomez, Estella Sicairos, the Washington State Department of Labor and Industries SHARP Program, and Mary Miller for their assistance in data collection and interpretation. And finally, we would like to thank the Pacific Northwest Agricultural Safety and Health Center for its financial support of the project.

EXECUTIVE SUMMARY

The Field Research and Consultation Group (Field Group) of the University of Washington Department of Environmental Health recruited, with the assistance of the Washington Growers League, three fruit packing companies in Yakima County, Washington to participate in an investigation of the musculoskeletal risks in the packing house industry. The goal of this study was to better understand the nature of musculoskeletal risks in this industry and to provide employers and employees with information to assist in the development of controls to reduce work-related musculoskeletal disorders (WMSDs).

Ergonomic evaluations were performed on sorting, packing, and segregating job tasks at three Washington apple warehouses. Observations of job tasks, workplace measurements, worker interviews, and videotaping were performed in April and May 1999. Data collected were then used to characterize and analyze musculoskeletal risk factors for six packing house jobs. Particular attention was paid to the manual and semi-automatic bagging and tray filling operations. The Washington State Ergonomics Rule, WAC-296-62-051, was finalized during the course of this evaluation, and an assessment of how this rule might apply to these jobs was also conducted.

There was good agreement among the variety of assessment instruments used with regard to the body sites at greatest risk of musculoskeletal injury. Repetition, static loading of neck and back, and extended reaches produced risk for injury to the back, shoulders, hand/wrist, and neck in sorters. Repetition, static loading of neck and back, high force, and extended reaches were evident in packing jobs, increasing the potential risk to shoulders, upper back, hand/wrist, shoulders, and elbows. Segregators were observed to engage in tasks with high force, repetition, and awkward postures creating a potential for back and shoulder injuries. Objective measures suggested that segregators were at high risk for injury, although they did not report symptoms. All jobs had at least one task that met the criteria of a “caution zone jobs” under the new Washington State Ergonomics Rule. Several jobs had at least on hazard zone risk factor. This report concludes with a variety of ergonomic risk factor reduction recommendations.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

1.0 INTRODUCTION

The Field Research and Consultation Group (Field Group) of the University of Washington Department of Environmental Health has focused some of its research efforts on the Washington State agriculture industry. Apples are Washington State's most valuable agricultural commodities. More than half of the apples grown for fresh eating in the United States come from Washington. Fresh apples are produced at the rate of 2.75 million tons annually for the domestic and export markets (Washington Agricultural Statistics Service, 1999). Approximately 4,000 growers and an estimated 41,000 people work in the apple industry (U.S. Bureau of the Census, 1994). Closely allied with the apple production industry is the fruit packing industrial sector. Approximately 12,000 to 15,000 people work in 125 Washington State fruit packing houses; a large percentage of this work is performed by Hispanics (Jarosz and Qazi, 2000), most of whom are women (Teamsters, 1997).

Of particular interest to the Field Group has been the risk of musculoskeletal injuries in this industry. Musculoskeletal injuries are the most commonly reported ailments in the agricultural sector, with over-exertions accounting for 19% of all agricultural nonfatal occupational injuries and illnesses involving lost workdays (National Safety Council, 1998). Packing house workers are exposed to similar work-related musculoskeletal risk factors as agricultural workers, including repetition, awkward postures, and manual material handling. In 1996, fruit and vegetable packing was identified as one of Washington States ten highest risk industries for upper extremity work-related musculoskeletal disorder (WMSD) cases (Silverstein and Kalat, 1998). However, little has been published characterizing the specific risk factors associated with fruit packing, nor is there much published information with regard to control strategies to mitigate musculoskeletal risks.

In April and May of 1999, Field Group recruited three Yakima-region fruit packing houses to participate in a pilot study to characterize the musculoskeletal risk factors in the Washington apple packing house industry. In addition to characterizing the risks, the researchers were interested in identifying existing or new controls that might be used to reduce identified risks.

1.1 Literature Review

The relationship between fruit packing workstations and the worker has long been of interest to the industry; however, the primary focus of the research in this area has been to determine ways to improve productivity. Identification and remediation of musculoskeletal risk factors has been of secondary interest**.** Smith (1963) compared the human factors of frontal fruit packing stations and side packing stations. He found that citrus packers who worked face-on eliminated body bending and twisting, maintained an erect posture, and were less fatigued than those workers at side packing stations. Meyers (1990) found an increase in performance and accuracy among sorters (workers who inspect products visually for shape, color, and defects) when product moved from the end rather than from the side of an inspection conveyor. Other studies have investigated the relationship between worker fatigue, postural discomfort, and break schedules and fruit inspection performance (Pang, 1994; Purswell and Hoag 1974, Hendrix, 1989; Bhatnager, 1985; 1974; Colquhoun, 1959). A review article by Bollen et al (1993) described the design and operation of sorting equipment, ergonomic factors (e.g. lighting, table size, product loading, and sorter position), and sorter performance. Miller (1991) compared fruit grading performance to such factors as product volume, position of reject chutes, and fruit rotational speed.

A growing body of evidence suggests a relationship between WMSD and a variety of one or more work-related physical factors (e.g., repetitive lifting of heavy objects in extreme or awkward postures) (NIOSH, 1997). In the agricultural sector, the majority of this work has taken place in the food processing industry, particularly meat packing and canneries (Chiang, 1993; Messing, 1992; Kurppa, 1991; Luopajarvi, 1979). The annual incidence of soft-tissue injury among women fish and meat packers ranged from 7-25% (Chiang, 1993; Kurppa, 1991). High incidence of work-related carpal tunnel syndrome (CTS) has been found among middle-aged women who perform tasks that had high levels of repetitiveness and sustained forceful movements (Chiang, 1990; Sandzen, 1981). Few studies have documented the musculoskeletal hazards associated with body discomfort, impaired work performance, and chronic muscle, tendon and nerve disorders in fruit packing houses; however, one intervention study reported improved self-reported comfort among apple sorters when the extent of forward reach was reduced (Studman, 1998). Across all industries in Washington State, musculoskeletal injuries have resulted in increasing workers compensation costs and time-loss, prompting industry, labor, and regulatory groups to work toward better understanding and controlling work-related musculoskeletal hazards.

1.2 Washington State Regulatory Action

Recognizing the human and financial cost of work-related musculoskeletal injuries, the Washington Department of Labor and Industries has promulgated an ergonomics rule to address these injuries. The rule, adopted in May 2000, includes agricultural work places, such as the packing house industry (WAC 296 62 051). The rule has several elements. Employers are covered by the rule if they have jobs with typical work activities that are a regular and foreseeable part of the job and that meet the "caution zone job" (CZJ) criteria. "Caution zone job" criteria include awkward postures, high hand force, highly repetitive motion, repeated impact, vibration, and heavy, frequent, or awkward lifting. If an employer determines there are jobs that meet the CZJ criteria, several activities must be implemented including the following:

- All employees in "caution zone jobs" and their supervisors must receive ergonomic awareness education at least every 3 years.
- "Caution zone jobs" must be analyzed to identify WMSD hazards and identify ways to reduce exposures below the hazard level or to the degree feasible.
- Employees must be involved in the analysis of hazards, selection of control methods, and in evaluation.
- Control priorities require that engineering or administrative measures should be considered first. Individual work practices or personal protective equipment are to be second priority controls.
- Employers must share information with employees through safety committees or safety meetings.
- Ergonomic activities must be reviewed annually.

The Washington State Ergonomics Rule has a phased implementation schedule. Large employers (more than 50 full time equivalent workers) must be in compliance with the awareness education and hazard analysis aspects of the rule by July 1, 2003, and must complete hazard reduction efforts as necessary by July 1, 2004. Mid-size fruit packing companies (11-49 FTE) must be in compliance with awareness education and hazard analysis aspects of the rule by July 1, 2004, and must complete hazard reduction efforts as necessary by July 1, 2005. Finally, small employers (fewer than 10 full time equivalent workers) must be in compliance with the awareness education and hazard analysis aspects of the rule by July 1, 2005, and must complete hazard reduction efforts as necessary by July 1, 2006. This report includes an evaluation of six apple packing jobs from the perspective of the Washington State Ergonomics Rule.

2.0 APPLE PACKING PROCESS

The apple packing process has been fairly well standardized across the industry with some minor modifications between companies (see Figure 1). Peleg provided a thorough overview of the process that generally includes sorting, packing, and segregating (Peleg, 1985). Job categories of primary interest to the Field Group were sorting, packing (including both manual and semi-automatic) and segregating.

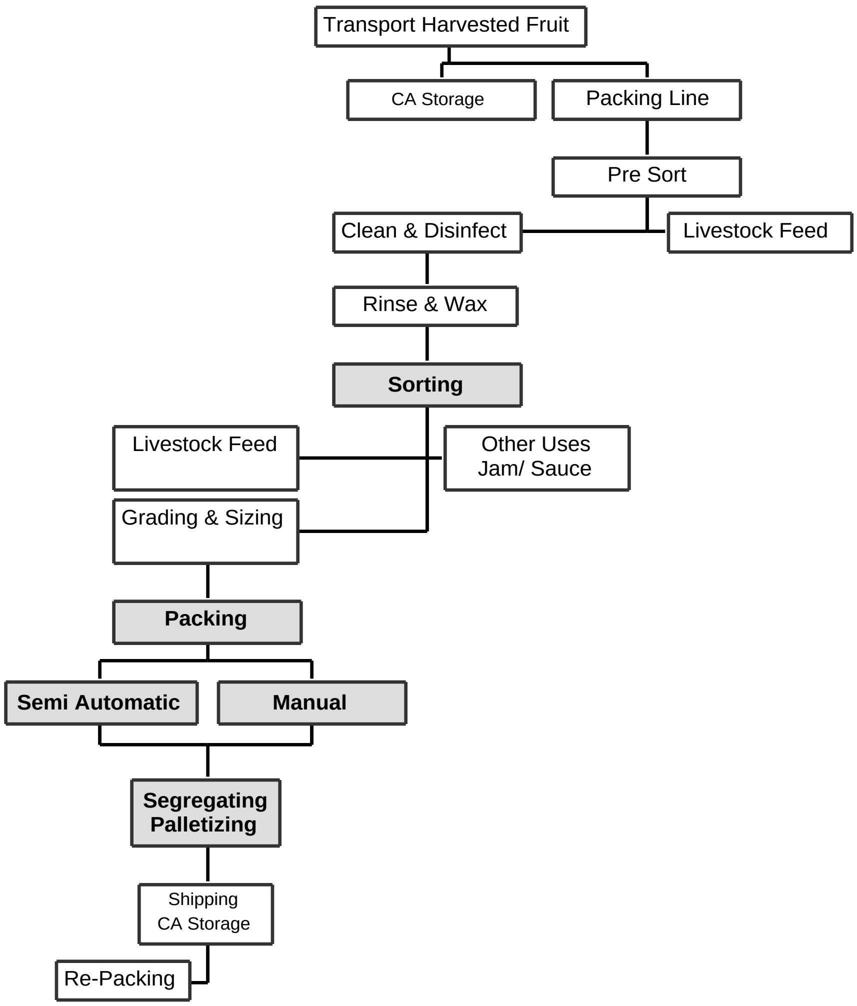


Figure 1 Apple Packing Process

2.1 Sorting

The packing line begins with the transport of bulk bins of fruit directly from the orchard or from controlled atmosphere storage to the packing line. As large-scale use of controlled atmosphere (CA) storage became more common in the 1970s and 1980s, packing houses could hold large amounts of fruit for up to one year. This technological advance allowed packing houses to move from seasonal to year-round work. Bins can weigh between 450 to 1,100 pounds depending on their capacity and fill level, and are transported to the packing line by forklift. Apples are fed onto the packing line either by hydro handling (immersion of bins in a soaking tank allowing the fruit to float out of the tote) or by dry feeding (tipping full bins onto a receiving conveyor belt). Severely damaged or rotten fruit is removed in an initial sort. Apples are then cleaned by soaking them in water that contains detergents and disinfectants and are then transported via a series of rotating brushes, under a rinse-water spray, to a dryer. The apples are dried by rotary sponges and overhead fans then they are sprayed with food-grade wax to improve storage and visual appeal. The clean apples are pre-sized by hand with workers selecting out undersized or damaged fruit, referred to as culls. Culls are used for livestock feed, jams, canning, applesauce, or cider.

After cleaning, waxing, and pre-size sorting, the apples move onto a roller-sorting table for final sorting. The roller-sorting table is designed to continually rotate fruit as it moves past human graders (AKA: sorters). Sorters pick out one or more grades that comprise the minority of the fruit flow (usually very large apples) while the predominate grade is allowed to flow onto the next processing station. This is known as “Reduction Sorting” and is the most common type of sorting performed in apple packing houses. Sorters also inspect apples for shape, color, bruising, insect and mite damage, sunburn, rot, and cuts. Rejects and culls are removed from the flow and are either thrown in a bucket for disposal or down a chute for other product processing. Sorter task cycle includes: 1) checking fruit quality, 2) deciding on the grade, 3) stretching out a hand to pick out and discard minority or defective fruit from the moving flow, and 4) monitoring the fruit as it moves on to the next operation. Sorters repeat this cycle thousands of times per shift.

Apples continue down the sorting conveyor line to a computer-controlled sizer. The sizer is programmed to evaluate the fruit by size and color. It labels each apple with a pressure sensitive adhesive label, and delivers the fruit to grade-specific conveyors leading to the packers. The sizing system concurrently collects information on total volume of fruit packed, fruit grade, size and source (orchard or grower).

2.2 Packing

Apples are packed into a variety of containers, primarily into boxes with trays or into bags or bins. The particular type of packing conducted at a packing house is determined by the type of apples (delicate fruit is usually boxed in trays) and design of the packing house. Also, client needs may determine the type of container (e.g. Costco and Wal-Mart require specialized box containers, other clients request display bins and bulk bins). Apples are boxed by size, ranging from 38 to 150 apples per box, with 88 apples per box being the most common size.

Packing can be divided into manual and semi-automatic processes. Manual packing is done with delicate varieties (such as galas), to meet client requests, and in small packing houses. Larger and some small packing houses have automated most of the packing processes. Workers may do both manual and semi-automated packing and pack into a variety of containers over the course of a single work shift, depending on the client needs, fruit varieties, and production abilities and standards of the packing house.

Manual packing workstations receive apples from the computer-controlled sizer via a conveyor according to the size and grade of the apple. Apples are delivered to the packers on conveyors or are deposited into rotating receiving tubs. Packers stand either to the side of or directly in front of the conveyor or tub; the physical dimensions of the workstation often require that the packer lean and twist over the conveyor or tub in order to reach the apples. The packers usually retrieve an apple with one hand, transfer the apple to the other hand, and then place it into waiting paper trays or bags. Some packers may fill box trays with two hands. The packer at piece-rate companies sets the work pace within the pace set by the automated filling of the receiving bins. The conveyor speed sets the work rate at companies that pay an hourly rate. Paper trays have indentations appropriately sized for a particular size of apple. Tray indentations determine the number of apples that can be placed in one tray. Each standard apple box holds five or six trays depending on the apple size. Full boxes weigh 40 to 50 pounds.

Packers may use pre-made boxes or be required to fold and make each box. Each box to be manually packed is held on a rolling cart that is called a "packing horse." Two designs of packing horse cart box holders were observed during this pilot project: roller tray and slide tray packing horses. The roller tray carts are a newer design and allow filled boxes to be easily pushed from the packing horse directly onto the next conveyor system without lifting the full box of apples. The slide tray packing horse requires the packer to lift the tray upon which the full box is sitting and slide or push the box onto the next conveyor system.

Some packing houses have moved to semi-automatic tray packing. Indented paper trays are mechanically or manually fed into the packing conveyor where they meet apples delivered from the computer-controlled sizer. Apples are gently rolled off the sizing conveyor onto the paper trays that are conveyed on to the packers. Packers manually adjust each apple in its tray for optimal presentation. The pace of the semi-automatic tray filling is determined by the speed of the conveyor. Filled trays are manually placed in boxes that are located at the end of each packing conveyor; full boxes are pushed onto another conveyor for labeling and delivery to storage.

Semi-automatic bagging has also been instituted in some packing houses. Apples are delivered from the computer-controlled sizer to either a standing or sitting semi-automatic bagging station. Apples roll from the delivery conveyor to a bagging machine chute that will hold a preset weight of apples. When the chute is full, the packer depresses a floor foot pedal to deliver the apples into an air-inflated bag. The bag is usually held in two hands, though some packers hold the bag in one hand. After the bag is full, the packer lifts it up with one hand, twists it, and applies a plastic closure clip or twist tie with the other hand. Closure clips may also be applied automatically. The bag is then placed with one hand onto another conveyor, which is either in front or behind the worker, for delivery to the labeling station and storage area.

Repacking. Often boxes need to be repacked to meet production needs, client requests for different containers, quality control requirements, or USDA requirements for storage limits. If the number of pallets to be repacked is small, repacking is done manually by the most experienced packers. This work is usually not performed at a standard packing station, but rather takes place at any available table. Apples are manually removed from one box, sorted, graded, and repacked in another box.

2.3 Segregating

Once boxes have been packed, labeled, and inventoried, segregators (usually male workers) manually lift boxes from a delivery conveyor and place them on wooden pallets according to labeled size and grade. A typical packing house may pack as many as 15 different apple varieties, sizes, and grades at once, and each must be stacked on a separate pallet. The boxes are stacked seven high, to approximately seven feet. Once the pallet is full, boxes are secured with twine and forklifts transport the pallets to the loading dock or to storage. Some packing houses use an automatic palletizer that stacks and shrink-wraps the boxes on pallets. The Yakima Valley Growers-Shippers Association reported that 81.6 million boxes of apples were processed in 1999 (YVGS, 1999).

3.0 STUDY DESIGN AND METHODS

3.1 Background

The Field Group worked with the Washington State Growers League, fruit packing house industry representatives, labor groups, the medical community, equipment vendors, and researchers from other universities starting in 1997 to develop cooperative relationships and to gain support for an occupational health pilot study of the fruit packing industry. In 1997 and 1998 the Field Group staff conducted four walkthroughs of Yakima valley packing houses to learn more about the various jobs and tasks performed during fruit packing. Although the basic packing processes were similar at the companies, several differences between small and large packing houses were recognized during the walkthroughs. Company representatives expressed a need for more information on musculoskeletal hazards, assistance with job task analysis, feedback on appropriate control strategies, and assistance with developing ergonomic programs. In the spring of 1999, packing house industry representatives agreed to support a pilot study of the musculoskeletal hazards in this industry.

3.2 Study Design

The purpose of the pilot study was to obtain a broad overview of musculoskeletal hazards in Washington State apple packing houses. A cross sectional, descriptive survey design was used to characterize musculoskeletal risk factors and reports of WMSD that might be related to selected apple packing house tasks, and the degree to which automation might influence the hazards and symptom reporting. A triangulation strategy was used, which allowed comparison between three different points of reference. The three sources used were: 1) management and workers compensation records of musculoskeletal injuries; 2) on-site observations of job tasks; 3) worker self-reported symptoms and perceptions of risk. One unique aspect of this project was the collaboration between industrial hygienists and an anthropologist to explore worker symptoms and risk perception. All study procedures, including subject consent, met the requirements of University of Washington Human Subjects Review Committee.

3.3 Recruitment

3.3.1 Company Selection

The Washington Growers League (League) distributed a recruitment flyer (Appendix A) describing the pilot study to its members and asked interested companies to contact the League directly. The League forwarded the names of interested companies and their contact people to the Field Group. Five companies contacted the League within a two-week period. The Field Group conducted a brief telephone survey with the company contact person to collect information on the company's packing operation, number of workers, types of work-related injuries, and availability to participate in the study. Four companies operated single packing houses and one company operated two packing houses in the Yakima area. All five companies engaged in packing apples; three packing houses also packed pears and one also packed cherries. Two companies operated one shift per day and three companies operated with at least two shifts during part of the year. All five companies packaged fruit throughout the year and all companies participated in the Washington State Workers Compensation Program. Not all companies were available to participate in a study during the spring of 1999. Three companies were invited to participate in the study based on the following eligibility criteria:

1. the company used either manual or automated packing processes or both
2. the company was located in the Yakima valley
3. the primary language of the workers was either English or Spanish
4. the company was available to participate in a study during April and May 1999.

Participating companies were offered as an inducement a company-specific final report identifying and discussing musculoskeletal hazards observed in their company and possible solutions for identified concerns.

3.3.2 Worker Selection

Six different job titles within each company were targeted for evaluation based on the following criteria:

1. repetitive tasks
2. job was performed regularly during most of a work shift
3. large number of workers had the job title.

The job titles selected for inclusion in the study were sorter, manual tray packer, semi-automatic tray packer, manual bag packer, semi-automatic bag packer, and segregator. Workers in these six job titles were invited to participate in the study at an informational meeting held at their place of work; the meeting was endorsed by company management and held during work time. The informational meeting was conducted in English and Spanish. Workers interested in participating approached the Field Group researchers after the informational meeting. All workers in the designated job titles were eligible to participate; however, due to study resource constraints participation was limited to 10 subjects per job title per company. Companies 1 and 2 were small, so all workers in the designated job titles were encouraged to participate. Company 3 had a large workforce consequently 10 full-time workers were randomly selected from each of the six job titles. Workers completed an informed consent form prior to data collection. All worker participants received a small monetary remuneration acknowledging their participation in the study.

3.4 Exposure Measures

3.4.1 Workstation Design Evaluation and Videotaping

The layout of each workstation was sketched and videotaped and the dimensions of the process equipment were measured. The height and width of each conveyor system and the weight of a full box of apples, a tray, and a bag were measured in each job category. The ambient room temperature and lighting levels were also measured and recorded. Non-stationary equipment at each workstation, such as packing horse carts, was also assessed for height and adjustability for range of worker heights. Sorting, grading, and packing lines of each company were videotaped on the day of on-site assessment to assist in analyzing the work processes and to review job tasks. Permission was obtained from workers prior to videotaping.

3.4.2 Job Task and Task Cycle Time Observations

Observational methods are commonly used in ergonomic field assessments to quantify the number and type of awkward postures, repetitive movements, and other musculoskeletal hazards (Pinzke, 1997). For the purposes of observation each of the six-selected job titles was broken down into one to four specific tasks that defined a job cycle. Designated tasks were used to modify a version of the Ergonomic Surveillance Checklist developed by the Safety and Health Assessment Research for Prevention (SHARP, 1999) program, a division of Washington State Department of Labor and Industries (Appendix B). The checklist enumerated 38 potential risk factors related to forceful hand exertions, awkward postures, contact stress, and general musculoskeletal hazards. Twenty of the 38 risk factors had left and right components (e.g. hand, wrist, forearm, and elbow factors) that were listed separately. An operating protocol for the use of the assessment tool was also developed. Four analysts (three industrial hygienists and one ergonomist) received one day of training on the use of the assessment tool, including definition of all risk factors on the checklist and a review of tasks associated with each fruit packing job title. Analysts also reviewed videotape of the workers performing tasks in the six job titles prior to using the assessment tool.

Time-motion study of the jobs was conducted during on-site observation. During the on-site observations a minimum of 10 and a maximum of 20 job cycles were recorded by each analyst as time allowed. Each job cycle was observed to identify and note checklist risk factors and to time the job cycle. The average cycle time of each job and the percentage of the work-shift the observed risk factors were present were calculated by multiplying the percent of time the risk factor was observed by the percent of time a given task occurred in a cycle. The findings for all observed risk factors are found in Appendix E. Two assumptions were made with regard to the calculations: 1) the risk factor observed during the sample time was present the entire time, and 2) a work shift was 480 minutes. It was not feasible to perform an interanalyst statistical test for reliability because analysts were not observing the same workers at the same time.

The four analysts observed four to six job titles at each company. At Company 1, workers were engaged in all six jobs, while at Companies 2 and 3, only four jobs were done. Each job cycle contained one to four tasks. Each analyst worked to observe each job up to 20 times. This target was not achieved for all observed jobs due to low production levels on the day of observation and inadequate time to complete observations during one shift. Table 1 presents the targeted and obtained observations for each company.

Table 1 Analyst Observations

Job Title	Number of Job Tasks	Targeted # of Observations Per Company			Obtained # of Observations Per Company		
		1	2	3	1	2	3
Sorter	1	80	80	80	80	80	80
Manual Tray Packer	4	320	320	*	140	260	*
Semi-Automatic Tray Packer	3	240	*	240	115	*	240
Manual Bagger	4	320	320	*	156	137	*
Semi-Automatic Bag Packer	2	160	*	160	160	*	160
Segregator	2	160	160	160	148	144	160

* Job was not performed at this company.

3.4.3 Lifting Hazard Analysis

The segregators who move filled boxes to pallets for shipping or storage engage in tasks that require considerable lifting. To assess the degree of risk to the segregators, two computer programs that predict lifting requirements were used: the NIOSH lifting model (NIOSH, 1991) and the University of Michigan 3D Static Strength Model (University of Michigan, 1993). The NIOSH lifting model was used to evaluate the segregator job for the potential for injury to the lower back. This model considers the frequency and distance of lifts and weight of the load. The University of Michigan 3D Static Strength Model was used to evaluate the forces and stresses on the upper body during lifts that occur above shoulder height. Despite the fact that the 3D model may underestimate risks from frequent lifting, it was deemed appropriate for analysis of segregating because the job included awkward back and upper body postures. Analyses were conducted for a 95th percentile male and a 50th percentile male lifting a 45 to 50 pound box.

Using the NIOSH lifting equation, the Lifting Index (LI) and Recommended Weight Limit (RWL) were calculated for segregators. The RWL is the object weight that would, most likely, not produce lower back discomfort for most workers. The Lifting Index (LI) is a ratio of lifted object weight to the RWL. A LI of one indicated that the lifted object weight equals the RWL. As the LI increases, the risk of low back injury increases. Only 1 percent of female and 25 percent of the male population could perform a lifting task with a LI of three without risk of injury. The LI is used to compare the relative severity of lifting risk for the purpose of evaluating and redesigning those jobs. For this study, the RWL was calculated by using measurements taken of segregators loading full apple boxes onto pallets. Measurements included the height of a stack, placement distance of the box, frequency of lifts, height of the conveyor, the angle of twist, and length of time spent lifting during the shift.

3.5 Outcome Measures

3.5.1 Injury Reports

The OSHA 200 Log information for calendar years 1994 to 1998 was collected from each participating company. Employers are required by federal law to report, via the OSHA 200 Log, all work-related injuries involving restricted or transferred work, lost time, or medical treatment requiring more than first aid. The number of reported musculoskeletal injuries was determined by summarizing all injuries and excluding all traumatic injuries including slips, trips, falls, or being caught in or struck by objects. Injuries were further sorted by body site injured.

Workers compensation incidence rates were also obtained for each participating company from the Department of Labor and Industries Public Disclosure Unit, as was the industry-wide rate for fruit and vegetable packing, risk class number 2104-02.

3.5.2 Subject Interviews

Information about study participant demographics, chronic health symptoms, and perceptions of risk was obtained via structured interviews. The interview format was adapted from a questionnaire developed by the SHARP program and included questions on work history, general health, and self-reported symptoms (Appendix C). In addition, questions about worker perception of work-related risks were added to the questionnaire. Risk perception questions were developed in collaboration with Karen Snyder, Doctoral Candidate in Anthropology at the University of Washington. Trained bilingual research staff members conducted interviews during regular work hours in either English or Spanish. Each interview took approximately 45 minutes.

3.5.2.1 Work History and General Health

The work history section of the questionnaire included questions about the participant's current warehouse job, past warehouse jobs, the number of years working in a fruit packing house, and the number of hours typically worked each week. Information about general health was also obtained with particular emphasis on conditions known or suspected to be related to WMSD, such as arthritis, joint problems, chronic disorders such as diabetes, smoking history, hobbies, and medication use.

3.5.2.2 Self-Reported Symptoms

This section of the questionnaire related to chronic pain or discomfort, particularly in neck, shoulder, elbow/ forearm, hand/wrist, back, hip, knee, and foot/ankle. Chronic symptoms were defined as those experienced during the preceding 12 months. The symptom location, onset, frequency, duration, severity, medical treatment, and amount of lost work time was recorded for each body part as well as activities that aggravated symptoms. A problem symptom was considered work related if it occurred at least once a week or lasted one week or more, did not start as the result of an acute trauma, occurred in the last year, and was first noticed on the current job.

3.5.2.3 Risk Perception

The risk perception questions were derived from previous research on risk perception of farmers and farm workers (Arcury 1995;Vaughan 1993) and consisted of three open-ended and two Likert-scale questions. The open-ended questions related to specific packing house tasks, actions an individual could take to avoid injury, and things a company could do to prevent injury. The interviewers were encouraged to fully record participant responses to open-ended questions. The Likert-scale questions (5 choices – "not likely" to "completely likely") related to effectiveness of safety precautions and likelihood of experiencing a work-related injury or illness.

3.5.3 Across Shift Body Discomfort

Acute changes in pain or discomfort were assessed pre-and post-shift with the aid of a diagram of the human figure or body map (Appendix D). Body maps have been used to describe areas of localized pain, discomfort, or fatigue (Borg, 1990; Corlett and Bishop, 1976) and provide an opportunity to characterize symptoms across several muscle groups. The body map used for this study was adapted from one developed by the SHARP program. Prior to starting the work shift, each study participant was asked to record the severity of any discomfort in 12 body sites. Severity was ranked on a scale of 1 to 5, with 5 indicating the most severe discomfort. At the end of the work shift, each subject completed a second body map. For example, a person might rate the neck as a 2 (mild discomfort) at the beginning of the shift and a 3 (moderate discomfort) at the end of the shift.

The pre- and post-shift discomfort severity for each participant was calculated by subtracting the pre-shift score from the post-shift score. The across shift change for all body sites was calculated by summing the pre- to post-shift change for each of the 12 body sites and dividing by the number of sites scored. Each of the 12 body site specific scores and the all-body site score were averaged for all participants in each of the six job titles. In addition, the body discomfort map was used as one measure to assess chronic discomfort by reviewing the number of subjects reporting high discomfort (a score of 4 or 5) at the start of the shift.

4.0 FINDINGS

4.1 Company Description

There are approximately 125 Washington State apple-packing companies (Teamsters 1997). Three Yakima valley fruit packing companies (Standard Industrial Classification 0723) participated in this pilot study characterizing the musculoskeletal hazards in the apple packing industry and worker self-reported work-related discomfort. For privacy purposes, the companies will be referred to as Company 1, 2, and 3. Data collection took place on April 20, April 29, and May 4, 1999 at companies 1, 2, and 3, respectively. The participating companies varied by size and the type of packing process used (Table 1). Companies 1 and 2 were similar in size but differed in the type of packing processes used, Company 2 used manual packing only. All companies housed packing operations in concrete tilt-up warehouses with concrete floors. The buildings were generally unheated, although area heating was provided in some parts of the warehouse. Workers were provided with lunchroom/break rooms.

Evaluations were conducted at each company during the first shift of the day (Company 3 was the only company operating 2 shifts). On the days of evaluation, Company 1 had 73 full time equivalent (FTE) workers and Company 2 had 52 FTE. Company 3 had 90 FTE per shift, or 180 production workers total. Based on the information collected on the days of sampling, an estimated daily production rate for each company was calculated by dividing the number of standard sized boxes packed on first shift by the number of FTE employees working on first shift (Table 2). The information regarding FTE and packed boxes varies daily; consequently, the production rate determined for the days of our evaluations may not reflect usual production or staffing levels.

Company 3 was the most automated of the three participating companies. Company 2 paid packers piece rate pay while Companies 1 and 3 paid straight salary. Workers at all companies had two 15-minute breaks and a 30 minute lunch period during an 8 hour work shift. None of the participating companies were unionized. Management at all three companies identified back injuries and upper extremity musculoskeletal disorders as occupational health concerns.

Table 2 Participating Company Overview

Co.	Fruit	FTE/ Shift	Company Reported Injuries	Packing Process	Pay Type	# Boxes Packed During Shift*	Daily Production Rate**** (Boxes/FTE)
1	Apples Pears	73	Slips/Falls Back and Wrist/Hand Injuries	Manual Tub Pack Semi-auto Tray Semi-auto Bag (stand)	Hourly Rate	2,678**	48
2	Apples Pears	52	Slips/Falls Back and Repetitive Motion Injuries	Manual Tub and Conveyor Pack	Piece Rate	3,733	72
3	Apples	90	Back and Wrist/Hand Shoulder Injuries	Semi-auto Tray Semi-auto Bag (sit)	Hourly Rate	4,609***	58

* Based on the number of standard boxes packed during observed 8-hour shift
** In addition 1,154 Costco boxes**,** 105 Wal-Mart bins, and 25 grocery store bins were packed
*** In addition 2,446 Costco boxes were packed
**** Production rate is calculated by dividing the number of standard boxes packed by the first shift FTE, assuming 1 tote = 16 standard boxes; 1 Wal-Mart bin = 1 standard box; 1 Costco box = 0.25 standard box.

4.1.1 Company 1

On the day of our evaluation 73 workers were present at the work site. Thirty-nine workers met the selection criteria for the study, and 95 percent of these volunteered to participate in the study. The company engaged in both manual and automatic packing. Workers packed in a standing position and primarily packed into three and five pound bags. A total of 8,352 three-pound bags and 13,665 five-pound bags were filled on the day of the site assessment. A total of 1,108 tray pack boxes; 1,570 bag boxes; 1,154 Costco boxes; and 130 other units (105 Wal-Mart bins and 25 grocery store bins) were filled. Agritech, Inc., manufactured the conveyor and packing line equipment.

4.1.2 Company 2

On the day of our evaluation 52 workers were present at this work site. Thirty-three workers met the selection criteria, and 91 percent of these volunteered to participate in the study. The company engaged in manual packing processes; workers were packing apples from tubs into trays and bags by hand. During the day of the site assessment, 3,505 standard sized boxes with trays and 228 boxes with bags were packed. Van Doren Sales, Inc manufactured the conveyor and packing line equipment. Workers were paid by piece rate at this company.

4.1.3 Company 3

On the day of our evaluation, 90 first-shift workers were present at the work site. Seventy-three workers at the company met the job title selection criteria. From the 73 eligible workers, 40 were selected randomly from workers in the job titles included in the study criteria. Thirty-two workers agreed to participate in the study (1 declined and 7 were found to be assigned at non-criteria jobs on the day of the study). Company 3 used an automatic packing process, primarily tray packing. During the first shift, 4,311 standard sized boxes with trays (3,608 boxes TP and 703 HP) and 2,446 one-layer Costco boxes were packed. Also 298 bag boxes (221 boxes of 3-pound bags and 77 boxes of 5-pound bags) were packed. The semi-automatic bagging was conducted at sitting stations. Van Doren Sales, Inc., manufactured the conveyor and packing line equipment. The company was in the process of installing several new packing lines, but these lines were not in operation at the time of this study.

4.2 Study Participants

A total of 105 workers across all three companies agreed to participate in the study. Twenty of the participants were working in the job title of sorter, 67 were working as packers, and 13 were working as segregators. Five workers from Company 3 were not engaged in sorting, packing, or segregating on the day of the evaluation and were excluded from further analysis. The number of sorters participating in the study ranged from five to nine per packing house, while the number of packers and segregators ranged from 22 to 23 and three to five respectively (Table 3). The sorters' mean age for Company 1 (57 years old) was considerably higher than the other two companies. The mean age of packers was high (45 years old) at Company 2. The female/male ratio of participants was similar in all companies, but the proportion of Hispanic workers who participated from each company varied between 22 and 100 percent. Most packers and sorters were female, while nearly all segregators were male. Subjects had been employed in the industry for seven to 18 years on average, although segregators tended to be more recently in the industry. Fifteen workers (15 percent) reported working second jobs during the packing season. Other jobs included orchard work (seven), other fruit/vegetable packing (two), and custodian (two). Outside activities, such as sports, crafts, and other hobbies, that might have musculoskeletal hazards were reported by 64 percent of workers, with an average duration of 5 hours per week. Ninety-eight percent of the workers were right handed.

Table 3 Study Participants

Company	Job Title	N	Mean Age (Range)	Percent Female	Percent Hispanic	Years at Packing Houses Mean (SD)	Second Job* # (%)	Other** Activities # (%)
1	Sorter	9	57 (43-69)	100	0	12.1 (12.1)	0 (0%)	7 (78)
	Packer	23	37 (19-67)	78	22	6.3 (5.8)	2 (9%)	17 (74)
	Segregator	5	28 (19-48)	20	60	4.7 (3.6)	1 (20%)	4 (80)
Total-1		**37**	**40 (19-69)**	**76**	**22**	**7.6 (7.9)**	**3 (8%)**	**28 (76)**
2	Sorter	6	48 (28-62)	100	67	14.0 (10.1)	1 (17%)	3 (50)
	Packer	22	45 (22-75)	100	55	20.5 (15.7)	4 (18%)	14 (64)
	Segregator	3	28 (25-32)	0	100	2.5 (2.3)	0	3 (100)
Total-2		**31**	**44 (22-75)**	**90**	**61**	**17.5 (14.9)**	**5 (16%)**	**20 (65)**
3	Sorter	5	45 (27-57)	80	100	5.4 (5.7)	1 (20%)	3 (60)
	Packer	22	38 (18-66)	91	100	8.4 (3.9)	2 (9%)	9 (41)
	Segregator	5	26 (23-31)	0	100	0.3 (0.2)	4 (80%)	5 (100)
Total- 3		**32**	**37 (18-66)**	**75**	**100**	**6.9 (5.1)**	**7 (22%)**	**16 (50)**
TOTAL		**100**	**40 (18-75)**	**80**	**59**	**10.3 (10.8)**	**15 (15%)**	**64 (64)**

* second job held during packing season; does not include those working elsewhere during non-packing season.
** Other activities include ball sports, auto repair, gardening, fishing, wood shop, shooting, knit/sew/crochet, craft work, walking, running, bowling, biking, musical instrument

4.3 General Findings

Some of the study survey instruments were designed to assess long-term health effects while others measured activities that occurred the day observations were made. Packing house workers may be assigned to different jobs on different days depending on production needs, resulting in a mixed job title history for many workers. Therefore it was not possible to analyze specific job titles for long-term exposure or outcomes. The findings are organized with long-term and general effects presented first, followed by more detailed findings for specific job titles.

4.3.1 Company-Reported Injury Rates

Each participating company provided OSHA 200 incidence logs (described below) for the years 1994-1998. Companies also gave the Field Group permission to contact the Department of Labor and Industries to obtain workers' compensation rates for their companies for the years of interest. The company-specific rates were obtained in order to compare state-reported workers' compensation rates to company-maintained OSHA 200 rates as well as to the fruit and vegetable packing risk class workers' compensation rate. Apple packing houses are categorized in the fruit and vegetable packing risk class; consequently, the industry-wide rate may not be an accurate reflection of the workers' compensation experience of apple packing houses alone.

The OSHA 200 log is an injury reporting form completed by each company annually to meet state and federal record-keeping requirements. All "recordable" injuries must be listed on the form. An injury is considered recordable if it is work-related; is a fatality, or a work-related illness; results in loss of consciousness, restriction of work, transfer to another job, or lost workdays; or requires medical treatment beyond first aid. The OSHA 200 annual work-related injury incidence rate is calculated by dividing the total number of reported injuries by the total hours worked by all company employees during the reference year (L&I, 1997). The annual state-reported workers' compensation claim rate is based on the number of workers' compensation claims accepted for payment divided by the total employee hours worked that year.

The industry-wide workers' compensation rate has been decreasing over the past several years. Companies 1 and 2's state-reported workers' compensation claims rates have also been decreasing, with Company 1 down from 25.9 in 1994 to 15.5 in l998 and Company 2 having a similar reduction from 20.4 to 7.5 over the same time period (Table 4). Company 3's workers' compensation rate increased from 9.1 in 1994 to 16.3 in 1998. Change in rates could be influenced not only by the number of injuries occurring, but also by an increased number of new workers (who often have an increased injury rate), by a change in worker awareness, or by an increased willingness to report injuries or initiate a claim. Company 3 experienced a significant increase in both production and process automation during this period. The OSHA 200 rates are similar to the workers' compensation rate for Companies 1 and 2, but Company 3 workers' compensation rates are higher than the OSHA 200 rates.

Table 4 Workers Compensation and OSHA 200 Rates

Year	Company 1		Company 2		Company 3		Industry Wide WC Rate**
	WC	OSHA200	WC	OSHA200	WC	OSHA200	
1994	25.9	25.9	20.4	17.9	9.1	2.0	22.2
1995	28.2	29.2	12.5	7.5	9.0	3.9	19.5
1996	25.2	22.4	14.4	12.9	14.2	2.6	19.3
1997	19.5	19.5	14.6	15.9	12.2	*	17.9
1998	15.5	19.9	7.5	7.5	16.3	3.0	16.3

WC = state reported workers compensation claims rate
OSHA 200 = company reported recordable injury rate
rates are number of injuries per 100 full-time workers
* Incomplete OSHA 200 log
** Includes all fruit and vegetable packing houses statewide

<u>Musculoskeletal Injury Reporting</u>. The companies OSHA 200 logs were further reviewed to identify injuries of a musculoskeletal nature over a five-year period. Only injuries of a strain, sprain, or repetitive character were included in this portion of the analysis. Accidents involving slips, trips, falls, or being struck by or caught in objects were excluded from this analysis. The musculoskeletal injury rate was calculated using the same method discussed above (L&I, 1997). Injuries were most frequently reported to the back, wrist/hand, and shoulder (Table 5). The OSHA 200 data could not be analyzed by job type because of inconsistencies in injury recording within and between companies.

Table 5 OSHA 200 Musculoskeletal Injury Rates by Body Site (1994-1998)

Company	Total OSHA 200 injuries	MS Injuries (%)	MS Injury	Back Injury	Wrist/Hand Injury	Shoulder Injury	Neck Injury	Other MS Injury
1	52	36 (69)	16.4	6.8	5.4	0.5	0.9	2.7
2	48	19 (40)	5.0	1.1	0.5	1.1	0.8	1.6
3	63	22 (35)	0.8	0.5	0.1	0.1	0	0.1
Total	163	77 (47)	2.2	0.9	0.5	0.2	0.1	0.5

rates are number of musculoskeletal injuries per 100 full-time workers

4.3.2 Subject Interviews

Study subjects were interviewed to obtain information with regard to their work and general health history, self-reported symptoms, and their perception of health and safety risks at work.

<u>4.3.2.1 General Health History</u>

Study subjects were asked about height and weight, whether they had ever had certain disorders diagnosed by a medical doctor, and whether they were currently taking any medication for pain. Ten subjects reported a tendonitis diagnosis (two sorters and eight packers) and six reported a carpal tunnel syndrome (CTS) diagnosis (six packers). Most of these disorders were reported by workers from Company 2 (five CTS and six tendonitis), with the remaining cases from Company 1. Current use of pain medication was reported for discomfort related to the back (15), hands (two), wrist (two), neck (five), arms (four), shoulder (four), and headaches (four).

Certain diseases or conditions, including diabetes, thyroid conditions, and high blood pressure, may predispose a person to musculoskeletal disorders (Putz-Anderson, 1988). The percent of study participants who reported these disorders was compared with the prevalence of each disease in the U. S. population. The study population's self-reported rates of high blood pressure, and thyroid conditions were similar to those reported in the United States population (Table 6). Diabetes rates were similar to published rates of various groups of US women (American Heart Association 2001, Resnick 2000, Canaris 2000).

Table 6 Participant Health Conditions Compared to U.S. Population

Condition	Study Population	U. S. Population
Diabetes	7%	
Diabetes (non-Hispanic white females)		5%
Diabetes (Mexican-American females)		11%
High blood pressure	19%	20%
Thyroid Condition	10%	10%*
Overweight or obesity	67%	55%

* up to 10% of women

Study participants' height and weight were used to calculate a body mass index. Overweight subjects were identified based on body mass index ranges. The study population was classified 67% overweight or obese compared to 55% for the general United States adult population. A modest increase in low back pain risk has been found for high body mass index (Leboeuf-Yde, 1999). There may be a somewhat higher risk of low back pain for this study group compared to the general population because of the greater proportion of overweight subjects.

4.3.2.2 Self-Reported Symptoms

The self-reported symptoms section of the interview questionnaire included questions about problems with the neck, shoulder, back, elbow/forearm, hand/wrist, hip, knee, foot/ankle, and related workers' compensation claims. A problem was defined as more than three occurrences or one occurrence that lasted more than one week within the last year. A work-related health problem was reported for at least one body site by 53% of the participants. Subjects indicated that pain or discomfort in the back, shoulder, neck, and hand/wrist were the most frequent and serious problems. More than half of back, hand/wrist, and shoulder injuries were work-related. Most problems were reported to be from chronic rather than acute (sudden) injuries. For example, only 8 of 48 back problems reported were from acute (sudden) injuries. Subjects often reported first noticing their musculoskeletal problems while working at their current job (Table 7).

Table 7 Symptom Reporting by Body Site

Body Site	N	# Workers Reporting a Problem	Problem Work Related	Problem from Sudden Injury	Problem First Noticed on Current Job	Most Problematic Body Site
Back	98	48	26 (54%)	8 (16%)	35 (73%)	25 (52%)
Shoulder	98	38	21 (55%)	8 (21%)	35 (92%)	15 (39%)
Neck	99	30	13 (43%)	10 (33%)	19 (63%)	12 (40%)
Hand/Wrist	94	38	20 (53%)	9 (24%)	29 (76%)	12 (32%)
Elbow/Forearm	99	30	7 (23%)	6 (20%)	23 (77%)	8 (27%)
Hip	99	22	8 (36%)	10(45%)	19 (86%)	4 (18%)
Knee	99	19	8 (42%)	6 (32%)	12 (63%)	5 (26%)
Foot/Ankle	99	23	7 (30%)	6 (26%)	15 (65%)	6 (26%)

4.3.2.3 Risk Perception

One hundred participants completed the risk perception interview questions. Sixteen percent of the workers stated that they had no concerns about their jobs. The remaining 84% listed 180 different concerns. Of those, one half of the responses referred to specific movements resulting in body pain. Generally, workers were similar in their reporting of work activities that they perceived to be risk factors for upper body discomfort. Some examples of the responses to the open-ended questions about activities that cause musculoskeletal pain included:

> *"Repetitive motion – going to get joint ache and muscle ache."*
> *"Lifting and turning apples and putting them in the bins hurts my wrists."*
> *"If you pick up a box wrong, you could get hurt."*
> *"When the boxes or the trays are stuck, we have to pull them."*
> *"Your back has a lot of wear and tear from bending."*

One quarter of the responses referred to air quality factors, such as chlorine, carbon monoxide, and other airborne contaminants. Other concerns included wet floors, equipment safety, noise, temperature, and work pace. Overall, responses to the question "what specific tasks of your job do you think are hazardous?" were similar across all workers. While most workers at each company identified musculoskeletal hazards, differences in risk perceptions between companies may be related to the type of equipment, plant layout, type of salary, and degree of automation.

The proportion of responses that identified musculoskeletal risks as a hazard was somewhat lower in Company 1 than in Companies 2 or 3. Air quality hazards were raised more frequently in Company 1 than at the other two companies. Workers at Company 1 also identified equipment malfunctions, unprotected sharp edges, and awkward height of machinery as hazardous.

Company 2 had a different production layout and pay structure. Packers were paid piece rate and many packers said they preferred a faster production pace because they had more control over their income. Packing materials, such as unfolded boxes, trays, and tissues, were stacked on the ground and on racks above each packer. Concerns about hand and wrist pain were lowest in Company 2, but these workers did cite problems with bending and reaching for materials.

Company 3 was the most automated and both workers and management emphasized "production" as a priority. In addition, all the machinery was quite new. Two thirds of the responses for workers from Company 3 related to body pain. Female packers listed bagging 10 pound bags of apples as hazardous, as well as pushing and pulling stuck boxes and trays out of the machinery.

Worker Actions to Prevent Injuries: Workers were asked to list things that they could do to prevent injuries or exposures at work. One quarter of participants said that there was nothing that they personally could do to prevent an illness or injury at work. One half of these responses came from Company 1. One third of all the recommendations for health and safety improvements were general comments about personal responsibility with regard to safety, such as "be careful" or "watch out". These comments were probably directed at avoiding acute accidents, rather than chronic musculoskeletal disorders.

Other themes raised by the question, "what can you do to prevent injuries?" included properly handling materials, using good work practices, maintaining clean floors, following company rules regarding restricted areas, informing management of problems, using personal protective equipment, and following the dress codes. One quarter of Company 1 participants suggested that it was important to make time for recovery from the work tasks, such as resting at home to conserve muscles for work. They also indicated a need to be properly trained to do the job, and especially how to lift properly. Workers in Company 3 mentioned the need to maintain a reasonable work pace and not push too hard. Packers from Company 2 and Company 3 mentioned the need to avoid lifting materials from floor level, while Company 3 workers mentioned the need to limit the weight of bags of apples as well as avoid pushing and pulling stuck trays and boxes out of the machinery.

Company Actions to Prevent Injuries: Workers were asked about things that they believe the company could do to prevent exposures or injury at work. Fifteen percent of the participants stated that there was nothing the company could do to make the workplace safer. Non-negative responses to the question were divided between things the companies already were doing to keep workers safe, and things they should do to improve workplace safety. Participants stated that their employers already had rules, safety meetings, and provided personal protective equipment such as gloves. Workers also mentioned that companies warned workers to be careful, posted signs, and conducted training sessions on safe work practices.

Workers made several suggestions to improve the health and safety of the workplace including improving the ventilation, modifying the location of packing materials, and slowing the pace of work. Purchasing new equipment or repairing existing equipment, improving forklift safety, and keeping the warehouse floors clean were also mentioned. A number of workers stated that women should not have to do heavy work such as lifting boxes. Workers also suggested the companies consider reducing the weight of the boxes, ensuring that the distribution of work among workers was fair, increasing the number of workers, and investigating job rotation.

4.3.3 Across Shift Body Discomfort

A body discomfort survey was administered to participants at the beginning and end of the shift on the same day that job observations were conducted. The pre/post shift discomfort map was administered to a total of 16 sorters, 49 packers, and 8 segregators. Each participant was asked to rate their comfort/discomfort on a scale of 1-5 (1= happy face; 5= frowning face) on 12 parts of a body map. Participants were also asked to record the specific job they were assigned to for that day. Work assignments varied somewhat from day to day depending on production requirements, especially for packers who may pack trays one day and bags the next. On the day of sampling at Company 2, some packers packed both bags and trays that day and were designated as "manual packers".

The pre/post shift discomfort survey was designed to characterize self-reported symptoms that may be related to or exacerbated by that shift's work activities. Since this tool was designed to measure discomfort for only one shift, the specific job assigned for that shift could be assessed. For example, the different packer types could be differentiated with this survey tool. In contrast, the self-reported symptoms interview addressed symptoms that occurred over time and did not differentiate between specific symptoms that might relate to one specific job.

The mean change in discomfort across the shift for each of the 12 body sites was calculated for each job category (Table 8). A mean change value of +1 across the shift indicates that a worker scored that body site one rank higher (higher = greater discomfort) on average at the end of the shift than the beginning of the shift. Semi-automatic packers had by far the highest across shift discomfort rating with a mean of 1.4 for all body sites, while sorters and manual packers both had a mean change of 0.5. Segregators had very little change from pre- to post-shift (all-body site mean of 0).

Table 8 Self–Reported Across Shift Discomfort

Job Type	N	Across Shift Change-All Body Sites Mean (SD)	Highest Risk Body Sites					
			Lower Back	Upper Back	Hand/ Wrist	Neck	Shoulder	Elbow
Sorter	11	0.5 (0.6)	0.8	1.4	0.8	1.1	1.5	0.8
Manual Packer	20	0.5 (0.6)	1.0	0.9	0.6	0.6	0.6	0.4
Semi-Automatic Packer	17	1.4 (1.1)	1.7	1.9	1.6	1.3	1.8	1.4
Segregator	8	0.0 (0.6)	0.0	0.0	0.5	-0.3	-0.1	0.3

4.4 Job Specific Findings

Despite similarities in the overall production processes across all companies, there were substantial differences in specific aspects of some of the work. The work tasks performed by sorters and segregators and their work station configurations were similar at all three companies. However, differences were found in packing tasks, equipment, and work station layouts across the companies. Because of these differences in packer tasks, the job title "packer" was subdivided into manual vs. semi-automatic and by the type of container (bags or trays).

4.4.1 Sorting

The number of workers sorting fruit at an given packing house ranged from 6 to 12 on average. Sorters had worked in the industry for an average of 10 years (Table 3). The sorting tables consisted of a cross-flow rolling table situated at a height of 36 to 38 inches and a width of 19 to 22 inches. Fruit judged to be minority grade was placed on one of two smaller conveyor belts located above the sorting table at a distance of 21 to 24 inches. Culls and damaged fruit were tossed down a chute located to the side of each worker at the rim of the sorting table. Rotten fruit was tossed into a bucket located on the floor near the sorter. Workers were observed frequently bending and twisting their necks while inspecting the apples. Some shorter sorters stood on a wooden box to reduce their reach to the fruit. Chairs or stools were provided for some sorters; however, most sorters were observed standing throughout the shift. Floor mats were seen at some workstations, with varying degrees of cushioning quality to serve for anti-fatigue purposes. Workers at Company 3 placed bubble wrap padding on edges of the sorting table to reduce pressure points from sharp edges.

The sorting cycle consisted of only one task: picking up an apple and placing it on a conveyor, chute, or bucket. The full cycle took a mean time of 3 seconds, with Companies 1 and 3 lasting 2 seconds, while Company 2 lasting 4 seconds (Table 9). Variability might be explained by the quality of fruit processed that day. The production rate was highest at Company 2.

Table 9 Mean Cycle Time Sorting Apples, by Company

Job	Description of Tasks	All Companies			Company 1			Company 2			Company 3		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Sorter	Inspect apples	238	3	4	80	2	2	60	4	7	78	2	2

NOTE: Mean time is in seconds

Figure 2 Sorter with Extended Reach to Place Apple on Conveyor

4.4.1.1 Job Task Observations

The primary risk factors related to sorting included neck position, static standing posture, and upper extremity motions of the hand/wrist, forearm, and elbow (Table 10). The results of the observations show that workers were sorting apples with their neck flexed >15 degrees during most of the shift (85% of shift time). Sorters were also standing stationary 67% of the shift time. Other predominant risk factors include: hand deviation, forearm twisting, elbow extension and wrist flexion/extension. Of hand/wrist postures, hand deviation occurred most frequently, and sorters spent more time deviating the right hand more (68%) than the left hand (52%) (Appendix E). Across the three companies, the majority of the risk factors on the right side were greater than the left side. Some sorters preferred to use gloves during sorting. The influence of gloves on dexterity and grip force was not assessed. Some workers from all companies spent some time leaning their torso onto the edge of the table while sorting.

Table 10 Percent of Shift Risk Factors were Observed – Sorters

Body Part	Risk Factor	% of Shift
Neck	Neck extend/flex>15deg.	85%
Hand/Wrist	Hand Radial/ulnar deviation	60%
	PPE-gloves/wrist band	32%
	Wrist flex/extend	31%
	Hand Pinch grip	18%
Elbow	Forearm twist/rotate	39%
	Full elbow extension	38%
Back	Stand stationary	67%
	Sitting	23%
	Torso contact stress	17%

4.4.1.2 Self-Reported Symptoms

Fifty-seven percent of sorters interviewed reported a work-related problem for at least one body site. The following criteria for work-relatedness was used: 1) occurred at least once a week or lasted one week or more, 2) did not start as the result of an acute trauma, 3) occurred in the last year and 4) was first noticed on the current job. Nearly half of back and shoulder problems were classified as work-related (Table 11). Most notably, not all work-related problems had workers compensation claims filed. Fifty-five percent of the reported back symptoms were severe enough to seek medical treatment in the last year. Nine of 20 sorters reported neck symptoms; however, 5 of these cases were due to a sudden injury. Sixty-six percent of the sorters with hand/wrist symptoms reported similar symptoms to that often used to describe carpal tunnel syndrome (pain that caused they to awake from sleep or pain up arm). Hand/wrist, neck, and back problems were most severe in terms of workdays missed with 25, 14, and 11 days missed, respectively. The sorters who experienced days of missed work reported that their hand/wrist problems began when they were working as packers. More hand/wrist problems (3 additional) would be classified as work-related if the criteria were expanded to include problems first noticed during a packing job (sorting is often considered a light duty job for injured packers). One-third of the sorters reported that their hand/wrist and back symptoms affected the pace they could work.

Table 11 Self-reported Symptoms – Sorters (n=20)

	Back # (%)	Hand/Wrist # (%)	Neck # (%)	Shoulder # (%)	Elbow # (%)
Problem reported (no.)	11	9	9	11	3
Problem work related	5 (45%)	2 (22%)	1 (11%)	5 (45%)	0
Workers comp claim filed	3 (27%)	2 (22%)	0	2 (20%)	0
From sudden injury	1 (9%)	3 (33%)	5 (55%)	1 (10%)	0
Started with current job	6 (5%)	6 (67%)	4 (44%)	8 (80%)	1 (33%)
Pain down leg	1 (9%)	NA	NA	NA	NA
Pain down arm	NA	NA	4 (44%)	NA	NA
Pain wake from sleep	NA	5 (56%)	NA	NA	NA
Pain up arm	NA	1 (11%)	NA	NA	NA
Trouble opening jars	NA	9 (100%)	NA	NA	NA
Medical treatment in last year	6 (55%)	4 (44%)	2 (22%)	3 (30%)	0
Missed work	3 (27%)	2 (22%)	2 (22%)	1 (10%)	1 (33%)
Total person-days work missed	11	25	14	2	2
Affected work pace	4 (36%)	3 (33%)	NA	NA	NA
Had surgery	1 (9%)	2 (22%)	0	1 (10%)	0

NA – not asked

4.4.1.3 Risk Perception

Sorters noted they were most concerned about hand and wrist and other repetitive motion. Also, sorters were more likely to complain of problems with their arms as compared to other workers. Sorters from Companies 1 and 3 suggested that slowing the work pace would be useful in preventing injuries.

4.4.1.4 Across Shift Body Discomfort

Sorters indicated that the areas of greatest across shift discomfort were the upper back, shoulders, and neck (Figure 3) with the upper back and shoulder producing highest across shift discomfort scores, 1.4 and 1.5, respectively (Table 8). The across shift discomfort score for the neck was 1.1.

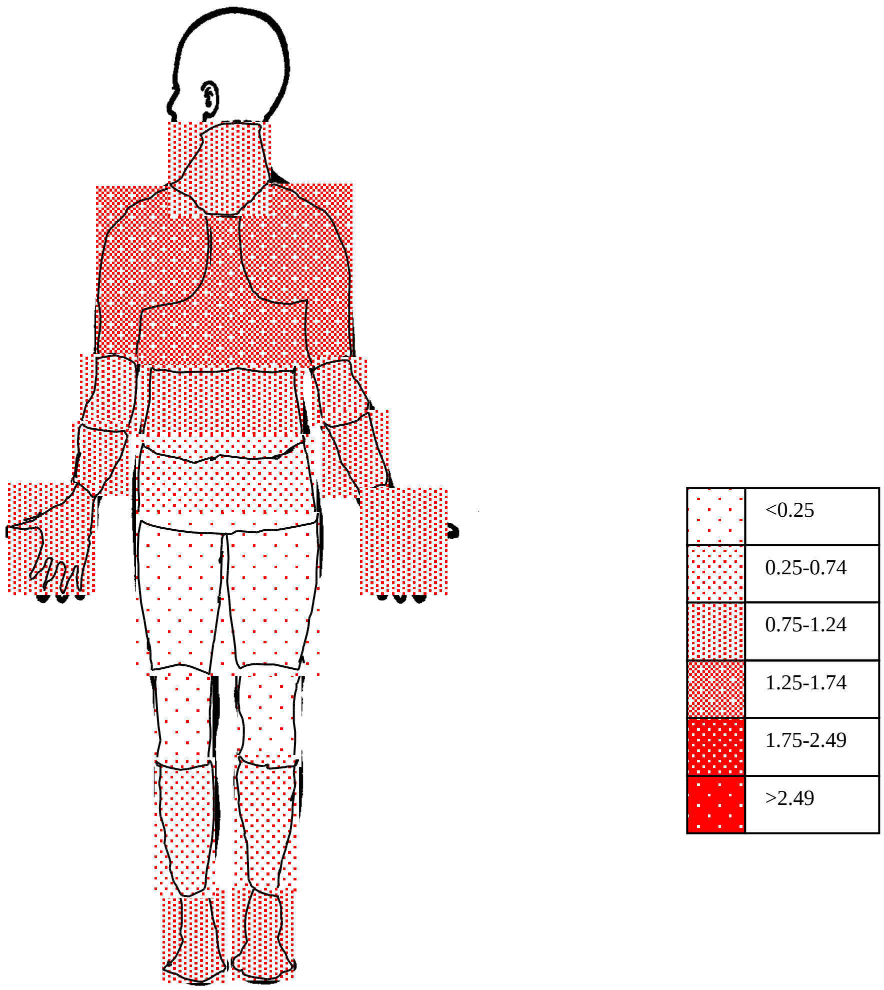


Figure 3 Sorter Across Shift Body Discomfort Map (n = 11)

4.4.1.5 Discussion of Sorting Job

Little ergonomic research and intervention have been done from a human factors perspective in agricultural workplaces. In fruit and vegetable warehouses, the task of sorting has received the most attention; however, this research has focused on the physical design parameters of equipment, productivity and work schedule of the sorter, and on the quality of the fruit inspected (Malcolm and DeGarmo, 1953; Nicholson, 1985; Prussia and Meyers, 1989; Meyers 1990; Bollen, 1986; Bollen, 1993; Colquhoun, 1959; Purswell and Hoag, 1974; Faulkner and Murphy, 1973; Miller, 1991). For example, one study found that the rate at which fruit can be sorted is affected by the type of defect (Bollen, 1993). Values range from around 5 fruit per second for simulated products with few defects to one to two fruit per second for real fruit. Another study reported that sorting efficiency decreases if a sorting table is wider than 0.75m (30 inches) (Bollen, 1986). And other ergonomic principles have been found to be important, such as visibility of the table and viewing location of the product (e.g. directly approaching the sorter vs. the side) (Nicholson, 1985; Meyers, 1990; Prussia and Meyers, 1989). Zegers (1989) provides a discussion regarding the mental workload of a sorter, but does not provide any data to support this opinion. Studman (1998) systematically measured physical discomfort among apple sorters and their performance while using a new apple handling system that passed apples directly in front of the sorter. Sorters preferred to work on a table designed so that maximum forward reaching distance was reduced and to sit rather than stand. Sorters also reported a high number of cases of neck and shoulder discomfort at the end of the shift. The Studman study was unable to detect changes in sorter performance due to changes in table design.

Our study is the first to characterize the ergonomic hazards in apple sorting. Sorters' posture at the sorting table, the reach required to pick up and deposit apples, and the repetition of the task pose a hazard to these workers for neck, hand/wrist, shoulder and back injury. Most sorters lean slightly forward with bent neck and maintain a constant static posture. This position fatigues the neck and back and, since there is no change of posture, the muscles do not have time to recover between muscle contractions. Shoulder discomfort could be related to reaching to the far end of the conveyor and lifting the hand above the shoulder to deposit apples on high conveyors.

Our findings show that more than 50% of sorters reported at least one problem relating to the back, hand/wrist, neck, and/or shoulder and that at least 25% of sorters reported a problem that met our definition of work-relatedness. The symptom survey identified back and shoulder as the most frequently reported work-related problem. Other work-related problems were reported in the hand/wrist and neck sites. This was in basic agreement with the discomfort map where upper back, shoulder, and neck had the highest across shift scores. The discomfort map is an indicator of how workers feel after a given day of work, and it provides body-site specific detail. For example, workers self reported the back as a problem, and the discomfort map results supported this. It is clear that the upper back and shoulder region should be targeted for intervention. Studman (1998) also found that 39% of sorters reported neck, shoulder, and upper back problems and 30% reported lower back and hip discomfort before initial changes were made to the system. Although the studies were designed for different purposes, our findings regarding the location of symptoms (with the exception of hands/wrist) and discomfort level among sorters are in general agreement with Studman (1998).

Although hand/wrist problems appeared to be most severe based on the number of work-days lost in the last year, they did not score as high as the back, neck, or shoulders on the discomfort map. Sorting is considered a light duty job in all three of these packing houses and injured packers are often assigned to sorting during recovery. Additionally, there are reports in the literature that it is a common practice for long-term packers to change jobs to graders/sorters because of the strain of standing all day (Smith, 1963).

Job task observations documented that sorters frequently engaged in hand, arm, and neck postures that could cause injury with highly repetitive tasks. Given a cycle time of 2-4 seconds, a sorter could possibly perform 7,000-14,000 cycles in a shift. Although the force of lifting apples during sorting is low (<1kg/hand), the repetition of stereotypical movements is one of the primary risk factors of sorting apples. High rates of work, such as 7,600 to 12,000 exertions per shift, were a major factor associated with upper extremity disorders among workers in a tea packing industry (Kurppa 1979). In addition to repetition as a risk factor, observations showed that sorters are exposed to the following risk factors: neck extension/flexion, standing, hand deviation, forearm twisting, full elbow extension, and wrist flexion/extension. Although risky shoulder postures were not frequently observed, static standing postures combined with observed forearm and elbow motions, and repetition could produce shoulder fatigue and potential injury. Ohlsson, (1989) found an increased prevalence of subjective complaints in the neck and upper extremities that increased with duration of employment among workers with exposures to repetitive movements and a fixed body posture. This suggests that a company with a very stable worker population, such as Company 2 (mean of 18 years at packing houses), could expect more complaints and potential for injuries with sorting.

The results from the job task observations and symptom questionnaires are only in partial agreement. Sorters reported that back and shoulder were the major body parts of concern from both an acute (body map) and chronic (symptoms as work-related) level. A few risk factors that may contribute to shoulder and back pain were found in the observations (e.g. standing stationary, forearm twist, elbow extension), but problems were found to be greater for other body parts (neck or hands/wrist). Several explanations are possible: 1) analysts observed awkward postures in the neck but the actual symptoms may be felt by workers in the shoulders and upper back region, 2) all companies reported that their light-duty job is sorting, and therefore, some of the symptom reporting by sorters may have been due to non-sorting jobs, 3) the observational checklist has several limitations, which is why it is important to have several measurement methods. Muscle strength testing may be useful to assess job demands and maximum capacities of the various muscle groups that are used specifically during sorting.

4.4.1.6 Washington Ergonomics Rule – Sorter Job

The sorting job was reviewed from the perspective of the Washington State Ergonomics Rule. According to the Ergonomic Rule, a job must first be evaluated to determine whether or not it has tasks that meet the criteria for a "caution zone job" (CZJ). If the job meets the CZJ criteria, it should be further evaluated to identify specific hazardous tasks that can be feasibly remediated. The sorter job was evaluated according to these criteria.

"Caution Zone Job" Criteria

Task Description	Risk Factor	Caution Zone Job?
Pick up apple and move to high conveyor (hand above shoulder) or bin to the side every 2 seconds- 7,000-14,0000/shift	Highly repetitive; awkward neck postures; elbows elevated	Yes

Since the sorter job was found to meet the CZJ criteria, it was further evaluated for specific WMSD hazards. This analysis was done using the criteria from the Specific Performance Approach described in WAC 296-62-05130-Appendix B.

Sorter Job Hazard Analysis

Task Description	Hazard Categoryand Criteria	Is Task Hazardous?
Pick up apple and move to high conveyor (hand above shoulder) or to bin at side every 2 seconds-7,000-14,0000/shift	Highly repetitive-same motion >6 hours/shift?	Yes
	Awkward neck posture shoulders – raising elbow above shoulder >1/minute?; neck bent 45º?	No

According to the criteria outlined in the Ergonomic Rule, hand repetition was above the hazard level for the sorting job and the employer should take action to reduce the hazard.

4.4.1.7 Sorter Recommendations

Reducing hand repetition below the hazard level may be possible through the implementation of regular job rotation. Rotating sorters during the day to other jobs involving less hand repetition may help to mitigate this risk factor. The static posture of the back and neck exhibited by sorters could be relieved if these workers periodically changed from standing to sitting, as was observed in some packing houses. Another way to provide periodic relief from high repetition and static postures would be to provide a micro-break. Colombini (1998) recommends micro-breaks of 10 minutes for every 60 minutes of repetitive work. These micro-breaks could include lunch, regular required break periods, work on non-sorting tasks, as well as periods when the conveyor is down for maintenance or product changes. During these times workers should be encouraged to change positions and stretch. Purswell and Hoag (1974) found that changing a conventional 8-hour shift to a work day with 5 minute breaks every 30 minutes improved sorting accuracy to 85% throughout the day as compared to 60% accuracy during a conventional work day without micro-breaks. Regular rotation in the sorting line position could also make subtle but important changes in worker body posture.

The addition of a foot rail would allow sorters to intermittently stand on one foot with the other foot elevated; this has been found to be useful in reducing back fatigue in other applications (Eastman Kodak Company, 1983). The elbow and shoulder risks could be limited by reducing the width of the conveyor, thus reducing elbow and shoulder extension. Companies in New Zealand have tried new methods of sorting such as using a cascade conveyor sorting technique (Studman, 1998) which reduces the extended reach observed in sorting. Finally, the industry might consider exploring a torso support, an application that has been used in other industries to support a forward bent posture.

Sorting involves standing in one position for long periods. This can lead to fatigue or discomfort in the lower extremities and back. Anti-fatigue floor mats or cushioned shoe inserts can reduce this fatigue or discomfort. Following are some suggestions for floor mats and platforms:

- mats should compress but not too much – see Appendix G for evaluation of comfort for various mats
- mats should have beveled edges, a non-slip surface, and should not slip on the floor
- if mats must be removed for cleaning, large mats are difficult to handle
- if the workstation is on a raised platform, the surface should be resilient rather than rigid (wood or plastic, not steel). The platform should also have a high ratio of surface to holes (not standing on "knives")

4.4.2 Segregators

The number of workers in each company segregating filled boxes on pallets ranged from three to five workers. Companies 1 and 3 located their segregation activities in the same area as their packing operations, and Company 2 segregated boxes in a separate and colder (45^{o} F) area away from the packing facility. A conveyor system delivered packed boxes to the segregation area. Boxes weighed 40-50 pounds with the industry-standard weight being 42 pounds. One segregator pushed a row of boxes on a roller conveyor to other segregators. The other segregators manually lifted boxes off of the conveyor and placed them on designated pallets. The workers rotated between pushing the boxes on the conveyor and stacking the boxes. The boxes were stacked seven layers high with the seventh layer at 80 inches from the floor. Completed pallets were secured with twine and the pallets were transported by forklift to controlled atmosphere storage or shipping. The conveyor heights were 29-30 inches. Two to three rows of pallets were arranged on each plant floor. The amount of room between pallets (for maneuverability) varied at different packing houses. Approximately 20 to 30 pallets are located in a row depending on production needs and area available.

The segregation cycle consisted of two tasks: pushing or pulling the box on a roller conveyor towards the pallet, and picking up the box, carrying it to a pallet, and positioning it on the pallet. The full cycle took a mean of 8 seconds at Companies 1 and 3, and 9 seconds at Company 2 (Table 12). The boxes were delivered to the segregation area sporadically and there was sometimes a short break between cycles while workers waited for another box. The average frequency of segregator lifts per minute was 4, with the highest frequency observed being 7. At a rate of 4 lifts per minute, a segregator who was stacking boxes for half of the shift (pushing boxes on conveyor the other half of shift) could lift as many as 1,000 boxes in a shift.

Table 12 Mean Cycle Time Segregating, by Company

Job	Description of Tasks	All Companies			Company 1			Company 2			Company 3		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Segregator	Manually roll box	162	4	3	66	4	2	37	5	4	59	4	3
	Pick up box and carry	192	4	3	70	4	2	62	4	3	60	4	2
	Total Cycle Time		8			8			9			8	

NOTE: Mean cycle time is in seconds; SD - Standard deviation

Figure 4 Segregator Stacking Box on Top Layer of Pallet

4.4.2.1 Job Task Observations

The most problematic risk factors associated with the segregation job were observed when workers stacked full boxes on a pallet. A variety of body postures and activities could produce fatigue and injury, primarily to the back, shoulders, elbows, and wrist. Pushing or pulling the box down the roller conveyor could also stress the back, elbows and wrists. The major risk factors identified from job task observations included: lifting, pushing/pulling, torso twisting, and wrist deviation (Table 13). In most cases, the risks were greater for the right side of the body than the left side (e.g. 41% pinch grip-right vs. 25% pinch grip-left) (Appendix E). The segregation tasks are dynamic and the use of the observational checklist selected for use in this study was not as useful for evaluating this job. Due to the heavy lifting requirement of the segregator job, the NIOSH lifting model and the University of Michigan 3D Static Strength Model were also used to evaluate this job.

Table 13 Percent of Shift Risk Factors were Observed – Segregators

	Risk Factors	Contributing Tasks	% of Shift
Hands/Wrist	Wrist flex/extend	Stack box on pallet, roll box down conveyor	38%
	Hand pinch grip	Stack box on pallet	25%
Elbows	Full elbow extension	Stack box on pallet, roll box down conveyor	28%
	Elbow away 45 deg	Stack box on pallet, roll box down conveyor	26%
Back & Shoulders	Walking	Stack box on pallet, roll box down conveyor	93%
	Lift/carry	Stack box on pallet	47%
	Torso twist>20deg.	Stack box on pallet	45%
	Push/pull	Roll box down conveyor	33%
	Asymmetric lift	Stack box on pallet	31%

4.4.2.2 Lifting Analysis of Segregators

Predictions using two separate models for assessing lifting requirements were developed to better understand the risks associated with the segregator job: the 1991 NIOSH lifting model and the University of Michigan 3D Static Strength Model. The NIOSH lifting model was used to evaluate the contribution of frequency and distance of lifts to the stresses on the lower back. The University of Michigan 3D Static Strength Model was used to evaluate the forces and stresses on the upper body during lifts that occurred above shoulder height.

The NIOSH lifting equation (Waters, 1994) was designed to assess the risk of low back injury by calculating a Recommended Weight Limit in pounds (RWL) of an object to be lifted. The RWL is the weight that nearly all healthy workers could lift without an increased risk of developing lifting-related low back pain. The RWL includes factors such as distance the box is held out from the body, distance of the hands above the floor, vertical distance the box is lifted from start to end, twisting angle of the lifter's body, frequency that lifts occur, and quality of the handle. The values for many of these factors changed depending on the pallet row and layer where the box was placed and on how much room there was between pallets to maneuver.

Two factors that had a large effect on the segregator RWL were the pallet layer (height of box at deposition) and how far into the pallet (horizontal distance from the body) that the box was deposited. Figure 5 illustrates that for all segregator lifts the current box weight of 40-50 pounds well exceeds the RWL. For example, at box layer 3, when the box is deposited at approximately waist height, the RWL is 26 pounds. At the highest layer (layer 7) the RWL drops to 16 pounds.

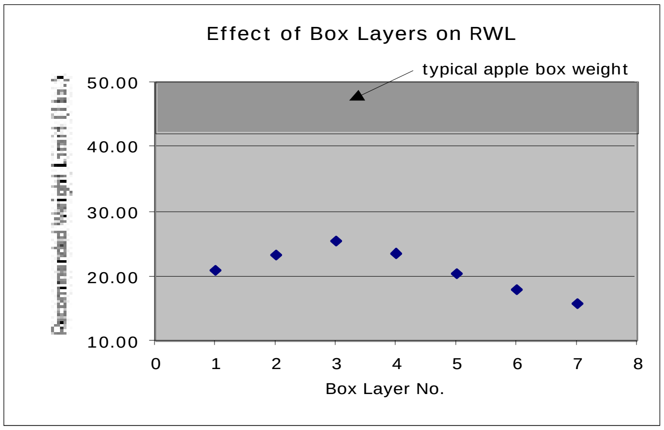


Figure 5 Effect of Box Layers on RWL

To load a pallet, the segregator must lean over and extend their reach to deposit boxes in the center of the pallet, while less leaning (horizontal distance from body) is required to deposit boxes on the outside of the pallet. Figure 6 shows that as the horizontal distance (leaning over the pallet) increases, the RWL decreases. When the box is dropped immediately in front of the worker's feet the RWL is 26 pounds, whereas it drops to 14 pounds when the box is deposited in the center of the pallet.

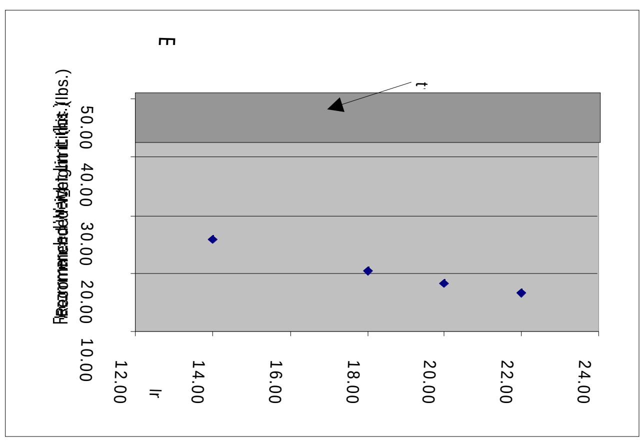


Figure 6 Effect of Horizontal Distance on RWL

To assess the potential for injury as a result of segregator lifting requirements, a Lifting Index (LI) was also calculated. The LI provides a relative estimate of the level of back stress associated with a lifting task. The LI is calculated by dividing the box weight by the RWL. With a LI of 1, most workers will be protected from injury. As the LI increases, the potential for injury increases (Waters, 1993). For example at a LI of 1 24% of females and 10% of males have an increased risk of low back pain, while at a LI of 3 99% of females and 75% of males have an increased risk of low back pain. Using the industry standard box weight of 42 pounds, the LI for the segregators' lifting tasks would range from 1.6 to 2.9. This suggests that there is considerable potential for low back pain resulting from the segregators' box lifting tasks**.**

3D Static Strength Test. This computerized model, developed by the University of Michigan, was used to evaluate the compressive force on the lower back during lifting above the shoulder (box layers 6 and 7). A static strength analysis was chosen for this job, as the task requires frequent lifting in awkward back and upper body postures. Analyses were conducted for a large or 95th percentile male and an average or 50th percentile male lifting a 45 to 50 pound box. Lifting boxes of this size and weight exceeds the Action Limit (AL) for back compressive force when stacking the first two layers of boxes on the pallet, and exceeds the strength capacity of the shoulders in about 33% of people when stacking the top two layers of boxes. This suggests that segregators are at increased risk for either back or shoulder injury while performing this job in its current configuration.

4.4.2.3 Self-Reported Symptoms

Only 1 of the 13 segregators interviewed reported a work-related problem. Segregators reported primarily back and shoulders symptoms (Table 14). All of the symptoms related to back, shoulder and elbow started with the current job with the exception of one back injury. Five of the 13 segregators interviewed reported shoulder problems; however, only one case was considered tied to a chronic work-related condition (three cases were reportedly from a sudden injury). Forty percent of the shoulder problems required medical treatment and one case was identified as severe, resulting in 30 days of missed work.

Table 14 Self-reported Symptoms – Segregators (n=13)

	Back # (%)	Hand/Wrist # (%)	Neck # (%)	Shoulder # (%)	Elbow # (%)
Problem reported (#)	3	1	0	5	1
Problem work related	0	0	0	1 (20%)	0
From sudden injury	1 (33%)	1 (100%)	0	3 (60%)	1 (100%)
Started with current job	2 (66%)	0	0	5 (100%)	1 (100%)
Pain down leg	1 (33%)	NA	NA	NA	NA
Medical treatment in last year	0	0	0	2 (40%)	0
Missed work	1 (33%)	1 (100%)	0	1 (20%)	0
Total person-days work missed	2	1	0	30	0
Workers comp claim filed	0	1(100%)	0	1 (20%)	0

NA – not asked

4.4.2.4 Risk Perception

Segregators mentioned fewer hazards associated with their work than did other workers. Segregators did report concerns about the air quality, including chlorine, carbon monoxide, and dust; lifting hazards; and concerns about slippery floors, forklift speed, and the location of the pallets. One half of the segregators stated that there was little a person could do to prevent work injuries. Segregators did comment that a person should be careful and mentioned use of personal protective equipment, such as back belts, to reduce the risk of injury.

4.4.2.5 Segregator Across Shift Body Discomfort

Segregators showed very little change in across shift discomfort level (Figure 7). However, at the start of the shift 18% of segregators reported high discomfort (a score of 4 or 5) in the knees.

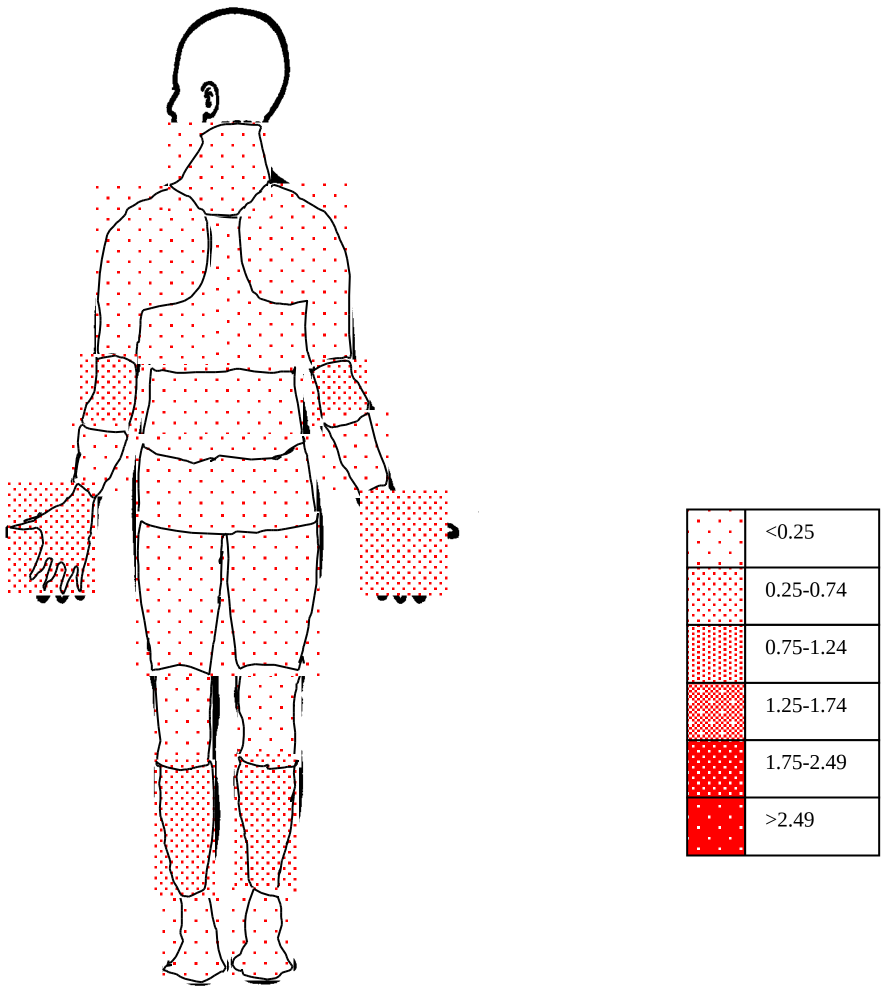


Figure 7 Segregator Cross Shift Body Discomfort Map (n=8)

4.4.2.6 Discussion of Segregator Job

A large body of evidence exists showing the hazards and associated adverse health effects with manual materials handling (NIOSH, 1997). The job task observations and lifting assessment tools clearly indicate that there is potential for musculoskeletal injury to segregators related to their lifting tasks. Job task observations showed that segregators were exposed to the following risk factors (right side dominant): lifting/carrying, flexing wrist, torso twisting, pushing/pulling, elbow extending, and elbow away. Although the number of segregators reporting symptoms in at least one body part was almost 40%, only one case was work-related using the study criteria. It was surprising to find that segregators showed very little change in across shift discomfort level; however, the few segregators who did report symptoms started their shift with a high level of discomfort (4 and 5). Some possible reasons for the lower symptom report rate of or among segregators include: 1) the segregators were the only men in the study, and they may not have felt comfortable disclosing their health problems; 2) the segregators may believe that the musculoskeletal discomfort associated with their work is expected and part of the job; and 3) the segregators are the youngest and most recently hired group of workers in the warehouse, and their lack of symptoms may be due to a healthy worker selection.

4.4.2.7 Washington Ergonomics Rule – Segregator Job

The amount and weight of lifting while segregating exceeds the hazard zone level for lifting according to Appendix B of the Washington Ergonomics Rule. This job was further evaluated for specific WMSD hazards. This analysis was done using the criteria from the Specific Performance Approach described in WAC 296-62-05130-Appendix B.

"Caution Zone Job" Criteria

Task Description	Risk Factor	Caution Zone Job?
Lift 40-50 lb. boxes to pallet 500-800 times per shift	Frequent & awkward lifting	Yes
Some boxes are lifted above shoulder or head height	Awkward posture - shoulders	Yes

Segregator Job Hazard Analysis

Task Description	Hazard Category and Appendix B Criteria	Is Task Hazardous?
Lift 40-50 lb. boxes to pallet 500-800 times per shift	Frequent heavy & awkward lifting – box weight limit is 11-15 lbs.[1] (depending on pallet layer where box is placed). Boxes weigh 40-50 lb.	Yes
Some boxes are lifted above shoulder or head height	Awkward posture, shoulders – Hands above head >1/minute for 4 hours/day	No

Weight limit calculated using these assumptions: Unadjusted weight limit of 30 or 40 lbs. depending on pallet layer, 4-5 lifts/minute for 2 or more hours/shift, segregator twists at least 45° on some lifts.

Segregating is considered hazardous using the heavy lifting criteria in Appendix B of the ergonomics rule. An allowable box weight limit was calculated using the formula outlined in Appendix B (unadjusted weight limit X limit reduction modifier X twisting adjustment = recommended box weight limit) and assuming a 45° twist and above the shoulder lift. The calculated weight limit was compared to the weight of boxes currently lifted by segregators.

Calculated weight limits ranged from 11-15 pounds, considerably lighter than the usual box weight lifted by segregators.

The 40-50 pound boxes lifted by the segregators in this study were approximately three times heavier than the allowable box weight limit, using the Appendix B weight limit calculations. If twisting were eliminated or reduced to less than 45 degrees, the box weight limits could increase to 15-18 lbs. If, in addition, the stacking process was modified so that box layers 6 and 7 were not added by lifting above the shoulders, the box weight limit would be 18 pounds. If the frequency of lifting were also reduced to 2-3 lifts per minute, the box weight limit would increase to 20 pounds.

Lifting above the shoulder in this job did not meet the Appendix B criteria for awkward shoulder postures. Segregators lift boxes to the top (seventh) layer on a pallet for approximately 14% (1/7) of all lifts. There were an average of 4 lifts/minute observed, therefore approximately 0.5 lifts/minute (4 lifts per minute x 14%) involved boxes above the head. A over the head lift frequency of over 1 lift/minute is considered hazardous under Appendix B of the Ergonomics Rule.

According to the criteria outlined in the Ergonomics Rule, the segregating job was considered hazardous and the employer must take action to reduce the hazard.

4.4.2.8 Segregator Recommendations

The weight lifted, the frequency of lifting, the height boxes are stacked, and the distance away from the body that boxes are deposited present a serious risk of back and shoulder injury to segregators. The greatest risk occurs when boxes are stacked on the fifth to seventh layer on the pallet. Automatic palletization would be the most efficient way to reduce these risks, but the capital expenditure may not be affordable for smaller packing houses. An alternative engineering solution would be to stack two shorter stacks (one four boxes high and the other three boxes high) and then place one of these stacks on top of the other using a slip sheet push-pull forklift attachment. We have included information on this mechanism and literature on an available forklift retrofit in Appendix F. This solution would require more floor space.

The frequency of lifting and the amount of twisting required to place boxes on pallets are also important factors in the risk of injury. Rotation of segregation tasks with other tasks could be used to limit the duration of lifting. The segregation area layout should be evaluated to determine if there are ways to reduce the amount of turning (where most segregators twist) required to move the box from the conveyor to the pallets. There should be adequate room so that a segregator can turn his body with his feet rather than twisting at the waist.

4.4.3 Packing

Four different types of packing were assessed in the three packing houses in this study. Companies 1 and 2 conducted manual packing of bags and, while companies 1 and 3 conducted semi-automatic bag and tray packing. Some of the assessment tools evaluated the specific jobs done by subjects the day of the evaluation (Observations, Cycle Time, Body Discomfort Map) while other tools evaluated more long-term effects (Symptoms Survey, Risk Perception) to workers who often change jobs from day to day. In this section the long term effects to packers will be presented first, followed by the findings for specific packing jobs.

4.4.3.1 Self-Reported Symptoms

Sixty percent of the packers interviewed reported a work-related musculoskeletal problem to at least one body site. The greatest number of problems occurred at the back, hand/wrist, neck, shoulder, and elbow (Table 15). Seventy to eighty percent of the problems reportedly started with the current job. Over half of the back, hand/wrist, neck, and shoulder problems reported met the criteria for being work related; however, less than 10% had workers compensation claims filed. Less than 25% of problems reported for any body site were acute (sudden) injuries. Back injuries were the most severe injuries based on self-reported medical treatment (29% of reported back problems received medical treatment) and missed work-days (132 person-days). Back injuries reportedly affected work pace for 29% of those reporting. Workers with wand/wrist problems also had a large number of missed workdays (74 person-days) and over half of reported hand/wrist problems involved radiated or nighttime pain. Packers sought medical treatment for 29% of neck injuries.

Packers reported more elbow problems than other workers. Further analysis of packer symptom reporting indicated that many workers who reported elbow problems also reported hand (61%), shoulder (50%), and/or neck (42%) problems.

Table 15 Self-reported Symptoms – Packers (n=67)

	Back # (%)	Hand/Wrist # (%)	Neck # (%)	Shoulder # (%)	Elbow # (%)
Problem reported (no.)	34	28	21	22	26
Problem work related	21 (62%)	18 (64%)	12 (57%)	15 (68%)	7 (27%)
Workers comp claim filed	1 (3%)	1 (4%)	2 (10%)	0	0
From sudden injury	6 (18%)	5 (18%)	5 (24%)	4 (14%)	5 (19%)
Started with current job	27 (79%)	23 (82%)	15 (71%)	22 (79%)	21 (81%)
Pain down leg	12 (35%)	NA	NA	NA	NA
Pain down arm	NA	NA	12 (57%)	NA	NA
Pain wake from sleep	NA	15 (54%)	NA	NA	NA
Pain up arm	NA	18 (64%)	NA	NA	NA
Trouble opening jars	NA	25 (89%)	NA	NA	NA
Medical treatment in last year	10 (29%)	3 (11%)	6 (29%)	4 (14%)	4 (15%)
Missed work	7 (21%)	2 (7%)	1 (5%)	2 (7%)	2 (8%)
Total person-days work missed	132	74	1	17	17
Affected work pace	10 (29%)	NA	NA	NA	NA
Had surgery	0	1 (3%)	0	0	0

NA – not asked

There were surprisingly few differences between older and younger workers in symptom report rate or by body site (Table 16). Hand/wrist problems did not vary among the three age groups. Younger packers were more likely to report neck problems, while older workers were more likely to report shoulder and elbow problems. Hip and knee complaints were reported considerably less frequently by workers over 50.

Table 16 Symptom Reporting by Age – Packers

Age Range	Workers Surveyed # (%)	% of Workers Reporting a Problem							
		Back	Hand/Wrist	Shoulder	Elbow	Neck	Hip	Knee	Foot/Ankle
< or =35	27 (40%)	52%	41%	26%	26%	41%	22%	30%	19%
>35 ≤ 50	28 (42%)	39	43	36	46	25	32	21	29
>50	12 (18%)	75	42	42	50	25	8	8	17
All Ages	67 (100%)	51	42	33	39	31	24	22	22

4.4.3.2 Risk Perception

Sixty percent of all concerns reported by packers were related to body discomfort, especially lifting, bending, and pushing and pulling stuck boxes and trays. Packer-reported activities that caused body discomfort included bagging, reaching, and standing. Packers were more likely to report concerns related to legs and feet, back, hand and wrist, shoulder, and neck. In addition, packers mentioned problems with the equipment, such as gaps in the belts where fingers could get caught, or incorrect sizing of the packing horses used to carry full boxes to the conveyer belt.

Company 2 packers were generous in making suggestions about modifications the company could make to improve packing work, the location of packing boxes, trays, and tissues. Packers at Company 1 and Company 3 suggested slowing the pace of the line to prevent injuries. At Company 2, where packing work is piece rate, slowing the conveyor rate was not mentioned.

4.4.4 Specific Packing Activities

4.4.4.1 Manual Tray Packing

The manual packing workstations were similar at Companies 1 and 2. Both companies had circular tubs (13 at Company 1 and 28 at Company 2). The tubs at Company 1 were 50 inches in diameter with the rim 35 inches from the floor, while the diameter and height from floor were 60 inches and 36 inches respectively at Company 2. The packer's reach to apples in the center of the tub was greatest with the wide diameter tubs. In addition, Company 2 had a series of workstations along a long conveyor where apples moved past the packer in a circular flow. This conveyor was 37 inches above the floor and 24 inches wide. Graded apples were delivered to the tub or conveyor by the computer-controlled sizing conveyor. Workers manually packed both bags and trays from these stations.

Packers were positioned between the tub or conveyor and a cart known as a packing horse that held a cardboard box positioned at a slight angle (Figure 8). Two types of packing horses were observed: a roller style and a sliding-tray style. Flat boxes were folded and placed on the packing horse. Unfolded boxes were retrieved from storage locations that required awkward bending and stooping positions. Once the box was filled, the packer rolled the packing horse to a receiving conveyor and pushed it on the conveyor. The sliding-tray horse required a packer to move the full box by lifting a handle on the packing horse, while pushing the box onto the receiving conveyor with the other hand. The roller style packing horse did not require lifting the box; consequently, pushing onto the receiving conveyor required less effort. The roller style packing horse also had greater height adjustability.

Figure 8 Manual Tray Packing at a Circular Tub

The manual tray packing process involved placing a hard paper tray with indentations into a box and placing apples in the indentations. Four to five trays are required to fill the box, depending on the size of apples being packed. The number of apples per box varied in this study from 64 to 150. The packer typically stood with back and neck slightly bent towards the tub or conveyor. The reach to grab one apple varied with a maximum reach of 21 inches. Apples were picked up in one hand and tossed to the other hand, which was located over the box, and was then positioned into the tray.

The manual tray packing cycle included folding a box, packing, closing, and marking the box, and placing it on the conveyor which took a mean time of 101 seconds with little difference between Companies 1 and 2 (99 vs. 102 seconds) (Table 17). Interestingly, company 2 pays its workers by piecework and company 1 pays by the hour.

Table 17 Mean Cycle Time Manual Tray Packing, by Company

Job	Tasks	All Companies (1-2)			Company 1			Company 2			Company 3		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Manu	Fold box	93	9	4	33	9	4	60	9	4	NA		
	Pack trays with apples	114	77	32	34	76	35	80	78	30	NA		
	Write on box	93	9	5	34	8	3	59	9	5	NA		
	Push box on conveyor	93	6	5	34	6	2	59	6	5	NA		
	Total cycle time (sec)		101			99			102		NA		

NOTE: Mean cycle time is in seconds; SD - Standard deviation
NA - not applicable – this company did not do manual packing

4.4.4.1.1 Manual Tray Packing Job Task Observations

Neck position, static standing posture, and upper extremity motions of the hand/wrist, elbow, and forearm were the body risk factors observed during manual tray packing. Packing trays had the greatest number of risk factors (Table 18). The pinch grip was most frequently observed when picking up apples, whether with the right or left hand. The other risk factors related to the hand, elbow, and forearm were noticeably different with regard to the side of the body that was affected; the right side was much more frequently involved in almost all cases with the exception of wrist flexion/extension. For example, the elbow raised away from the right side of the body was observed for 60% of the shift compared with 25% of the shift for the left side of the body (Appendix E). Workers also fully extended the right elbow more frequently than the left (49 % vs. 9%). Most workers used their right hand to pack apples and tended to lean slightly into the tub to extend their reach.

Table 18 Percent of Shift Risk Factors were Observed – Manual Tray

Body Part	RISK FACTOR	Contributing Tasks	% of Shift
Neck	Neck extend/flex>15deg.	Fold box, pack trays	82%
	Neck twist>15deg.	Pack trays	53%
Hands/Wrist	Pinch grip	Pack trays	56%
	Radial/ulnar deviation	Pack trays	54%
	Wrist flex/extend	Fold box, pack trays	39%
Elbows	Elbow away 45 deg	Pack trays	42%
	Forearm twist/rotate	Pack trays	37%
	Full elbow extension	Pack trays	29%
Back	Stand stationary	Pack trays	72%
	Torso side bend>20deg.	Pack trays	34%

4.4.4.1.2 Manual Tray Packing Across Shift Body Discomfort

Manual tray packers reported the lowest across shift discomfort scores of all packing jobs. Most problematic areas were feet (.86), hands (.75), and upper (.75) and lower back (.71) (Figure 9).

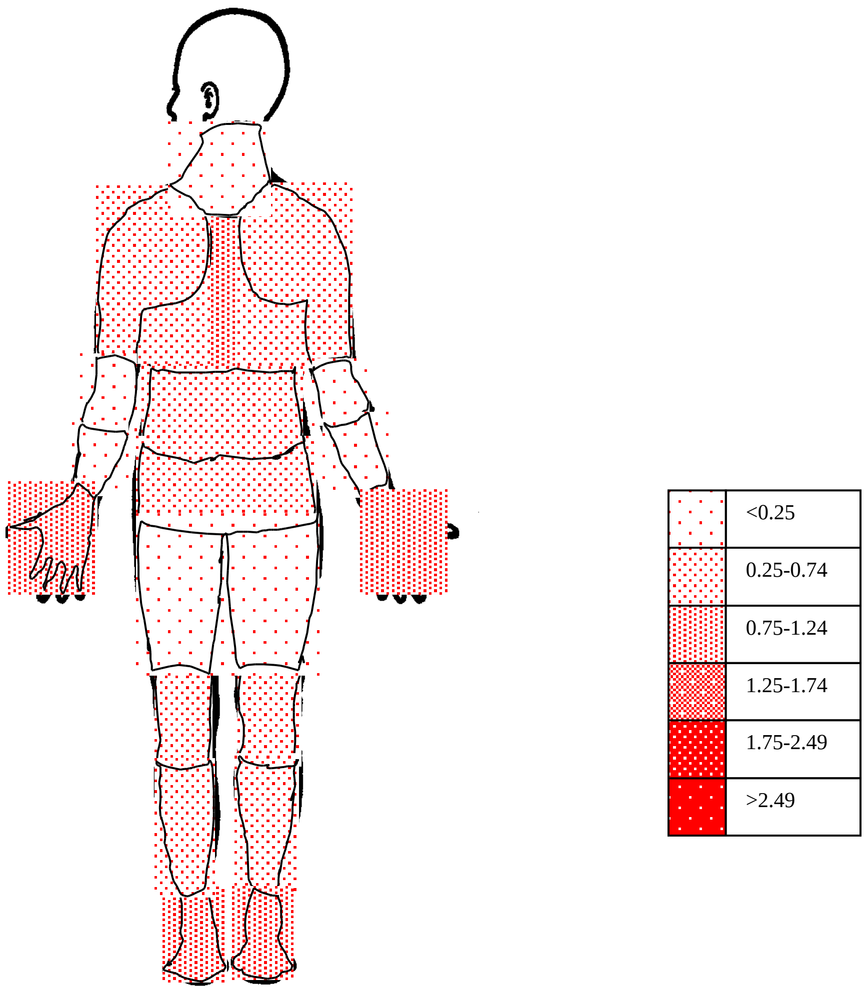


Figure 9 Manual Tray Packer Across Shift Discomfort Map (n=6)

4.4.4.1.3 Washington Ergonomics Rule – Manual Tray Packer Job

The manual packing job was reviewed from the perspective of the Washington State Ergonomics Rule and was found to meet the CZJ criteria. Manual packing was further evaluated for specific WMSD hazards. This analysis was done using the criteria from the Specific Performance Approach described in WAC 296-62-05130-Appendix B.

"Caution Zone Job" Criteria

Task Description	Risk Factor & Criteria	Caution Zone Job?
Place apple on tray every 0.9 seconds for full shift	Highly repetitive – same motion every few seconds for more than 2 hours per day?	Yes
Make box and cover box with elbows away from body	Awkward postures – no criteria in Rule	No
Stooping to obtain unformed box	Awkward postures – no criteria in Rule	No

Manual Packing Job Hazard Analysis

Task Description	Hazard Category and Criteria	Is Task Hazardous?
Place apple on tray every 0.9 seconds for full shift	Highly repetitive-same motion >6 hours/shift?	Yes

According to the criteria outlined in the Ergonomics Rule, the Manual Packing job was considered hazardous and the employer must take action to reduce the hazard.

4.4.4.2 Manual Bag Packing

Manual bag packing is often done at the same circular tub or conveyor workstations as manual tray packing with the addition of a bagging stand, which holds a scale (not height adjustable) and bagging supplies. The packer places an empty bag on the bagging scale and fills the bag with apples with one hand while holding the bag open with the other hand. Some packers pick up two apples at a time to fill the bag more quickly. When the bag reaches a predesignated weight (or predesignated number of apples), the packer picks up the bag with one hand and spins it and applies a twist or clip tie with the other hand. The bag is then placed in a box and the process is repeated until the box is full. At the time of this evaluation, bag packers were filling 3- or 5-pound bags, 10 to 12 apples were packed per bag, and 8 bags to a box.

The manual bag packing cycle included: folding a box, packing, closing, and marking the box, and pushing the box onto a receiving conveyor. The full cycle took a mean of 159 seconds for Company 1 (Table 19). At Company 2, analysts only timed the bagging portion of the cycle, assuming that folding the box, closing and marking the box, and pushing the box onto the conveyor would take the same amount of time as was measured for manual tray packing activity at Company 2. This procedural change was made in order to have time to complete as many manual bag packer observations as possible. At Company 2, the complete cycle time was nearly three times as fast, 59 seconds, including the calculated post-bagging task. The large difference in cycle times between companies could be due to differences in sizes of apples bagged on the days observed or differences in production rates. The production rate was lower in Company 1 than Company 2 (48 vs. 72 boxes/FTE); Company 1 workers reported the line was moving more slowly than normal on the day of observations.

Table 19 Mean Cycle Time Manual Bag Packing, by Company

Job	Description of Tasks	Companies 1-3			Company 1			Company 2			Company 3
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N Mean SD
Manual Bag Packer	Fold box	49	6	4	29	6	3	20	7	3	NA
	Pack bags with apples	115	71	63	39	133	25	76	39	52	NA
	Write on box	58	12	9	38	15	10	20	8	3	NA
	Push box onto conveyor	*	*	*	40	5	5	*	*	*	NA
	Total Cycle Time:		89			159			54		NA

NOTE: Mean cycle time is in seconds; SD - Standard deviation

Figure 10 Manual Bag Packer Twist-Tying a Bag

4.4.4.2.1 Manual Bagging Job Task Observations

The upper extremity motions of the hand/wrist, elbow, and forearm, bag lifting, and static standing posture including neck bending were the observed risk factors with the greatest potential for producing musculoskeletal injury (Table 20). The analysis of the observations shows that baggers were using both hands about equally with right hand use slightly more than the left; this is because most packers reached into the tub with the right hand, and thrust the apple into the left hand for placement into the waiting bag (Appendix E). The risk factors observed during manual bagging were similar to manual tray packing; however, two additional factors were observed during manual bagging: lift/carry (right) and asymmetric lift.

Table 20 Percent of Shift Risk Factors were Observed – Manual Bagging

Body Part	RISK FACTOR	% of Shift
Neck	Neck extend/flex>15deg.	59%
	Neck twist>15deg.	40%
Hands/Wrist	Hand pinch grip	59%
	Hand radial/ulnar deviation	42%
	Wrist flex/extend	25%
Elbows	Forearm twist/rotate	30%
	Elbow away 45 deg	29%
	Full elbow extension	26%
Back and Shoulders	Stand stationary	58%
	Lift/carry	20%
	Asymmetric lift	24%
	Torso side bend>20deg.	22%

4.4.4.2.2 Manual Bagging Across Shift Discomfort

Manual bag packers reported the greatest across shift discomfort of the elbow, shoulder, upper back, and neck (Figure 11). These data only represent manual baggers from Company 1 because at Company 2 packers either packed trays all day or did a combination of manual tray and bag packing.

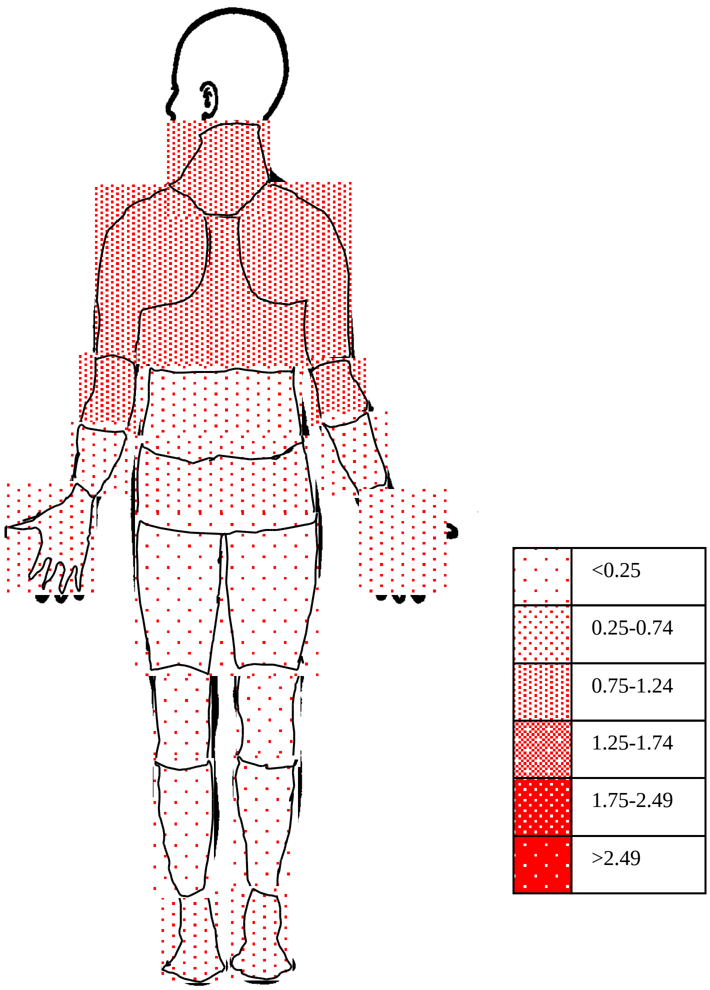


Figure 11 Manual Bag Packer Across Shift Body Discomfort (n=9)

At the start of the shift, 20% of manual bag packers reported high discomfort (a score of 4 or 5 on a scale of 1-5) for the hand/wrist. This pre-shift discomfort may be an indicator of inadequate recovery from the previous shift and may suggest a chronic problem.

4.4.4.2.3 Washington Ergonomics Rule – Manual Bag Packer Job

The manual bagging job was reviewed from the perspective of the Washington State Ergonomics Rule and was found to meet the CZJ criteria. Manual bagging was further evaluated for specific WMSD hazards. This analysis was done using the criteria from the Specific Performance Approach described in WAC 296-62-05130-Appendix B.

"Caution Zone Job" Criteria

Task Description	Risk Factor & Criteria	Caution Zone Job?
Put apple in bag – 13,000 apples/shift	Highly repetitive – same motion every few seconds for more than 2 hours per day?	Yes
Make box and cover box with elbows away from body	Awkward postures – no criteria in Rule.	No
Stooping to obtain unformed box	Awkward postures – no criteria in Rule.	No
Grip apple bag of 3-10 lbs. (palmer or pinch grip)	High hand force – pinch 2 lb. object or grip 10 lb. object >2 hours/day	Yes
Pick up 1,200 bags/shift	Highly repetitive – same motion every few seconds for more than 2 hours per day?	Yes

Manual Bagging Job Hazard Analysis

Task Description	Hazard Category and Criteria	Is Task Hazardous?
Put apple in bag – 13,000 apples/shift	Highly repetitive – same motion >6 hours/shift	Yes
Grip apple bag of 3-10 lbs. (palmaror pinch grip)	High hand force – pinch grip of 2 lb. object w/ high repetition; any grip of 10 lb. object w/ high repetition	Yes
Pick up 1,200 bags/shift	Highly repetitive – same motion >6 hours/shift	Yes

According to the criteria outlined in the Ergonomics Rule, the manual packing job was considered hazardous and the employer must take action to reduce the hazard. Manual bag packing must be modified to reduce repetitive motion and high hand force below the hazard level or to the degree feasible.

4.4.4.3 Manual Packing Discussion

The incidence or prevalence of musculoskeletal disorders has been reported in the literature for many occupations (e.g. meat processors, packers, assembly-line packers, and frozen food factory workers) that require repetitive or intensive use of the hands (Armstrong, 1993). The incidence of muscle-tendon syndrome was 56% (Luopajarvi, 1979) among assembly-line packers in food production who performed repetitive arm work (repetitive motions up to 25,000 cycles per workday). Chiang (1990) found a 40% incidence of carpal tunnel syndrome (according to nerve conduction velocity tests) among workers who packed non-frozen food using "high" repetitive wrist movements (no specific information on the number of repetitive motions was provided). Amano (1988) reported a 14% incidence of tension neck syndrome among female assembly-line workers who used repetitive arm movements to handle 3,400 shoes per day. Ohlsson (1995) found a statistically significant association between exposure to repetitive work and diagnoses in both the neck/shoulders and elbows/hand among women assembling fuses and other electrical equipment. Several studies have found that workers with exposure to repetitive work of upper extremities and who are paid on a piece-rate system may have increased risk for musculoskeletal disorders (Kuorinka and Koskinen, 1979; Brisson, 1989; and Ohlsson, 1995).

In agricultural warehouses, the application of ergonomic research has been applied to the process of manual packing but limited to citrus crops, such as oranges. Smith (1963) compared the packing rate and cost of packing between a frontal pack method and a side pack method. He found that a frontal packing method was cost-effective, and applied ergonomic principles of work station design and posture to explain his findings. The purpose of the frontal pack method is to eliminate the packers need to lean and twist over a bin when reaching for the fruit. No measurements of worker fatigue, strain, or discomfort were provided in this early study. The frontal pack method is common in citrus warehouses; however, the side pack method is common in the apple and pear packing lines in Washington State. Smith (1963) provides a good description of the advantages and disadvantage of frontal packing of citrus fruit and outlines parameters of the system that are key to reducing worker fatigue and strain. No other studies were found that discussed ergonomic hazards or incidence of musculoskeletal disorders among fruit packers.

Manual apple packers have a static posture of the neck and back as they lean into the tub or conveyor to pick apples. A static posture can produce fatigue because constantly tensed muscles never have an opportunity to recover. The degree of leaning depends on the height of the packer, the dimensions of the tub, and the reach required to grab an apple. A bent neck requires neck muscles to hold the weight of the head – with greater bending producing greater stress – also known as the bowling ball effect. Workstation design that reduces the reach and offers adjustability for workers of different heights would limit bending as well as awkward postures of the elbow and shoulder.

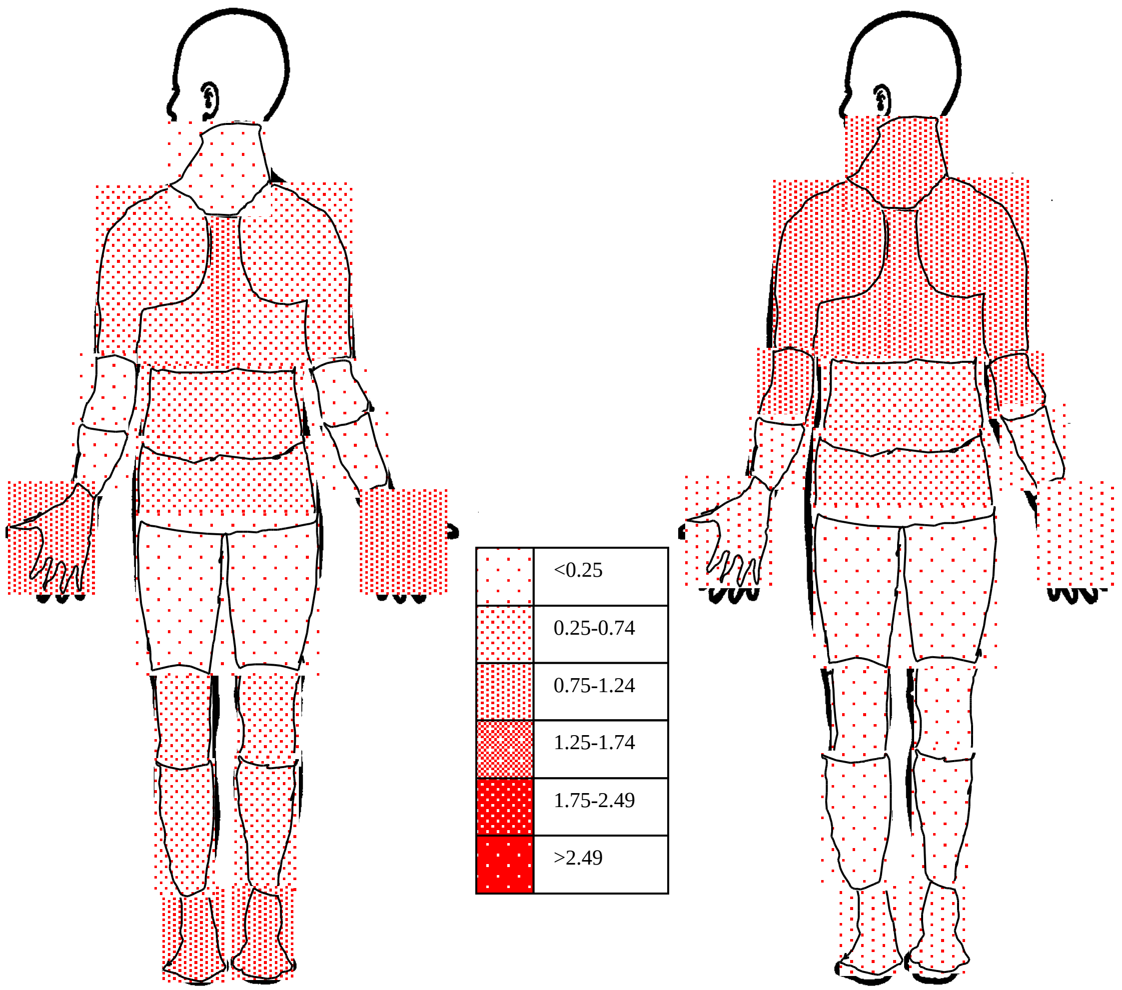
Both tray and bag packing are highly repetitive, with packers handling approximately 13,000 apples per shift (88 apples/box x 150 boxes/shift). Silverstein (1986) found that workers in high repetition/low force jobs had a three-times greater risk of cumulative trauma disorders of the hand and wrist than workers in low repetition/low force jobs; the risk increased to 30 times for high repetition/high force jobs. Manual tray packing would be classified as a high repetition/low force job since there is no lifting of heavy weight or other forceful hand or wrist exertion. In contrast, manual bag packers lift bags of 3-10 pounds more than 1,000 times per shift (8 bags/box x 150 boxes/shift). This could classify manual bag packing as a high repetition/high force job. This may also explain why manual bag packers reported more discomfort at the end of the shift than manual tray packers. On the day of our observations, packers were bagging 3- and 5-pound bags. The discomfort disparity between tray and bag packers might be greater on days when packers were packing heavier bags (up to 10 pounds).

A comparison of discomfort map, job task observations and symptoms data offers insight into which body parts and motions may be important for self reported symptoms (Table 21 and Figure 12). Because most packers do both kinds of manual packing, the symptom data are an amalgamation of tray and bag packing.

Tray packers reported more across shift discomfort of the hands. Tray packing requires more precision in placing apples in tray indentations, and more hand and wrist movement to adjust apples for optimal positioning within the tray. Tray packers must also continuously negotiate over the box lip to place apples in trays. This causes the most hand and wrist bending when placing apples in the bottom tray layers when the tray is deep inside the box. Wrist flexion/extension was observed more frequently in tray packers than bag packers (39% vs. 25%).

Tray packers also reported more across shift discomfort of the lower extremities (feet, calves, and knees). Tray packers stand stationary more frequently than bag packers (72% vs. 58%). The greater neck flexion in tray packers (82% vs. 59%) could also relate to standing for longer periods of time in a static posture. Static positions produce muscle fatigue increasing the potential for discomfort.

Bag packers reported more across shift discomfort of the back, shoulders, neck, and elbows. After a bag is filled, it is picked up to twist and close. The more frequent lift/carry (20% vs. 10%) and asymmetric lift (20% vs. 2%) in baggers as compared to tray fillers relate to picking up the bag. The severity of fatigue from this activity may depend on the weight of the bags lifted.



Manual Tray (N=6) Manual Bag (N=9)

Figure 12 Discomfort Map Comparison of Manual Tray and Bag Packing

Table 21 Manual Packer Symptoms and Job Task Observations

Symptoms (% of All Packers w/ Work-Related Problem)	Job Task Observations (% of shift)			
	Manual Tray		Manual Bag	
Back - 31%	Lift/carry	10%	Lift/carry	20%
	Asymmetric lift	2%	Asymmetric lift	24%
	Torso side bend	34%	Torso side bend	22%
	Stand stationary	72%	Stand stationary	58%
Hand – 27%	Hand deviation	55%	Hand deviation	42%
	Wrist flex/extend	39%	Wrist flex/extend	25%
	Pinch grip	56%	Pinch grip	60%
Shoulder – 22%	Hand above shoulder	12%	Hand above shoulder	9%
Neck – 18%	Neck flex	82%	Neck flex	59%

The muscle groups of the back, shoulders, neck, and elbows are interrelated and strain on one group can affect other muscle groups. The discomfort reported by manual baggers for these body sites may all be related, at least in part, to lifting bags.

The pre-shift discomfort map may also be used to identify discomfort that may be carried over from previous shifts. Thirty-three percent of manual packers reported a high discomfort score (rating of 4 or 5) at the start of the workday in the hand/wrist and 17% reported pre-shift discomfort in the shoulders.

4.4.4.4 Manual Packer Recommendations

Both manual tray and bag packing use the same tub and conveyor system workstations; so, modifications to the tub and conveyor system would benefit both jobs. Extended reaches and bending into the tub could be reduced by reducing the width of the tub or installing a cone-shaped tub insert or center ring so that apples will roll toward tub edges and thereby be easier to reach. Other workstation changes could reposition the packer from the side to the front of the tub as recommended by Smith (1963).

Manual packing involves standing in one position for long periods. This can lead to fatigue or discomfort in the lower extremities and back. Anti-fatigue floor mats or cushioned shoe inserts can reduce this fatigue or discomfort (Appendix G).
Static postures and fatigue could be reduced if packers had the option of leaning or standing supported for part of the time. Sit/stand stools (Appendix H) are available that have been designed for industrial applications where assembly line workers stand at a workstation.

Manual bagging results in considerable hand repetition. Reducing hand repetition below the hazard level may be possible through the implementation of regular job rotation. Job rotation or rest breaks as noted above for sorters would also be beneficial for packers. If the break involved stopping the conveyor, all jobs would benefit from the break schedule. As with sorting, packers should use mini-break times to change position and stretch.

The newer roller tray carts seen in some packing houses do not require a lift to move the box onto the receiving conveyor. The roller tray carts are also more adjustable in height than the older style slide tray carts.

A tray platform could be placed inside the box sleeve, lifting the bottom tray to a position at the top of the box. Each time another tray was added to the box, the platform would lower pneumatically, or with springs or cords, so that the next tray added would be positioned at the top of the box. This modification would keep the tray at the most accessible level and reduce the amount of back and hand/wrist bending observed while loading trays, particularly the bottom tray layers – and may improve production rates.

The duration of time a bagger holds a filled bag could be reduced if the bag could be twisted in place while supported on a lazy-Susan type mechanism. This would reduce the high force hand and asymmetric lifting of the bag. In addition, adhesive or tab closures could be applied mechanically. This equipment would be best placed on a height adjustable pole in front of the worker to reduce the amount of side twisting or bending.

The scale on the bag table was observed to be too high for some packers, creating awkward shoulder and arm positions and wrist/hand bending when placing fruit in the bag. A lower scale that matched the height of the tub lip could reduce arm and shoulder fatigue and possible injury.

In two packing houses unfolded boxes were stored underneath the receiving conveyor. This required packers to twist and bend to retrieve box material. Storing the boxes in a location within the workers comfort zone could reduce bending, twisting, and awkward postures.

4.4.4.5 Semi-automatic Tray Packing

Companies 1 and 3 had semi-automatic packing lines, including both tray packing and bag packing. The tray packing equipment was very similar at the two companies, while the bag packing equipment was similar except that the packers at one company stood while packers at the other company sat on low stools. Tray packing and bag packing are very different processes so they will be discussed separately.

The computer-controlled sizer delivers apples to tray pack lines according to apple grade. The packer faced the 20-inch wide and 40-inch high conveyor, where trays were automatically fed onto the conveyor and apples rolled into the tray from the conveyor above. Packers repositioned apples in the tray indentations for optimal presentation with all apples positioned in the same direction while concurrently sorting out damaged or misgraded fruit, which is deposited on a conveyor above the tray packing line, requiring a 28-inch reach (Figure 13). Filled trays moved to the end of the packing conveyor to the boxing station. Sometimes the packer who arranged trays also worked the boxing station, while at other times a second packer was assigned to that station, depending on the production rate. At times the trays backed up on the conveyor and the continuous line extended to the boxing station. Box packers did not wait for filled trays to come to them; rather, they often pushed or pulled the trays to the end of the conveyor in order to fill the boxes more quickly. Packers pull trays with a pinch grip or push with one or both hands. Filled trays weigh approximately 8 to 12 pounds. A full box contains 4 to 5 trays, depending on the apple size.

At the boxing station, filled trays are picked up and deposited into a preformed cardboard box (Figure 13). Boxes were marked, and pushed onto a conveyor which carried the box to the palletizing area. Company 3 had a load leveler at the boxing station that reduced the awkward postures and reach required to place the first layers of trays into the box. When a box was full, the boxer rotated the box one-quarter turn and pushed it onto a receiving conveyor. A box packer may provide boxing support to two or three packing lines.

Rubber mats of varying degrees of resiliency were observed at some packing stations to reduce back and leg fatigue that often occurs from standing on concrete floors.

Figure 13 Box Filling and Apple Arranging – Semi-automatic Tray Packing

The semi-automatic tray packing cycle consisted of these tasks: arranging apples on the tray, placing the preformed box at the boxing station, and filling the box. The cycle time varied between the two companies – Company 1 had a cycle time of 159 seconds, while Company 3 had a cycle time of 55 seconds. At Company 1, mechanical problems occurred with the semi-automatic tray pack line during the observed work shift. Packers reported that the line pace was slower than usual and observers had a difficult time assessing a complete job cycle because of the slow pace.

Since semi-automatic tray and box packing is sometimes conducted by two different workers, the observation of a cycle sometimes involved both a tray packer and a box packer; consequently, one observation was sometimes of two individuals (Table 22).

Table 22 Mean Cycle Time Semi-automatic Tray Packing, by Company

Job	Description of Tasks	Companies 1-3			Company 1			Company 2			Company 3		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Semi	Place box	114	6	3	36	6	3	NA			78	6	3
Automatic	Arrange apples in trays	109	41	49	29	93	65	NA			80	23	21
Tray Pack	Load box	116	26	19	39	25	29	NA			77	26	12
	Total Cycle Time:	73			124			NA			55		

NOTE: Mean cycle time is in seconds; SD - Standard deviation

4.4.4.5.1 Semi-automatic Tray Packing Job Task Observations

Neck position, static standing posture, and upper extremity motion of the hand, wrist, forearm, and elbow were the risk factors observed with the greatest potential for producing musculoskeletal injury (Table 23). The pinch grip used to pull filled trays to the box was of particular concern because it is coupled with high force when pulling 8-12 pound trays with finger muscles. The elbow positions and hands above shoulders relate to the width of the conveyor and position of re-sort conveyors. The full elbow extension occurred when packers extended their arms out to pull the tray toward the boxing end of the conveyor, and when reaching to the farthest side of the conveyor to arrange the apples. A higher percentage of right side use was found with full elbow extension (54% vs. 27%) and pinch grip (55% vs. 38%) as compared to other risk factors (Appendix E). These two risk factors were observed when packers needed to exert some force during product handling, and may be explained by the fact that most packers were right handed and relied on the more dominant hand to do this exertion.

Table 23 Percent of Shift Risk Factors were Observed – Semi-auto Tray

Body Part	RISK FACTOR	Contributing Tasks	% of Shift
Neck	Neck extend/flex>15deg.	Arrange apples on tray, load box	67%
	Neck twist>15deg.	Arrange apples on tray, load box	28%
Hand/Wrist	Hand Pinch grip	Load box, arrange apples on tray, place box	47%
	Hand Radial/ulnar deviation	Arrange apples on tray, load box	47%
	Wrist flex/extend	Arrange apples on tray, load box	36%
Elbow	Full elbow extension	Arrange apples on tray, load box	41%
	Elbow away 45 deg	Arrange apples on tray, load box	29%
	Forearm twist/rotate	Arrange apples on tray	27%
Shoulder	Hand above shoulder	Arrange apples on tray, load box	20%
Back	Stand stationary	Arrange apples on tray, load box	65%

4.4.4.5.2 Semi Automatic Tray Packing Across Shift Body Discomfort

Semi-automatic tray packers reported the greatest increase in discomfort in the area of hands/wrist (1.9), upper back (1.7), shoulders (1.6), and feet (1.5) (Figure 14). Their discomfort scores were considerably higher than were the scores for the manual tray packers, although hands, upper back, and feet were high in both groups. It may be that the manual tray packers were engaged in more varied tasks (making boxes and depositing the box on the conveyor) that served as micro-breaks for various muscle groups.

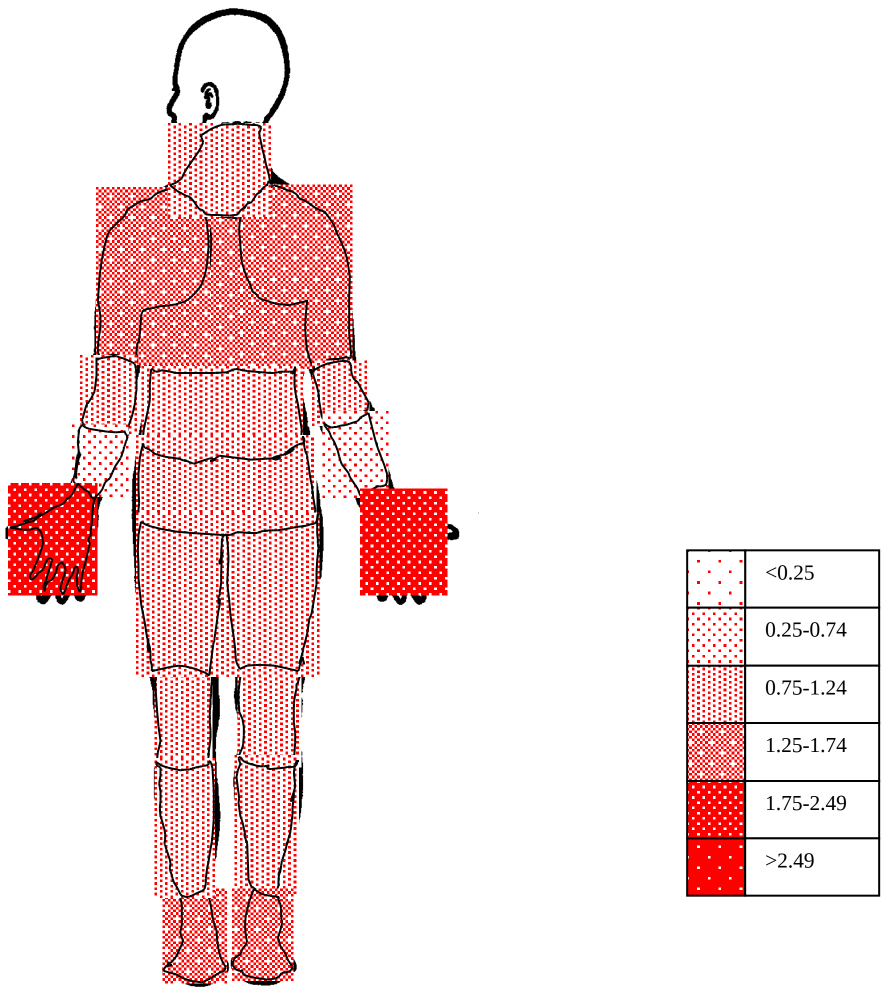


Figure 14 Semi-automatic Tray Packer Across Shift Body Discomfort (n=10)

Further analysis of the pre/post - shift discomfort map data revealed there were differences in the level of discomfort reported by packers at the two companies observed (Table 24). Packers at Company 3 reported more than two times the across shift change did the packers at Company 1. The difference may be due to the slower production pace observed at Company 1 (48 vs. 58 standard boxes/FTE).

Table 24 Across Shift Body Discomfort Semi-automatic Tray Packers

Company	Type of Packing	N	Across Shift Change	Worker Age	Yrs at Packing Houses
1	Semi-auto tray	5	0.7	34	4
3	Semi-auto tray	4	1.7	37	9

At the start of the shift, 21% of semi-automatic tray packers reported high discomfort (a score of 4 or 5 on a scale of 1-5) for the lower back. This pre-shift body discomfort is an indicator of inadequate recovery from the previous shift and may suggest a chronic problem.

4.4.4.5.3 Washington Ergonomics Rule – Semi-automatic Tray Packers Job

The semi-automatic tray packing job was reviewed from the perspective of the Washington State Ergonomics Rule and was found to meet the CZJ criteria. Semi Automatic Tray Packing was further evaluated for specific WMSD hazards. This analysis was done using the criteria from the Specific Performance Approach described in WAC 296-62-05130-Appendix B.

"Caution Zone Job" Criteria

Task Description	Risk Factor & Criteria	Caution Zone Job?
Constant modest wrist flexion and deviation to arrange apples on tray for full shift	Highly repetitive – same motion every few seconds for more than 2 hours per day?	Yes
Pinch grip to pull 8-10 lb. trays down conveyor 1-5 times/minute* for full shift	High hand force – pinching 2 lb. object per hand more than 2 hours total per day	Yes – if 5 times/min. No – if <5 times/min.

*Assuming 3 seconds/pull, 5 pulls/minute = 15 seconds/minute or 25% (2 hours) of 8 hour shift

Semi Automatic Tray Packing Job Hazard Analysis

Task Description	Hazard Category and Criteria	Is Task Hazardous?
Constant modest wrist flexion and deviation to arrange apples on tray for full shift	Highly repetitive-same motion more than 6 hours/shift?	Yes
Pinch grip to pull 8-10 lb. trays down conveyor 1-5 times/minute for full shift	Pinch 2 lb. object with highly repetitive motion more than 3 hours total per day	No

According to the criteria outlined in the Ergonomics Rule, the semi-automatic tray packing job was considered hazardous and the employer must take action to reduce the hazard. Semi-automatic tray packing must be modified to reduce repetitive motion below the hazard level or to the degree feasible.

4.4.4.6 Semi-automatic Bag Packing

Semi-automatic bagging equipment was similar at the two companies, with the primary difference being that packers at Company 1 stood while packing and packers at Company 3 sat on low stools (Figure 15). Apples were dispensed from the computer-controlled sizing conveyor to a bagging machine chute. The packer held an empty bag out at about a 60º angle with two hands while waiting for the chute to fill with apples. This required the packer to hold the weight of his/her arms in that position for approximately 2-3 seconds. When the chute was filled with a predetermined weight of apples, the packer depressed a foot pedal to deliver apples into the air-inflated bag. The packer then lifted the 3- to 10-pound bag with one hand, usually using a pinch grip, twisted it, and applied a plastic closure clip using a pinch grip with the other hand (Company 1); or used an extended reach to insert the bag into the twist tie or clip closure machine (Company 3). The bag was then placed onto a conveyor for transport to boxing and palletizing. At Company 1, there was one transporting conveyor to the rear of the packers and another in front running under the bagging machines. Packers at Company 1 alternated between placing bags in front or behind them. At Company 3, all packers placed bags on a conveyor behind their workstations. Depositing apples on the conveyor to the rear of the packer required an extended elbow and twisted forearm, shoulder, and torso.


Figure 15 Semi-automatic Bag Packing at Company 1 (L) and Company 3 (R)

The semi-automatic bag packing cycle included filling the bag, applying the closure, and placing the bag on the conveyor. The mean cycle time was 7 seconds for Company 1 and 9 seconds for Company 3 (Table 25). Working at this rate with only limited breaks, a packer could handle 2,000-3,000 bags in one 8-hour day.

Table 25 Mean Cycle Time Semi-automatic Bag Packing, by Company

Job	Description of Tasks	Companies 1-3			Company 1			Company 2			Company 3		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Semi Automatic Bag Packer	Dispense apples	160	3	3	80	2	1	NA			80	3	4
	Twist, tie, place bag	160	5	3	80	5	2	NA			80	6	4
	Total Cycle Time:	8			7			NA			9		

4.4.4.6.1 Semi-automatic Bagging Job Task Observations

While positioning and filling bags, awkward hand postures were the most frequent risk factor observed (Table 26). When closing the bag and placing it on the conveyor, holding the bag out to the side (asymmetric lift) and wrist, elbow, and torso twisting positions created the greatest potential for musculoskeletal injury. Torso twisting was twice as frequent in baggers in Company 3 as compared to Company 1 (45% vs. 21%). In general, the mechanism for operating the bagging machines were the same in each company; however, the position of the worker was very different. On average, baggers were sitting 34% of the shift (Table 26); however, this does not accurately reflect the work situations at both companies. Workers were standing at Company 1 and sitting at Company 3. Reaching behind the torso activity was substantially different at the two companies (9% for company 1 vs. 29% for company 3). Workers also reached behind the right side (27% vs. 12%) of the body more often than the left (Appendix E).

Table 26 Percent of Shift Risk Factors were Observed – Semi-automatic Bagging

Body Part	Risk Factor	Contributing Tasks	% of Shift
Neck	Neck extend/flex>15deg.	Position and fill bag	43%
Hands/Wrist	Hand Pinch grip	Position and fill bag, close and place bag	73%
	Hand Radial/ulnar deviation	Position and fill bag, close and place bag	27%
	Wrist flex/extend	Close and place bag, position and fill bag	21%
Elbow	Elbow away 45 deg	Close and place bag, position and fill bag	26%
Back and Shoulders	Asymmetric lift	Close and place bag	36%
	Sitting*	Close and place bag, position and fill bag	34%
	Torso twist>20deg.	Position and fill bag	33%
	Lift/carry	Close and place bag	22%
	Reach behind torso	Close and place bag	19%

* Workers were standing at Company 1 and sitting at Company 3.

4.4.4.6.2 Semi-automatic Bagging Across Shift Body Discomfort

Semi-automatic bag packers reported greater across shift body discomfort than did workers in any other job assessed. The most discomfort was reported for the lower back (2.9), shoulders (2.1), upper back (2.1), elbows (2.1), and forearms (1.9) (Figure 16).

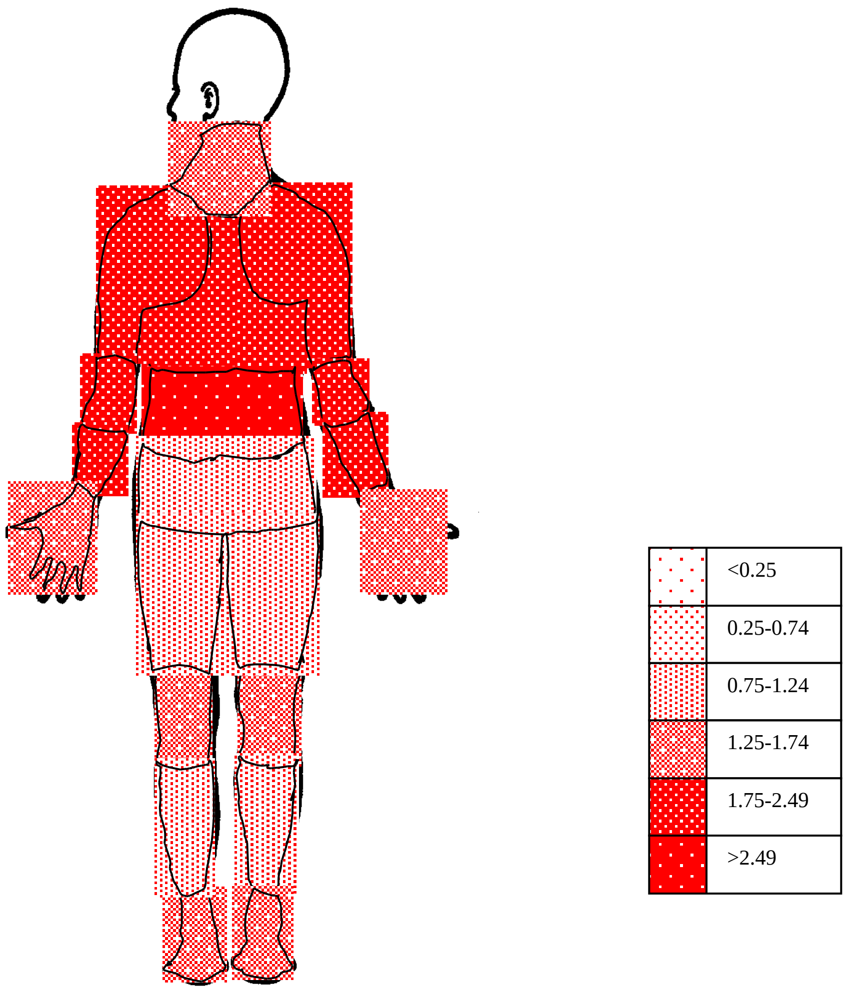


Figure 16 Semi-automatic Bag Packers Across Shift Body Discomfort (n=10)

Further analysis of the discomfort map data revealed there were differences in the level of discomfort reported by packers at the two companies observed (Table 27). The across shift discomfort level reported by Company 3 packers was greater than that reported by packers at Company 1. Company 3 semi-automatic bag packers were older, had worked in packing houses longer, and sat at workstations on low stools. Older workers have slower recovery time when muscles become fatigued (DeZwart 1995) and more years performing these repetitive tasks can cause wear and tear on ligaments and joints which produce longer recovery time and an increasing risk of injury. Sitting on low stools limited the ability to move and re-position body weight – movements that allow redistribution of muscle stress. Sitting on low stools also forced packers to engage in greater torso twisting angles when placing bags on the rear conveyor. Alternatively, a standing station allowed the packer to step back and move the entire body to reach the conveyor rather than twisting the torso.

Table 27 Across Shift Body Discomfort – Semi-automatic Bag Packers

Company	Type of Packing	N	Across Shift Change	Worker Age	Yrs at Packing Houses
1	Semi-auto bag	3	1.3	24	3
3	Semi-auto bag	4	2.1	44	10

4.4.4.6.3 Washington Ergonomics Standard – Semi-automatic Bag Packers Job

The semi-automatic bagging job was reviewed from the perspective of the Washington State Ergonomics Rule and was found to meet the CZJ criteria. Semi-automatic bagging was further evaluated for specific WMSD hazards. This analysis was done using the criteria from the Specific Performance Approach described in WAC 296-62-05130-Appendix B.

"Caution Zone Job" Criteria

Task Description	Risk Factor & Criteria	Caution Zone Job?
Pick up bag of 3-10 lbs.* (sometimes palmar, sometimes power grip) 2,00-3,000 bags/shift	Highly repetitive – same motion every few seconds for more than 2 hours total per day?	Yes
Hold unsupported arms out at 60^o angle for 3 out of every 8 seconds for full shift	No criteria in the Rule	No

* Assume 5 seconds of each 8-second cycle (more than 4 hours/day)

Semi Automatic Bagging Job Hazard Analysis

Task Description	Hazard Category and Criteria	Is Task Hazardous?
Pick up bag of 3-10 lbs.* (sometimes palmar, sometimes power grip) 2,000 to 3,000 bags/shift	High hand force-pinch of 2 lb. or any grip of 10 lb. with high repetition more than 3 hours total per day	Yes

*Assume 5 seconds of each 8-second cycle (more than 4 hours/day)

According to the criteria outlined in the Ergonomics Rule, the semi-automatic bagging job was considered hazardous and the employer must take action to reduce the hazard. Manual bag packing must be modified to reduce repetitive motion and high hand force below the hazard level or to the degree feasible.

4.4.4.7 Semi-automatic Packing Discussion

The production process of packing apples into trays or bags has been automated to some extent. Automation appears to decrease the physical load and repetition of packing apples into trays and bags. The semi-automatic processes in the participating companies reduced small repetitive motion because each apple is not handled separately. This moves the unit of repetition to the bag or tray. Most notably, the number of tasks that a worker performed and the cycle times for these tasks has decreased in semi-automatic packing. Although the same set of muscle groups are used (shoulders, arms, and hands) in semi-automated packing as in the manual process, the working postures changed to a more static nature, and the level of across shift discomfort was noticeably higher. Machinery, equipment, and workstation layout of semi-automatic tray packing was much different than was observed for manual packing. The impact of automation on workers' health and working postures has received little attention in the literature. Several studies focused on the stress associated with machine paced work, and reported higher frequency of psychological and behavioral strain among workers engaged in automated or semi-automated processes. (Wilkes, 1981; Amick and Celentano, 1991; and Wands and Yassi, 1993).

Semi-automatic tray packers maintained fairly static neck and back positions that were slightly bent and leaning into the conveyor. Arranging apples on the tray required modest and continual hand and wrist bending and twisting. These static postures may result in fatigue, since they offer no opportunity for tensed muscles to relax and recover. When the packer was responsible for both tray arranging and box filling there was a break from the continual static postures. Packers should be encouraged to frequently change position and stretch as they work in order to reduce the effects of static posture.

Box fillers often pulled filled apple trays down the conveyors to the boxing station rather than wait for the trays to move to the boxing station. This allowed the workers to fill the boxes more quickly; however, when conducting this activity, workers used a pinch grip to pull the 8-10 pound trays. Since this is a high repetition task (600-700 trays/shift), it could be classified as a high repetition/high force task with significant increased risk of hand and wrist cumulative trauma disorder (Silverstein, 1986). The filled trays will be delivered to the box filling station automatically if the box filler waits for the tray to be pushed along the conveyor by the trays behind them. Alternatively, some box fillers used a hand on each side of the tray to push/pull the tray down the conveyor rather than using a pinch grip. This method for manually moving the trays is preferable to the pinch grip because it uses the larger and stronger muscles of the forearm rather than those in the fingers.

Semi-automatic bagging is a highly repetitive and high-force job. Working at a rate of seven bags per minute with only limited breaks, a packer handled 2,000-3,000 bags in a work shift. Semi-automatic baggers hold their hands out in front of their bodies while the apples drop into the bag, which requires holding the weight of their arms at about a 60^{o} angle for approximately one third of the cycle time. They also held the weight of the full apple bag (3-10 pounds) while applying the closure tab, just as the manual bag packers do. The severity of fatigue from this activity would depend on the weight of the bags lifted.

Semi-automatic packers reported the greatest number of problems in the back and hand/wrist regions of the body. By combining information from the general symptoms questionnaire, the discomfort map, and observations, more details about the semi-automatic bag packer was elicited. Semi-automatic tray packers reported the most across shift discomfort of the hands (Figure 14). Job task observations indicated tray packers demonstrated three of the four hand risk factors. Tray packing required more precision in placing apples in tray indentations, and more hand and wrist movement to adjust apples for consistent position within the tray. Tray packers also reach with an elbow fully extended when adjusting apples in the tray row farthest from them, and this may be responsible for some of the reported discomfort in the elbows and upper shoulder regions.

Semi-automatic bagging risk factors (Table 28) and body discomfort were compared to that reported by semi-automatic tray packers (Figure 17). Bag packers had more frequent lifting risk factors than did tray packers (22% vs. 8% for lift and carry and 36% vs. 3% for asymmetric lift). Bag packers lifted filled bags in one hand while applying clip closures with the other hand. Bag packers were more likely to twist their torso (33% vs. 18%) and reach behind (27% vs. 3%) to place the bags on a moving conveyor than were tray packers. Twisting and reaching behind the torso occurred regardless of whether the bag packer was sitting or standing; however, sitting limited the ability to use the legs to step back and reposition the body thus reducing the degree of back twisting.

Table 28 Semi-automatic Packer Symptoms and Job Task Observation

Symptoms (% of All Packers w/ Work-Related Problem)	Job Task Observations (% of shift)			
	Semi-Automatic Tray		Semi-Automatic Bag	
Back – 31%	Lift/carry	8%	Lift/carry	22%
	Asymmetric lift	3%	Asymmetric lift	36%
	Torso twist	18%	Torso twist	33%
	Sitting	0%	Sitting	34%
	Standing	65%	Standing	17%*
Shoulder - 22%	Reach behind torso	3%	Reach behind torso	27 %
Hand – 27%	Hand deviation	47%	Hand deviation	27 %
	Wrist flex/extend	36%	Wrist flex/extend	21%
	Pinch grip	47%	Pinch grip	73%
Elbow - 10%	Full elbow extension	41%	Full elbow extension	18%

* bag packers at Company 3 were sitting

The stress of these awkward postures combined with the static motion and weight of the bags may produce fatigue to the shoulders and back. Semi-automatic bag packers reported the highest across shift discomfort of the back, shoulders, neck, and elbows. Bag packers also reported high discomfort in the back and shoulders (Figure 17). Bag packers reported greater across shift discomfort by the end of the shift than did workers in any other job assessed. Packers at Company 3 reported the greatest across shift body discomfort in the back and shoulder region. At Company 3, the combination of sitting on low stools during an entire shift and twisting the back to handle the bags may create greater discomfort.

The muscle groups of the back, shoulders, neck, and elbows are interrelated and strain on one group can affect other groups. The discomfort reported by semi-automated baggers in these body sites may all be related, at least in part, to holding up the weight of their arms in a static posture and to lifting filled bags. Corlett and Manenica (1980) found that no posture can be maintained without rest. Others have found that alternating between standing and sitting is more beneficial than maintaining a single posture for prolonged periods of time.

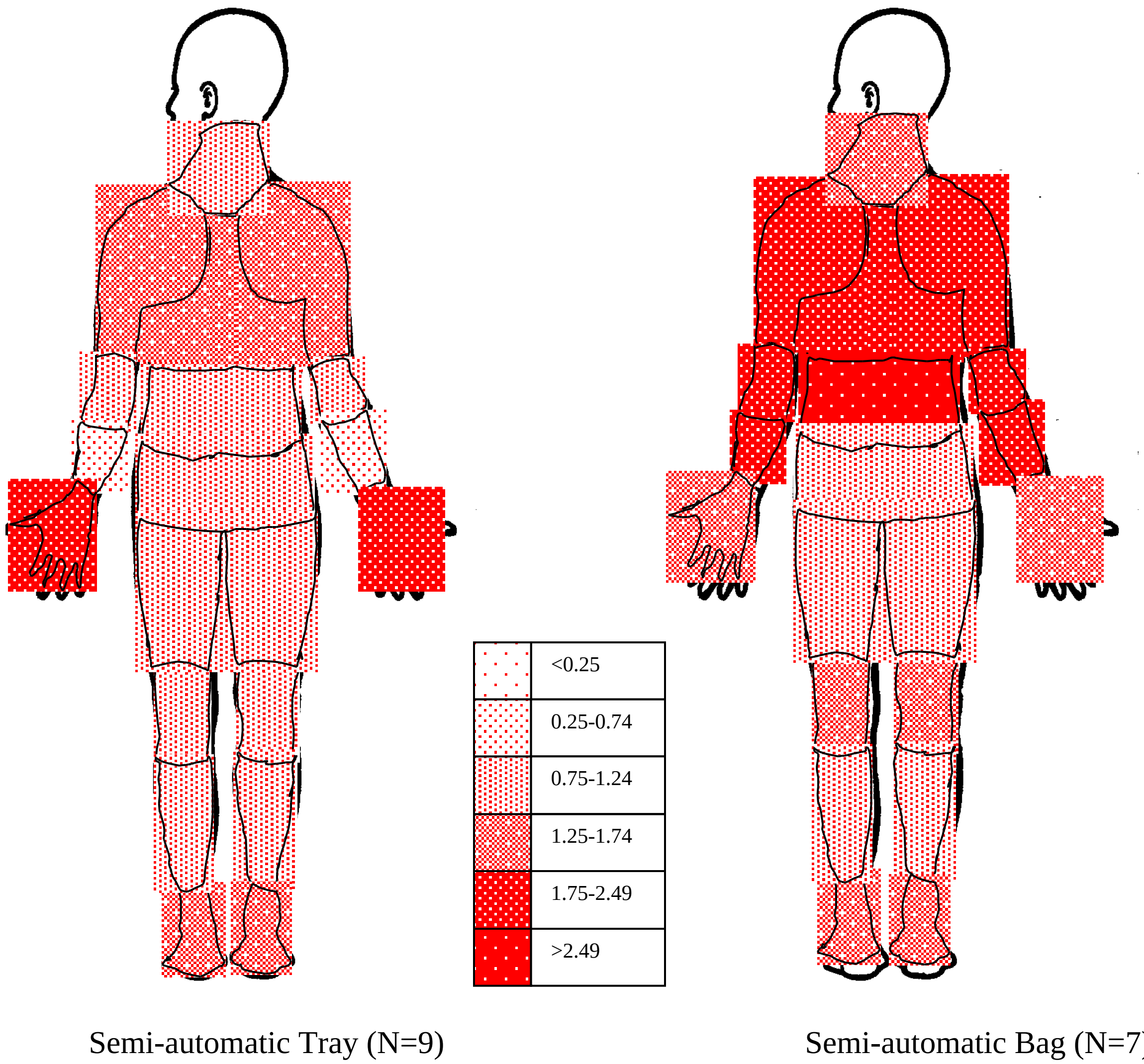


Figure 17 Across Shift Body Discomfort: Semi-automatic Tray Packing and Bagging

4.4.4.8 Semi-automatic Packing Recommendations

Remaining in a static posture for extended periods creates fatigue for both semi-automated tray and bag packers. The recommendations for floor mats (Appendix G) and sit/stand stools (Appendix H) are applicable for all prolonged standing activities. Rest breaks would be beneficial for packers as well as sorters. If the break involved stopping the conveyor, all jobs would benefit from the brief break. Packers should use frequent mini-break times to change position and stretch.

An arms-extended position to hold the bag in place creates fatigue in the shoulders and back. Some of the bagging machines were designed with a drop-down bag chute. These machines allowed the operator to stand close to the machine, thereby reducing the angle and distance arms were held away from the body. At machines where greater arm extension was needed, a reciprocating armrest could be added to the workstation (see Appendix I for a commercially available example). To reduce the time the bag is held by the operator, a lazy Susan type mechanism could be designed to support the bag of apples as it is twisted and the closure tag attached.

Workstations with the conveyor positioned in front of the operator should be explored because they may eliminate the back and elbow twisting observed when the conveyor was located behind the packer. Alternatively, a slide chute could be installed to the right of each workstation directed to the rear of the conveyor. This would allow the packer to deposit the filled bag onto the conveyor without turning. Chutes could be hinged to ease access to the work area.

Twisting backward from the sitting position is a hazard for the back. When standing, the packer can take a step at a backward angle, at least reducing the angle of back twisting. If baggers are sitting at the bag machine, we highly recommend that bag-receiving conveyors be positioned in front of the machine.

Applying a twist tie to each bag involves a pinch grip and twisting of the forearm, which may be repeated as many as 2,000-3,000 times each shift. Machines are available that can attach adhesive or tab closures to the bags. This equipment should be positioned in front of the operator to avoid twisting.

The bag machines use a one-size-fits-all design. Ideally workstations should be adjustable to accommodate a variety of worker statures or allow workers to customize the work area. Other, low-cost solutions may include provision of adjustable 2- to 6-inch platforms for shorter workers.

Rotating the trays 90 degrees to place the long edge toward the packer could reduce the reach distance for automatic tray packing workers. A bar could be installed along the back edge of the conveyor to push the tray toward the packer. The box to be filled could also be rotated 90 degrees and the box filler would change position to a location facing the length of the conveyer. This would eliminate long reaches and twisting for the box filler.

High hand forces are required when packers pull trays down the conveyor. We propose two ways to reduce this risk factor: training for packers and modification of the equipment. Awareness training can be employed to explain the risk of pinch gripping and describe alternate methods for moving trays down the conveyor. Some packers used both hands to slide trays rather than pinch grip. Two-handed sliding is much less hazardous because larger muscles of the forearm are employed rather than the small muscles of the fingers. Another alternative is to wait for the trays to reach the conveyor end automatically. Trays left on the roller tray will be pushed to the end by the trays behind them. The disadvantage of this method is that trays cannot be loaded into boxes as quickly if the line is not delivering trays one after another. To engineer out the pinch grip motion, the roller tray portion of the conveyor could be replaced with a faster take-away. A light-switch cut-off could be installed at the end to stop the conveyor when the trays reach the box.

5.0 GENERAL DISCUSSION

The six apple packing jobs assessed in this pilot study were found to be at risk for work-related musculoskeletal disorders. Fifty-three percent of the workers reported a work-related symptom in at least one body site. The criteria used to define a symptom as work-related were conservative, including frequency and duration (occurred at least once a week or lasted one week or more), a continuing problem (occurred in the last year), job-related (was first noticed on the current job), and of a chronic nature (did not start as the result of an acute trauma). There is probably at least some misclassification of work-related symptoms. One example would be sorters who had worked as packers and reported fairly severe symptoms (workers compensation claims, medical aid), but these symptoms were not classified as work-related because they did not start on the current (sorting) job. Many packers are reassigned to sorting as a light-duty job.

Packers reported more than half of the back, hand/wrist, neck, and shoulder problems that met the criteria of being work-related (62%, 64%, 57%, and 68% respectively), although very few workers' compensation claims had been filed (3%, 4%, 10%, and 0% respectively) (Table 15). This suggests that there is great potential for increasing workers' compensation costs associated with this job. Sorters had a high rate of work-related back, hand/wrist, neck, and shoulder problems (45%, 22%, 11%, and 45% respectively) that resulted in workers' compensation claims rate of 27%, 22%, 0%, and 20% respectively. This represented about half of the claims. In addition to workers' compensation costs, nearly 30% of the packers and 36% of the sorters reported than their injuries affected their pace of work, potentially contributing to higher production costs.

Repetition

Manual packing is highly repetitive, with packers handling approximately 13,000 apples per shift. Semi-automatic packing is highly repetitive, and it also has a high force component (baggers hold bags outstretched and tray packers use pinch grips to pull trays). Silverstein (1986) found that workers in high-repetition/low-force jobs had a 3 times greater risk of cumulative trauma disorders of the hand and wrist than workers in low repetition/low force jobs; the risk increased to 30 times for high-repetition/high-force jobs. This may, in part, explain the higher discomfort scores for semi-automatic packers.

Static Postures

Packing tasks performed by workers in the packing house industry are characterized by repetitive hand and wrist movements and static postures of the neck, arm, and shoulder muscles. Both static posture and repetition can produce injury when there is no break from muscle contraction (Putz-Anderson, 1988), Ohlsson (1994). When these packing house subjects (79% female) are compared to a reference group (Battevi, 1998) of female workers not exposed to repetitive tasks of the upper limbs, 13% of the reference group reported some upper limb pain compared to 68% of packing house subjects. Muscles become fatigued when there is no opportunity for blood flow to nourish the muscles and remove waste products. Micro-breaks from continual motion should be instituted by: a) encouraging workers to frequently make conscious minor changes in their posture and to use any breaks that occur due to equipment malfunction or other production changes to significantly change position and stretch; and b) briefly stop the conveyor system a few times per hour and encourage packers and sorters to change position and stretch.

Manual vs. Semi-automatic

Manual packing is more repetitive than semi-automatic packing; however, it also involves more continual and dynamic body movement. Packers have a high force component and a greater degree of static postures. The only two survey tools that could differentiate between manual or semi-automatic packing were job task observations and the across shift discomfort map. In looking at the findings of these two tools in combination, the highest hazard motions could be identified. No studies were found that addressed the effect of increased automation on musculoskeletal risk, self-reported discomfort, or injury. Jonsson (1988) found reallocation of female electronic workers from a job with highly repetitive tasks to more varied work tasks was a strong predictor of reduced symptoms in the neck, shoulder, and arm regions. Changing the job decreased static loading and increased the dynamic pattern of movements of the workers. Haider (1981) found increased pulse rates and longer reaction times for machine-paced work compared with self-paced work, especially early in the shift. Increased automation may affect a worker’s sense of discomfort because of greater restriction of movement, a sense of loss of control of the work process, and greater monotony reducing motivation.

Age Effect

Musculoskeletal disorders are multifactorial in nature, and certain studies have taken into account individual factors (e.g. age, gender, body mass index) to control for their confounding or modifying effects when looking at the strength of work-related factors. Buckwalter (1993) reported that musculoskeletal impairments are among the most prevalent and symptomatic health problems of middle and old age. The prevalence of neck and neck/shoulder disorders tends to increase with age (NIOSH, 1997). The mean age in this study population is 40 (ranging from 18-75). Our findings do not indicate higher symptom reporting or discomfort in older packers. The manual packers were generally older (mean age 47) than semi-automatic packers (mean age 36) and one would expect greater, rather than less, discomfort in an older population since recovering from muscle fatigue takes longer for older workers (deZwart, 1995). This may be due to the role of “survivor bias” (workers who have health problems leave their jobs, and the remaining population includes only those workers whose health has not been adversely affected by their jobs). Ohlsson (1989) found that for younger subjects, the odds of neck and shoulder pain increased significantly as the duration of employment increased, but for older workers no statistical change was found with the length of employment. Older workers with longer periods of employment reported fewer symptoms than did younger workers. Survivor bias underestimates the true risk of developing work-related musculoskeletal disorders.

Triangulation Method

This study was designed with a three-pronged approach using management records, worker self-reported symptoms, and risk factor observation. Findings from each evaluation tool are summarized in Table 29. There is general agreement among the assessment methods with regard to the hazardous areas for each job.

Although the OSHA 200 logs identified the same body sites as other tools, they were not all completed with the same degree of detail from year to year and company to company, so it was not possible to differentiate between jobs. These management records could provide a good source of information for a company to assess and manage work-related musculoskeletal disorders (WMSD) injury rates if attention is paid to details when recording injuries. A strong motivator for reducing the number and severity of WMSD claims could be lower workers' compensation payroll costs.

Observations using the checklist tool identified risky body postures, particularly of the upper body. Repetition, high force, and high muscle loading, especially for the back, were not particularly well assessed with the visual observation checklist used in this study. The checklist approach also lacked an exposure time element, so the assumption that an item checked on the checklist occurred for the entire cycle overestimates the actual exposure. The observational checklist used in this pilot study was useful as a quick, inexpensive screening tool to identify the greatest risk factors. Li and Buckle (1999) report that observational methods are limited but most applicable for static jobs, where body postures are held for longer periods of time or the body movements follow a simple pattern that is repeated during work. The checklist was most appropriate for observing sorter and packer jobs in this study. It was a poor tool for assessing simultaneous load/force, repetition, and duration, or for weighing or quantifying the interactions of checklist factors. We found the checklist to be least appropriate for assessing the segregator job. The NIOSH lifting equation focused on the risk of low back pain related to lifting activities and the 3-D Static Strength Test was used to assess forces and stresses of the shoulder that occur during lifts above shoulder height. We found these tools to be more sensitive in identifying injury risk than was the observation checklist.

Table 29 Summary of Hazard by Body Site

Evaluation Tool	Sorters	Packers	Segregators
OSHA 200	back, hand/wrist, shoulder, neck*		
Observations	neck, hand/wrist, forearm, elbow	neck, hand/wrist, back, elbow	back, wrist, elbow
NIOSH Lifting	NA	NA	back
3-D Static Strength	NA	NA	shoulder, back
Symptoms survey	back, shoulder, hand/wrist, neck	back, hand/wrist, shoulder, neck	shoulder
Risk Perception	upper body	upper body	none noted
Body Discomfort Map-Pre/Post Shift Change	shoulder, back, neck, hand/wrist, elbow	back, shoulder, hand/wrist, neck, elbow	none noted
Body Discomfort Map – Pre Shift		hand/wrist for manual baggers, low back for semi-auto tray packers	shoulder

* could not be designated by job type

The three survey tools used for self-reporting symptoms (symptom survey, discomfort map, and risk perception) were in good agreement with regard to the body sites of concern. The symptom survey and discomfort map were more focused on specific body sites than the risk perception survey, allowing more in-depth assessment. The open-ended risk perception survey, on the other hand, identified items of concern to employees that researchers may not have detected without more comprehensive assessment tools. The results from the risk perception survey may also be beneficial in developing an ergonomics training program for workers in this industry. Worker-perceived risks might need to be addressed before workers are receptive to information on musculoskeletal risks and discussion of possible solutions.

Occupational vs. Nonoccupational Exposure

Nonoccupational risk factors can play an important role in the development and progression of work-related musculoskeletal disorders. To evaluate the importance of nonoccupational activities in the development of reported packing house injuries, worker self-reported back pain symptoms were compared to reports of back and upper limb pain in other studies of populations at risk for work related low back pain (Table 30). Nursing and construction work are occupations with known risk of low back pain related to occupational exposure. Cust (1972) compared nurses and teachers to ascertain whether or not low back pain was work or non-work-related. Latza (2000) selected a cohort of male construction workers free of low back pain and conducted a follow up three years later and determined that there was 50% prevalence of low back pain over the last 12 months. Packing house workers reported low back pain symptoms more frequently than did nurses and at the same rate as construction workers. Approximately half of the packing house participants had work-related back pain, similar to the rate reported by nurses.

Table 30 Back Pain: Packing House Workers vs. Reference Group

Industry (gender studied)	Reference	All Low Back Pain	Occup. Low Back Pain	Non-Occup. Low Back Pain
Nurses (female)	Cust, 1972	34.6%	19.9%	14.8%
Teachers (female)	Cust, 1972	30.0%	12.8%	17.2%
Construction (male)	Latza, 2000	50.1%		
Packing House (79% female)		48.5%*	26.5%*	

* general back pain, not specifically low back pain

Although some study participants reported having a second job (15%) or non-occupational activities (64%) with potential for musculoskeletal risk, the time spent with these activities (mean of 5 hours/week) is considerably less than the 40 hour work shift spent at the packing house. Some of our study participants had health conditions that have been associated with an increased risk of WMSD, although the prevalence did not exceed the prevalence in the general population.

The Washington Ergonomics Rule

All six packing house jobs evaluated in this study would be classified as "Caution Zone Jobs" (CZJ) under the Washington Ergonomics Rule, with most jobs having more than one task meeting the selection criteria. Further analysis of CZJ tasks, using the hazard criteria in

Appendix B of the rule, showed that all jobs continued to have at least one task that would be classified as hazardous. According to the rule, such tasks must be modified to reduce the hazard below the hazard level or to the degree feasible. Repetition is the primary hazard for packers and sorters. The repetition hazard could be reduced by instituting breaks, stretching exercises, rotation schedules, or through new engineering solutions.. The same would be true of manual materials handling tasks done by segregators.

Packing houses with more than 49 employees are scheduled to complete ergonomics awareness training and hazard analysis by July 2003 and complete hazard reduction efforts by July 2004. Under the requirements of the Rule, workers and their supervisors must receive ergonomics awareness education initially and at least every three years. Another employer or organization may provide this training.

When considering controls to reduce hazards, engineering or administrative measures should be considered first (examples include changes to workstations and tools, change in size and weight of loads, process redesign, job rotation, and work schedule modification). Individual work practices or personal protective equipment (such as kneepads, impact gloves, and team lifting) should be second priority controls. Employees must be involved in the analysis and in the selection and evaluation of control methods to reduce hazards. Others, such as ergonomic consultants or manufactures of packing house production equipment, may be helpful in exploring hazard controls.

Some specific controls to reduce the hazards to segregators include eliminating above-the-shoulder lifting and twisting, and reducing the frequency of lifting to less than four boxes per minute. Controls to reduce repetition in sorter and packer tasks would be important priorities.

6.0 CONCLUSIONS

Repetition, static-loading postures, extended reaches, and high force are characteristics of packing house jobs that put workers in this industry at risk of developing work-related musculoskeletal disorders (WMSD). The high force, high repetition, and awkward postures associated with segregator lifting tasks produces high risk of back and shoulder injury. The repetitive nature of packing creates greater potential for upper limb repetitive trauma injury. The high forces used in manually packing bags and semi-automatically packing bags and trays increases the risk of injury. Initial efforts to reduce WMSD risks should begin in the packer and segregator jobs in that they have the most frequent and severe risk factors. The first priority should be to eliminate any high force aspects of the packing job, since force combined with repetition greatly increases the risk of injury. Another area for focus should be on re-examining the way that segregators palletize boxes. These and other possible interventions to reduce or eliminate musculoskeletal risks need to be reviewed for feasibility with input from the industry.

To address how to best modify jobs to reduce risk of WMSD for a specific packing house, studies (Griffith 1985; Rosecrance 2000; Moore 1996) have shown that an inclusive and iterative process that involves management, line workers, and vendors is the best method for finding company-specific solutions. Many companies have successfully established and trained ergonomics committees or teams that assessed specific jobs, they then worked with industry vendors to identify existing solutions or encourage vendors to develop new engineering solutions. This is particularly effective when vendors believe there is a developing market for new solutions. Finally, worker perception of risk should be included when contemplating any intervention strategy. Perception of risk may identify areas of greatest opportunity to enlist worker cooperation in finding and fixing problems.

Limitations

This study was designed to survey the breadth of size and packing styles found in Washington packing houses. The small number of participating packing houses limits the ability to extrapolate these findings to the entire industry. However, we believe the processes and work conditions observed and reported here are similar, if not identical, to those found throughout the industry. Since only one or two days were sampled, it may not reflect the variability in production and exposure as well as other conditions that may change over time. For example, observations were made in the spring, yet the highest production times are in the fall of the year when more or different risk factors may have been observed. Many workers change jobs from day to day, so chronic health effects could not be assessed for specific jobs. Because company injury data could not be confidently categorized by job, job-specific symptoms, discomfort, and risk factors could not be compared with injury rates. Medical examinations of participating workers would have provided some objective verification of self-reported symptoms.

Future Studies

The focus of this study was limited to a musculoskeletal risk assessment and possible ergonomic solutions in four job classifications in the packing house industry. Risks and solutions in other jobs in this industry could and should be evaluated. Air quality, safety, and other issues also would be appropriate topics for a follow-up study of this industry. The effect of machine pacing on discomfort levels could be further explored to determine whether the incidence of WMSD is greater with machine pacing vs. self-pacing. As the industry implements interventions to reduce the hazard of WMSD, comparing risk factors to the baseline data in this study could assess the effectiveness of these interventions over time.

7.0 REFERENCES

Amano M, Umeda G, Nakajama H, Yatsuki K. 1988. Characteristics of work actions of shoe manufacturing assembly line workers and a cross-sectional factor-control study on occupational cervicobrachial disorders. Jpn J Ind Health 30:3-12.

American Heart Association. 2001. 2001 Heart and Stroke Statistical Update. http://www.americanheart.org/statistics/hb.html.

Amick BC, Celentano DD. 1991. Structural determinants of the psychosocial work environment: introducing technology in the work stress framework. Ergonomics 34(5):625-646.

Arcury TA. 1995. Risk perceptions of occupational hazards among black farmers in the Southeastern Untied States. J Rural Health 11:240-250.

Armstrong, TJ, Buckle P, Fine LJ, Hagberg M, Jonsson B, Kilbom A. 1993. A conceptual model for work-related neck and upper-limb musculoskeletal disorders. Scand J Work Environ Health 19(2):73-84.

Battevi G, Menoni O, Vimercati C. 1998. The occurrence of musculoskeletal alterations in worker populations not exposed to repetitive tasks of the upper limbs. Ergonomics 41:9:1340-1346.

Bhatnager V, Drury CG, Schiro SG. 1985. Posture, postural discomfort, and performance. Human Factors 27(2):189-199.

Bollen AF. 1986b. How efficient is your packhouse—and its sorting table. N Z Kiwifruit March:20-21.

Bollen AF, Prussia SE, Lidror L. 1993. Visual inspection and sorting. In Postharvest Handling- A systems approach. Eds. (Shewfelt RL and Prussia SE eds), CA: Academic Press.

Borg G. 1990. Psychophysical scaling with applications in physical work and the perception of exertion. Scand J Work Environ Health 16(suppl 1):55-58.

Brisson C, Vinet A, Vezina M, Gingras S. 1989. Effect of duration of employment in piecework on severe disability among female garment workers. Scand J Work Environ Health. Oct;15(5):329-34.

Buckwalter JA, Woo SL-Y, Goldberg VM, Hadley EC, Booth F, Oegema TR, et al. 1993. Current concepts review: soft-tissue aging and musculoskeletal function. J Bone Joint Surg (AM) 75A(10):1533-1548.

Canaris GJ, Manowitz N, Mayor G, Ridgway E. 2000. The Colorado Thyroid Disease Prevalence Study. Arch Intern Med 160(4):526-34.

Chiang H, Chen S, Yu H, Ko Y. 1990. The occurrence of carpal tunnel syndrome in frozen food factory employees. Kao Hsiung J Med Sci 6:73-80.

Chiang H-C, Ko Y-C, Chen S-S, Yu H-S, Wu T-N, Chang P-Y. 1993. Prevalence of shoulder and upper-limb disorders among workers in the fish processing industry. Scan J Work Environ Health 19:126-131.

Chiang H-C, Ko Y-C, Chen S-S, Yu H-S, Ko YC. 1990. The occurrence of carpal tunnel syndrome in frozen food factory employees. Kaohsiung J Med Sci 6:73-80.

Colombini D. 1998. An observational method for classifying exposure to repetitive movements of the upper limb. Ergonomics 41(9):1261-1289.

Colquhoun WP. 1959. The effect of a short rest pause on inspection efficiency. Ergonomics 2:367-372.

Corlett EN, Manenica I. 1980. The effects and measurement of working postures. Applied Ergonomics 11(1):7-16.

Corlett EN, Bishop RP. 1976. A technique for assessing postural discomfort. Ergonomics 19(2):175-182.

Cust G, Pearson J, Mair A. 1972. The prevalence of low back pain in nurses. International Nursing Review 19(2):169-179.

DeZwart B, Frings-Dresen M, van Dijk F. 1995. Physical workload and the aging worker: A review of the literature. Int Arch Occup Environ Health 68:l-12.

Eastman Kodak Company. 1983. Ergonomic Design for People at Work – Volume 1. p 60-63. Van Nostrand Reinhold. New York.

Faulkner TW, Murphy TJ. 1973. Lighting for difficult visual tasks. Human Factors 15(2):149-162.

Griffith DK. 1985. Safety Attitudes of Management. Ergonomics 28(1):61-67.

Haider M, Koller M, Groll-Knapp E , Cervinka R, Kundi M. Psychophysiological Studies on Stress and Machine-Paced Work. *Machine Pacing and Occupational Stress – Proceedings of the International Conference.* Purdue University. March 1981.

Hendrix ATM.1989. An analysis system to establish the degree of incapacity. Acta Horticulturae 237:123-128.

Hunter JH, Yaeger EC. 1970. Use of a float roll table in potato grading operations. Maine Agricultural Experimental Station Bulletin No. 690. Orono, Maine.

Jarosz L and Qazi J. 2000. The geography of Washington's word apple: global expressions in a local landscape. Journal of Rural Studies 16:1-11.

Jonsson BG, Persson J, Kilbom A. 1988. Disorders of the cervicobrachial region among female workers in the electronics industry. A two-year follow up. Int J Ind Ergon 3(1):1-12.

Karwowski W, Marras W, ed. 1999. The Occupational Ergonomics Handbook. p.880. CRC Press.

Kuorinka I, Koskinen P. 1979. Occupational rheumatic diseases and upper limb strain in manual jobs in a light mechanical industry. Scan J Work Environ Health 5(suppl 3):39-47.

Kurppa K, Viikari-Juntura E, Kuosma E, Huuskonen M, Kivi P. 1991. Incidence of tenosynovitis or peritendinitis and epicondylitis in a meat processing factory. Scan J Work Environ Health 17:32-37.

Kurppa K, Warris P, Rokkanen P. 1979. Peritendinitis and tenosynovitis, A review. Scand J Work Environ Health 5(suppl 3):19-24.

Latza U, Karmaus W, Sturmer T, Steiner M, Neth A, Rehder U. 2000. Cohort study of occupational risk factors of low back pain in construction workers. Occupational and Environmental Medicine 57:28-34.

Leboeuf-Yde C, Kyvik KO, Bruun NH. 1999. Low back pain and lifestyle. Part II—Obesity. Information from a population-based sample of 29,424 twin subjects. Spine 24(8):779-783.

Li G, Buckle P. 1999. Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods. Ergonomics May 42(5):674-695

Luopajarvi T, Kuorinka I, Virolainen M, Holmbert M.1979. Prevalence of tenosynovitis and other injuries of the upper extremities in repetitive work. Scan J Work Environ Health 5(suppl 3):48-55.

Malcolm DG, DeGarmo ED. 1953. Visual Inspection of Products for Surface Characteristics in Grading Operations. USDA Marketing Research Report No. 45. U.S. Govt Printing Office, Washington, D.C.

Messing K, Saurel-Cubizolles MJ, Bourgine M, Kaminski M. 1992. Menstrual cycle characteristics and work conditions of workers in poultry slaughterhouses and canneries. Scand J Work Environ Health 18:302-309.

Meyers JB, Prussia SE, Thai CN, Sadosky TL, Campbell DJ. 1990. Visual inspection of agricultural products moving along sorting conveyors. Transactions of the ASAE 33(2):367-372.

Miller KJ.1991. Attaining and maintaining human performance in quality grading of horticultural produce. Postharvest News and Information 2(2):85-89.

Moore, J.S. 1996. Use of participatory ergonomics teams to address musculoskeletal hazards in the red meat packing industry. Am J Ind Med 29(4):402-408.

National Institute of Occupational Safety and Health (NIOSH). 1991. Epidemiological basis for manual lifting guidelines. In: Scientific support documentation for the revised 1991 NIOSH lifting equation: technical contract reports. Springfield, VA: National Technical Information Service (NTIS), NTIS No. PB-91-226274.

National Institute of Occupational Safety and Health (NIOSH). 1997. Bernard BP (ed). Musculoskeletal disorders and workplace factors: a critical review of epidemiologic evidence for work-related disorders of neck, upper extremity, and low back. DHHS (NIOSH) Publication No. 97-141. Centers for Disease Control and Prevention. NIOSH, Cincinnati, Ohio.

National Safety Council. 1998. Accident Facts. 1998 ed. National Safety Council, Chicago, Illinois.

Nicholson JV. 1985. Color and light for the inspection table. SIRTEC Publication No. 1. New Zealand Department of Scientific and Industrial Research. Wellington, New Zealand.

Ohlsson K, Attewell R, Paisson B, Karlsson B, Balogh I, Johnsson B, et al. 1995. Repetitive industrial work and neck and upper limb disorders in females. Am J Ind Med 27(5):731-747.

Ohlsson K, Attewell RG, Skerfving S. 1989. Self-reported symptoms in the neck and upper limbs of female assembly workers. Scand J Work Environ Health 15: 75-80.

Ohlsson K, Hansson GA, Balogh I, Stromberg U, Palsson B, Nordander C, et al. 1994. Disorders of the neck and upper limbs in women in the fish processing industry. Occup Environ Med 51:826-832.

Pang, DW. 1994. Prediction and quantification of apple bruising. PhD Thesis. Massey University, New Zealand.

Peleg K.1985. *Produce handling, packaging, and distribution.* Westport, Connecticut: Avi Publishing Company, Inc.

Pinzke S. 1997. Observational methods for analyzing working postures in agriculture. J Agric Safety & Health 3(3):169-194.

Prussia SE, Meyers JB Jr. 1989. Ergonomics for improving visual inspection at fruit packing houses. Acta Hort 258:357-364.

Purswell JL, and Hoag L. 1974. Strategies for improving visual inspection performance. Proceedings of the 18th Annual Meeting of the Human Factors Society, California, 397-403.

Putz-Anderson V, ed., 1988. *Cumulative Trauma Disorders – A Manual for Musculoskeletal Diseases of the Upper Limbs.* Taylor and Francis. London.

Resnick HE, Harris M, Brock D, Harris T. 2000. American Diabetes Association diabetes diagnostic criteria, advancing age, and cardiovascular disease risk profiles: results from the Third National Health and Nutrition Examination Survey. Diabetes Care 23(2):176-80.

Rosecrance JC, Cook T. 2000. The use of participatory action research and ergonomics in the prevention of work-related musculoskeletal disorders in the newspaper industry. Appl Occup Environ Hyg 15(3):255-262.

Safety and Health Assessment and Research for Prevention Program (SHARP), Washington State Department of Labor and Industries. 1999. Participatory ergonomics interventions in tree nurseries. Under Cooperative Agreement U06/CCU012917-02. December, 29, 1999.

Sandzen SC Jr.1981. Carpal tunnel syndrome. Am Fam Physician 24:190-204.

Silverstein B, Kalat J.1998. Incidence of work-related disorders of the back and upper-extremity in Washington state, 1989-1996. Safety and Health Assessment and Research for Prevention Program (SHARP), Washington State Department of Labor and Industries. Technical Report Number 40-1-1997. Olympia, Washington

Silverstein B, Fine LJ, Armstrong TJ. 1986. Occupational factors and carpal tunnel syndrome. Am J Ind Med 11:343-358.

Smith RJ. 1963. The rapid pack method of packing fruit. California Agricultural Experimental Station Extension Service Circular, No. 521.

Studman C. 1998. Ergonomics in apple sorting: a pilot study. Journal of Agricultural Engineering Research 70:323-334.

Teamsters. 1997. An industry ripe for fairness: Washington state apple workers unite for dignity and a living wage.

U.S. Bureau of the Census.1994. 1992 Census of Agriculture: Washington. Volume 1. Washington, DC: U.S. Department of Commerce.

University of Michigan Center for Ergonomics. 3D Static Strength Prediction Program, Version 2.0. Ann Arbor, Michigan, 1993.

Vaughan. 1993. Chronic Exposure to Environmental Hazards: risk perceptions and self protective behavior. Health Psycho Jan 12(1):74-85.

Wands SE, Yassi A. 1993. Modernization of a laundry processing plant: is it really an improvement? Applied Ergonomics 24(6):387-396.

Washington Agricultural Statistics Service. 1999. Washington Agricultural Statistics:1997-1999. Washington State Department of Agriculture.

Washington State Department of Labor and Industries (L&I). 1997. *Injury and Illness Recordkeeping. F415-013-000(2/97).*

Waters TR, Putz-Anderson, Garg A, Fine LJ. 1993. Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics 36(7):749-776.

Waters TR, Putz-Anderson V, Garg A. 1994. *Applications Manual for the Revised NIOSH lifting Equation.* DHHS Publication No. 94-110.

Wilkes B, Stammerjohn L, Lalich N. 1981. Job demands and worker health in machine-paced poultry inspection. Scand J Work Environ Health 7 suppl 4:12-19.

Yakima Valley Growers-Shippers Association. Monthly Apple Storage Report (YVGS). December 1, 1999.

Zegers DHA. 1989. Perceptual and mental workload during selection tasks. Acta Horticulturae 237:149-155.

8.0 OTHER RESOURCES

Andersson JAD. 1984. Shoulder pain and tension neck and their relation to work. Scand J Work Environ Health 10(6):435-442.

Arch Intern Med. 1998. Executive Summary of the Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults. Arch Intern Med 158(17):1855-67.

Armstrong J, Fine LJ, Goldstein SA, Lifshitz YR, Silverstein BA. 1987. Ergonomics considerations in hand and wrist tendinitis. J Hand Surg 12A (2 Pt 2):830-837.

Armstrong, TJ. Introduction to Industrial Ergonomics. Continuing Education Course offered January 16-17, 1996. Northwest Center for Occupational Health and Safety, Department of Environmental Health, University of Washington. Seattle, WA.

Guangyan L, Buckle P. 1999. Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods. Ergonomics 42(5):674-695.

Kaplan PE. 1983. Carpal tunnel syndrome in typists. JAMA 250(6), 821-822.

Meyers JM, Miles JA, Faucett J, Janowitz I, Tejeda DG, Kabashima JN. 1997. Ergonomics in agriculture: workplace priority setting in the nursery industry. AIHA Journal 58:121-126.

National Institute of Occupational Safety and Health (NIOSH). 1994. Participatory ergonomic interventions in meatpacking plants. NIOSH Publication No. 94-124. Centers for Disease Control and Prevention. NIOSH, Cincinnati, Ohio.

Occupational Safety and Health Administration (OSHA). OSHA Draft Proposed Ergonomics Standard for General Industry. 1996. CFR 1910.500-513. Website address: www.osha-slc.gov/SLTC/ergonomics/ergoreg.html.

Punnett L, Robins JM, Wegman DH, Keyserling WM. 1985. Soft-tissue disorders in the upper limbs of female assembly workers: impact of length of employment, work pace, and selection. Scand J Work Environ Health 11(6):417-425.

Qazi, JA. 1998. The hands behind the apple: farm women and work in north central Washington. Dissertation, University of Washington.

Silverstein BA, Fine LJ, Armstrong TJ. 1986. Hand wrist cumulative trauma disorders in industry. Br J Ind Med 43:779-784.

Silverstein B, Welp E, Nelson N, Kalat J. 1988. Claims incidence of work-related disorders of the upper extremities: Washington State, 1987-1995. Am J Public Health 88:1827-1833.

Appendix A: Recruitment and Consent

Appendix B: Observational Checklists and Protocol

Appendix C: Structured Interview Questionnaires

Appendix D: Body Discomfort Map

Appendix E: Observed Risk Factors for All Jobs

SORTERS – Percent of Shift Posture Occurs

Sorters Risk Factor	% of Shift Co.1	% of Shift Co. 2	% of Shift Co. 3	%of Shift Total
Power grip-right	0%	0%	0%	0%
Power grip-left	0%	0%	0%	0%
Power grip-mean	0%	0%	0%	0%
Grip slippery object-right	0%	0%	0%	0%
Grip slippery object-left	0%	0%	0%	0%
Grip slippery object-mean	0%	0%	0%	0%
Push/pull-right	0%	0%	0%	0%
Push/pull-left	0%	0%	0%	0%
Push/pull-mean	0%	0%	0%	0%
Lift/carry-right	0%	0%	0%	0%
Lift/carry-left	0%	0%	0%	0%
Lift/carry-mean	0%	0%	0%	0%
Pinch grip-right	0%	15%	46%	20%
Pinch grip-left	5%	20%	20%	15%
Pinch grip-mean	3%	18%	33%	18%
Wrist flex/extend-right	25%	25%	45%	32%
Wrist flex/extend-left	14%	44%	30%	29%
Wrist flex/extend-mean	20%	35%	38%	31%
Radial/ulnar deviation-right	79%	60%	64%	68%
Radial/ulnar deviation-left	45%	68%	43%	52%
Radial/ulnar deviation-mean	62%	64%	54%	60%
Forearm twist/rotate-right	55%	34%	38%	42%
Forearm twist/rotate-left	38%	48%	23%	36%
Forearm twist/rotate-mean	47%	41%	31%	39%
Elbow away 45 deg.-right	24%	6%	14%	15%
Elbow away 45 deg.-left	8%	21%	13%	14%
Elbow away 45 deg.-mean	16%	14%	14%	15%
Full elbow extension-right	63%	34%	39%	45%
Full elbow extension-left	30%	41%	18%	30%
Full elbow extension-mean	47%	38%	29%	38%
Hand above shoulder-right	0%	19%	13%	10%
Hand above shoulder-left	0%	0%	4%	4%
Hand above shoulder-mean	0%	10%	9%	7%
Reach behind torso-right	4%	0%	0%	1%
Reach behind torso-left	3%	0%	0%	1%
Reach behind torso-mean	4%	0%	0%	1%
Torso flex>45 deg.	5%	5%	5%	5%
Torso side bend>20deg.	0%	0%	6%	2%
Torso twist>20deg.	1%	24%	9%	11%
Neck extend/flex>15deg.	91%	66%	98%	85%

Sorters cont. - Risk Factor	% of Shift Co.1	% of Shift Co. 2	% of Shift Co. 3	%of Shift Total
Neck twist>15deg.	8%	15%	11%	11%
Asymmetric lift	0%	0%	0%	0%
Obstructed lift	0%	0%	0%	0%
Hand/wrist contact stress-right	3%	1%	1%	2%
Hand/wrist contact stress-left	1%	0%	6%	3%
Hand/wrist contact stress-mean	2%	1%	4%	3%
Forearm contact stress-right	4%	8%	0%	4%
Forearm contact stress-left	13%	4%	0%	5%
Forearm contact stress-mean	9%	6%	0%	5%
Torso contact stress-right	0%	25%	14%	13%
Torso contact stress-left	25%	25%	13%	21%
Torso contact stress-mean	13%	25%	14%	17%
Leg contact stress-right	0%	0%	25%	8%
Leg contact stress-left	0%	0%	25%	8%
Leg contact stress-mean	0%	0%	25%	8%
Hand as hammer-right	0%	0%	0%	0%
Hand as hammer-left	0%	0%	0%	0%
Hand as hammer-mean	0%	0%	0%	0%
Static body part-right	0%	0%	0%	0%
Static body part-left	0%	0%	0%	0%
Static body part-mean	0%	0%	0%	0%
Stand w/ foot activator-right	0%	0%	0%	0%
Stand w/ foot activator-left	0%	0%	0%	0%
Stand w/ foot activator-mean	0%	0%	0%	0%
Stand w/ foot rest-right	11%	0%	0%	4%
Stand w/ foot rest-left	6%	0%	0%	2%
Stand w/ foot rest-mean	9%	0%	0%	3%
Stand stationary	59%	41%	100%	67%
Kneel/crawl	4%	0%	0%	1%
Squat	4%	3%	0%	2%
Sitting	16%	53%	0%	23%
Walking	0%	0%	0%	0%
Uneven surface	0%	0%	0%	0%
Wet/slippery surface	0%	0%	0%	0%
Whole body vibration	0%	0%	0%	0%
Jump up/down level	0%	0%	0%	0%
PPE-back belt	0%	0%	0%	0%
PPE-gloves/wrist band	40%	15%	40%	32%

MANUAL TRAY– Percent of Shift Risk Factor Occurs

Manual Tray Risk Factor	% of Shift Co.1	% of Shift Co. 2	% of Shift Total
Power grip-right	2%	4%	3%
Power grip-left	2%	2%	3%
Power grip-mean	2%	3%	3%
Grip slippery object-right	0%	21%	13%
Grip slippery object-left	0%	19%	11%
Grip slippery object-mean	0%	20%	12%
Push/pull-right	5%	3%	4%
Push/pull-left	5%	5%	5%
Push/pull-mean	5%	4%	4%
Lift/carry-right	1%	6%	4%
Lift/carry-left	33%	5%	16%
Lift/carry-mean	17%	6%	10%
Pinch grip-right	76%	50%	61%
Pinch grip-left	63%	42%	51%
Pinch grip-mean	70%	46%	56%
Wrist flex/extend-right	34%	37%	35%
Wrist flex/extend-left	42%	43%	42%
Wrist flex/extend-mean	38%	40%	39%
Radial/ulnar deviation-right	56%	68%	63%
Radial/ulnar deviation-left	16%	65%	46%
Radial/ulnar deviation-mean	36%	67%	54%
Forearm twist/rotate-right	55%	51%	52%
Forearm twist/rotate-left	14%	29%	22%
Forearm twist/rotate-mean	34%	40%	37%
Elbow away 45 deg.-right	59%	62%	60%
Elbow away 45 deg.-left	15%	31%	25%
Elbow away 45 deg.-mean	37%	47%	42%
Full elbow extension-right	53%	46%	49%
Full elbow extension-left	13%	6%	9%
Full elbow extension-mean	33%	26%	29%
Hand above shoulder-right	6%	22%	15%
Hand above shoulder-left	13%	5%	8%
Hand above shoulder-mean	10%	13%	12%
Reach behind torso-right	5%	3%	4%
Reach behind torso-left	0%	0%	0%
Reach behind torso-mean	3%	2%	2%
Torso flex>45 deg.	3%	11%	8%
Torso side bend>20deg.	24%	40%	34%
Torso twist>20deg.	4%	5%	4%
Neck extend/flex>15deg.	80%	84%	82%
Neck twist>15deg.	37%	64%	53%
Asymmetric lift	5%	0%	2%

Manual Tray cont. - Risk Factor	% of Shift Co.1	% of Shift Co. 2	% of Shift Total
Obstructed lift	0%	0%	0%
Hand/wrist contact stress-right	0%	0%	0%
Hand/wrist contact stress-left	0%	0%	0%
Hand/wrist contact stress-mean	0%	0%	0%
Forearm contact stress-right	0%	0%	0%
Forearm contact stress-left	0%	0%	0%
Forearm contact stress-mean	0%	0%	0%
Torso contact stress-right	12%	12%	12%
Torso contact stress-left	12%	11%	11%
Torso contact stress-mean	12%	11%	12%
Leg contact stress-right	9%	05	3%
Leg contact stress-left	9%	0%	3%
Leg contact stress-mean	9%	0%	3%
Hand as hammer-right	0%	0%	0%
Hand as hammer-left	9%	05	3%
Hand as hammer-mean	4%	0%	2%
Static body part-right	0%	0%	0%
Static body part-left	0%	0%	0%
Static body part-mean	0%	0%	0%
Stand w/ foot activator-right	0%	0%	0%
Stand w/ foot activator-left	0%	0%	0%
Stand w/ foot activator-mean	0%	0%	0%
Stand w/ foot rest-right	0%	0%	0%
Stand w/ foot rest-left	0%	0%	0%
Stand w/ foot rest-mean	0%	0%	0%
Stand stationary	77%	685	72%
Kneel/crawl	0%	0%	0%
Squat	0%	2%	3%
Sitting	0%	0%	2%
Walking	0%	0%	3%
Uneven surface	0%	0%	0%
Wet/slippery surface	0%	0%	0%
Whole body vibration	0%	0%	0%
Jump up/down level	2%	11%	0%
PPE-back belt	0%	0%	0%
PPE-gloves/wrist band	3%	3%	3%

MANUAL BAG– Percent of Shift Risk Factor Occurs (Packing Task Only)

Manual Bag Risk Factor	% of Shift Co.1	% of Shift Co. 2	% of Shift Total
Power grip-right	11%	0%	3%
Power grip-left	0%	0%	0%
Power grip-mean	5%	0%	2%
Grip slippery object-right	0%	0%	0%
Grip slippery object-left	2%	0%	1%
Grip slippery object-mean	1%	0%	0%
Push/pull-right	0%	0%	0%
Push/pull-left	0%	0%	0%
Push/pull-mean	0%	0%	05
Lift/carry-right	29%	22%	24%
Lift/carry-left	225	14%	16%
Lift/carry-mean	25%	18%	20%
Pinch grip-right	73%	53%	58%
Pinch grip-left	67%	60%	61%
Pinch grip-mean	70%	57%	59%
Wrist flex/extend-right	27%	25%	25%
Wrist flex/extend-left	25%	24%	24%
Wrist flex/extend-mean	26%	25%	25%
Radial/ulnar deviation-right	55%	42%	45%
Radial/ulnar deviation-left	38%	41%	39%
Radial/ulnar deviation-mean	46%	42%	42%
Forearm twist/rotate-right	44%	41%	40%
Forearm twist/rotate-left	20%	19%	19%
Forearm twist/rotate-mean	32%	30%	30%
Elbow away 45 deg.-right	49%	31%	36%
Elbow away 45 deg.-left	18%	24%	21%
Elbow away 45 deg.-mean	34%	27%	29%
Full elbow extension-right	13%	45%	34%
Full elbow extension-left	11%	22%	18%
Full elbow extension-mean	12%	33%	26%
Hand above shoulder-right	0%	10%	7%
Hand above shoulder-left	2%	15%	11%
Hand above shoulder-mean	1%	13%	9%
Reach behind torso-right	0%	1%	1%
Reach behind torso-left	0%	1%	1%
Reach behind torso-mean	0%	1%	1%
Torso flex>45 deg.	2%	3%	2%
Torso side bend>20deg.	22%	24%	22%
Torso twist>20deg.	0%	24%	16%
Neck extend/flex>15deg.	58%	62%	59%
Neck twist>15deg.	42%	41%	40%
Asymmetric lift	42%	16%	24%

Manual Bag cont. - Risk Factor	% of Shift Co.1	% of Shift Co. 2	% of Shift Total
Obstructed lift	0%	1%	1%
Hand/wrist contact stress-right	0%	0%	0%
Hand/wrist contact stress-left	0%	0%	0%
Hand/wrist contact stress-mean	0%	0%	0%
Forearm contact stress-right	0%	0%	0%
Forearm contact stress-left	0%	0%	0%
Forearm contact stress-mean	0%	0%	0%
Torso contact stress-right	18%	14%	15%
Torso contact stress-left	18%	14%	15%
Torso contact stress-mean	18%	14%	15%
Leg contact stress-right	0%	0%	0%
Leg contact stress-left	0%	0%	0%
Leg contact stress-mean	0%	0%	0%
Hand as hammer-right	0%	0%	0%
Hand as hammer-left	0%	0%	0%
Hand as hammer-mean	0%	0%	0%
Static body part-right	0%	0%	0%
Static body part-left	0%	0%	0%
Static body part-mean	0%	0%	0%
Stand w/ foot activator-right	0%	0%	0%
Stand w/ foot activator-left	0%	0%	0%
Stand w/ foot activator-mean	0%	0%	0%
Stand w/ foot rest-right	0%	0%	0%
Stand w/ foot rest-left	0%	0%	0%
Stand w/ foot rest-mean	0%	0%	0%
Stand stationary	76%	51%	58%
Kneel/crawl	0%	0%	0%
Squat	0%	0%	0%
Sitting	0%	0%	0%
Walking	0%	0%	0%
Uneven surface	0%	0%	0%
Wet/slippery surface	0%	0%	0%
Whole body vibration	0%	0%	0%
Jump up/down level	0%	0%	0%
PPE-back belt	0%%	0%	0%
PPE-gloves/wrist band	4%	3%	3%

SEMIAUTO TRAY– Percent of Shift Risk Factor Occurs

Semi-Auto Tray - Risk Factor	% of Shift Co.1	% of Shift Co. 3	% of Shift Total
Power grip-right	0%	0%	0%
Power grip-left	0%	0%	0%
Power grip-mean	0%	0%	0%
Grip slippery object-right	0%	0%	0%
Grip slippery object-left	0%	0%	0%
Grip slippery object-mean	0%	0%	0%
Push/pull-right	6%	26%	13%
Push/pull-left	4%	8%	6%
Push/pull-mean	5%	17%	9%
Lift/carry-right	5%	16%	9%
Lift/carry-left	5%	12%	8%
Lift/carry-mean	5%	14%	8%
Pinch grip-right	57%	63%	55%
Pinch grip-left	56%	23%	38%
Pinch grip-mean	57%	43%	47%
Wrist flex/extend-right	37%	41%	38%
Wrist flex/extend-left	35%	34%	33%
Wrist flex/extend-mean	36%	37%	36%
Radial/ulnar deviation-right	37%	50%	46%
Radial/ulnar deviation-left	35%	46%	44%
Radial/ulnar deviation-mean	36%	48%	47%
Forearm twist/rotate-right	30%	21%	28%
Forearm twist/rotate-left	31%	18%	27%
Forearm twist/rotate-mean	31%	19%	27%
Elbow away 45 deg.-right	27%	33%	30%
Elbow away 45 deg.-left	27%	28%	28%
Elbow away 45 deg.-mean	27%	31%	29%
Full elbow extension-right	53%	54%	54%
Full elbow extension-left	39%	17%	27%
Full elbow extension-mean	46%	36%	41%
Hand above shoulder-right	24%	31%	28%
Hand above shoulder-left	18%	7%	11%
Hand above shoulder-mean	21%	19%	20%
Reach behind torso-right	1%	2%	2%
Reach behind torso-left	7%	1%	4%
Reach behind torso-mean	4%	1%	3%
Torso flex>45 deg.	12%	12%	12%
Torso side bend>20deg.	0%	8%	3%
Torso twist>20deg.	7%	33%	18%
Neck extend/flex>15deg.	51%	71%	67%
Neck twist>15deg.	23%	33%	28%
Asymmetric lift	3%	6%	3%
Obstructed lift	0%	0%	0%

Semi-Auto Tray cont. - Risk Factor	% of Shift Co.1	% of Shift Co. 3	% of Shift Total
Hand/wrist contact stress-right	2%	1%	2%
Hand/wrist contact stress-left	4%	1%	3%
Hand/wrist contact stress-mean	3%	1%	2%
Forearm contact stress-right	0%	0%	0%
Forearm contact stress-left	3%	2%	3%
Forearm contact stress-mean	1%	1%	1%
Torso contact stress-right	23%	13%	19%
Torso contact stress-left	23%	13%	19%
Torso contact stress-mean	23%	13%	19%
Leg contact stress-right	0%	0%	0%
Leg contact stress-left	0%	0%	0%
Leg contact stress-mean	0%	0%	0%
Hand as hammer-right	0%	1%	1%
Hand as hammer-left	0%	1%	0%
Hand as hammer-mean	0%	1%	0%
Static body part-right	0%	0%	0%
Static body part-left	0%	0%	0%
Static body part-mean	0%	0%	0%
Stand w/ foot activator-right	0%	0%	0%
Stand w/ foot activator-left	0%	0%	0%
Stand w/ foot activator-mean	0%	0%	0%
Stand w/ foot rest-right	0%	0%	0%
Stand w/ foot rest-left	0%	0%	0%
Stand w/ foot rest-mean	0%	0%	0%
Stand stationary	80%	52%	65%
Kneel/crawl	0%	0%	0%
Squat	0%	0%	0%
Sitting	0%	0%	0%
Walking	12%	19%	15%
Uneven surface	0%	0%	0%
Wet/slippery surface	0%	0%	0%
Whole body vibration	0%	0%	0%
Jump up/down level	0%	0%	0%
PPE-back belt	0%	0%	0%
PPE-gloves/wrist band	0%	2%	2%

SEMIAUTO BAG– Percent of Shift Risk Factor Occurs

Semi-Auto Bag Risk Factor	% of Shift Co.1	% of Shift Co. 3	% of Shift Total
Power grip-right	7%	3%	5%
Power grip-left	10%	7%	8%
Power grip-mean	8%	5%	7%
Grip slippery object-right	0%	0%	0%
Grip slippery object-left	0%	0%	0%
Grip slippery object-mean	0%	0%	0%
Push/pull-right	0%	13%	6%
Push/pull-left	0%	8%	4%
Push/pull-mean	0%	10%	5%
Lift/carry-right	32%	14%	23%
Lift/carry-left	33%	9%	21%
Lift/carry-mean	33%	12%	22%
Pinch grip-right	76%	69%	73%
Pinch grip-left	75%	71%	73%
Pinch grip-mean	76%	70%	73%
Wrist flex/extend-right	25%	24%	25%
Wrist flex/extend-left	13%	20%	17%
Wrist flex/extend-mean	19%	22%	21%
Radial/ulnar deviation-right	33%	31%	32%
Radial/ulnar deviation-left	18%	27%	23%
Radial/ulnar deviation-mean	25%	29%	27%
Forearm twist/rotate-right	29%	8%	18%
Forearm twist/rotate-left	3%	4%	4%
Forearm twist/rotate-mean	16%	6%	11%
Elbow away 45 deg.-right	28%	25%	26%
Elbow away 45 deg.-left	25%	25%	25%
Elbow away 45 deg.-mean	27%	25%	26%
Full elbow extension-right	14%	23%	18%
Full elbow extension-left	22%	15%	18%
Full elbow extension-mean	18%	19%	18%
Hand above shoulder-right	2%	0%	1%
Hand above shoulder-left	0%	1%	0%
Hand above shoulder-mean	1%	0%	1%
Reach behind torso-right	9%	44%	27%
Reach behind torso-left	9%	14%	12%
Reach behind torso-mean	9%	29%	19%
Torso flex>45 deg.	5%	8%	6%
Torso side bend>20deg.	3%	2%	2%
Torso twist>20deg.	21%	45%	33%
Neck extend/flex>15deg.	48%	38%	43%
Neck twist>15deg.	9%	18%	14%
Asymmetric lift	39%	33%	36%
Obstructed lift	0%	0%	0%

Semi-Auto Bag cont. - Risk Factor	% of Shift Co.1	% of Shift Co. 3	% of Shift Total
Hand/wrist contact stress-right	0%	0%	0%
Hand/wrist contact stress-left	6%	0%	3%
Hand/wrist contact stress-mean	3%	0%	2%
Forearm contact stress-right	0%	0%	0%
Forearm contact stress-left	0%	0%	0%
Forearm contact stress-mean	0%	0%	0%
Torso contact stress-right	0%	0%	0%
Torso contact stress-left	0%	0%	0%
Torso contact stress-mean	0%	0%	0%
Leg contact stress-right	0%	0%	0%
Leg contact stress-left	0%	0%	0%
Leg contact stress-mean	0%	0%	0%
Hand as hammer-right	0%	0%	0%
Hand as hammer-left	0%	0%	0%
Hand as hammer-mean	0%	0%	0%
Static body part-right	0%	0%	0%
Static body part-left	0%	0%	0%
Static body part-mean	0%	0%	0%
Stand w/ foot activator-right	25%	8%	17%
Stand w/ foot activator-left	3%	0%	1%
Stand w/ foot activator-mean	14%	4%	9%
Stand w/ foot rest-right	0%	0%	0%
Stand w/ foot rest-left	0%	0%	0%
Stand w/ foot rest-mean	0%	0%	0%
Stand stationary	26%	10%	17%
Kneel/crawl	0%	0%	0%
Squat	0%	27%	13%
Sitting	0%	68%	34%
Walking	23%	2%	12%
Uneven surface	0%	0%	0%
Wet/slippery surface	0%	0%	0%
Whole body vibration	0%	0%	0%
Jump up/down level	0%	0%	0%
PPE-back belt	0%	0%	0%
PPE-gloves/wrist band	6%	0%	3%

SEGREGATORS– Percent of Shift Risk Factor Occurs

Segregators Risk Factor	% of Shift Co.1	% of Shift Co. 2	% of Shift Co. 3	%of Shift Total
Power grip-right	0%	05	3%	1%
Power grip-left	0%	0%	0%	0%
Power grip-mean	0%	0%	2%	1%
Grip slippery object-right	0%	0%	0%	0%
Grip slippery object-left	0%	0%	0%	0%
Grip slippery object-mean	0%	0%	0%	0%
Push/pull-right	41%	36%	44%	41%
Push/pull-left	14%	32%	29%	25%
Push/pull-mean	28%	34%	37%	33%
Lift/carry-right	45%	55%	50%	50%
Lift/carry-left	42%	51%	38%	43%
Lift/carry-mean	44%	53%	44%	47%
Pinch grip-right	28%	27%	22%	26%
Pinch grip-left	28%	27%	17%	24%
Pinch grip-mean	28%	27%	19%	25%
Wrist flex/extend-right	57%	48%	43%	49%
Wrist flex/extend-left	25%	29%	26%	27%
Wrist flex/extend-mean	41%	38%	34%	38%
Radial/ulnar deviation-right	19%	12%	19%	17%
Radial/ulnar deviation-left	11%	14%	16%	14%
Radial/ulnar deviation-mean	15%	13%	17%	16%
Forearm twist/rotate-right	1%	5%	4%	3%
Forearm twist/rotate-left	0%	1%	0%	0%
Forearm twist/rotate-mean	0%	3%	2%	2%
Elbow away 45 deg.-right	36%	20%	34%	31%
Elbow away 45 deg.-left	22%	16%	25%	21%
Elbow away 45 deg.-mean	29%	18%	28%	26%
Full elbow extension-right	37%	25%	33%	32%
Full elbow extension-left	30%	16%	26%	24%
Full elbow extension-mean	34%	20%	29%	28%
Hand above shoulder-right	20%	16%	14%	17%
Hand above shoulder-left	19%	9%	13%	14%
Hand above shoulder-mean	20%	12%	14%	15%
Reach behind torso-right	0%	0%	0%	0%
Reach behind torso-left	0%	0%	0%	0%
Reach behind torso-mean	0%	0%	0%	0%
Torso flex>45 deg.	16%	16%	13%	15%
Torso side bend>20deg.	14%	27%	9%	16%
Torso twist>20deg.	52%	41%	41%	45%
Neck extend/flex>15deg.	17%	12%	26%	19%
Neck twist>15deg.	10%	22%	18%	17%
Asymmetric lift	35%	29%	29%	31%

Segregators cont.- Risk Factor	% of Shift Co.1	% of Shift Co. 2	% of Shift Co. 3	%of Shift Total
Obstructed lift	0%	0%	0%	0%
Hand/wrist contact stress-right	0%	3%	7%	3%
Hand/wrist contact stress-left	0%	2%	1%	1%
Hand/wrist contact stress-mean	0%	2%	4%	2%
Forearm contact stress-right	3%	1%	0%	1%
Forearm contact stress-left	0%	0%	0%	0%
Forearm contact stress-mean	1%	1%	0%	1%
Torso contact stress-right	0%	0%	0%	0%
Torso contact stress-left	0%	1%	0%	0%
Torso contact stress-mean	0%	0%	0%	0%
Leg contact stress-right	0%	0%	0%	0%
Leg contact stress-left	0%	0%	0%	0%
Leg contact stress-mean	0%	0%	0%	0%
Hand as hammer-right	0%	0%	0%	0%
Hand as hammer-left	0%	0%	0%	0%
Hand as hammer-mean	0%	0%	0%	0%
Static body part-right	0%	0%	0%	0%
Static body part-left	0%	0%	0%	0%
Static body part-mean	0%	0%	0%	0%
Stand w/ foot activator-right	0%	0%	0%	0%
Stand w/ foot activator-left	0%	0%	0%	0%
Stand w/ foot activator-mean	0%	0%	0%	0%
Stand w/ foot rest-right	0%	0%	0%	0%
Stand w/ foot rest-left	0%	0%	0%	0%
Stand w/ foot rest-mean	0%	0%	0%	0%
Stand stationary	2%	0%	0%	1%
Kneel/crawl	0%	0%	0%	0%
Squat	0%	0%	1%	0%
Sitting	0%	0%	0%	0%
Walking	95%	98%	86%	93%
Uneven surface	0%	0%	2%	1%
Wet/slippery surface	0%	0%	0%	0%
Whole body vibration	0%	0%	0%	0%
Jump up/down level	0%	0%	05	0%
PPE-back belt	0%	0%	4%	2%
PPE-gloves/wrist band	0%	48%	3%	15%

NOTE: <u>Percent of Shift Risk Factor Occurs</u> : is the sum of an observed risk factor / number of observations of the risk factor * mean task duration in seconds (assuming that a risk factor that was observed during a task occurred for the full period of the task) / mean cycle time in seconds.

<u>% of Shift Total:</u> the percent of time this risk factor was observed for all tasks of a work cycle

Appendix F: Slip-Sheet Fork Truck Retrofit

Appendix G: Anti-fatigue Mats

Appendix H: Stand/Lean Stool

Appendix I: Reciprocating Armrest