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Ergonomic analysis of posture among members of a landscape tree crew

Kim Granata-Clark
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ERGONOMIC ANALYSIS OF POSTURE AMONG MEMBERS OF A LANDSCAPE
TREE CREW

A Thesis

Presented to

The Faculty of the Program in Human Factors and Ergonomics

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Masters of Science

By

Kim Granata-Clark

August 2005

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ABSTRACT

ERGONOMIC ANALYSIS OF POSTURE AMONG MEMBERS OF A LANDSCAPE TREE CREW

By Kim A. Granata-Clark

This study examined the probable risk of low back injuries among Landscape Tree Crew members in the City of San Jose. The purpose of this study was to conduct an ergonomic analysis of posture among members of a Landscape Tree Crew. Eleven employees were surveyed regarding which job tasks they consider to be high-risk activities for the lower back. The tasks selected by the employees were lifting logs, pushing and pulling brush, and shoveling debris. The Ovako Working Posture Analyzing System (OWAS) was used to record positions for the back, feet, and lower limbs while conducting a task. This study reported the most frequent combination of postures overall and separately based on age and if the employee had back pain/injury. The results of this study determined that combination of back bent, feet side by side or one foot behind, and both limbs flexed was most commonly used by the tree crew.

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CHAPTER I

INTRODUCTION

According to the 1992 National Safety Council's Accident facts, back injuries accounted for 32% of all worker compensation cases, making it the most common disabling occupational injury in the United States (Wang et al., 1998). According to Imrie (1996) back injuries occur as frequently in sedentary jobs as in physically demanding jobs. Twenty percent of employees filing a claim have a history of significant back injury. In 2001, Bureau of Labor Statistics (BLS) reported 372,683 back injury cases involving days away from work (BLS, 2003 a,b). Two industry sectors (transportation and public utilities and construction) had consistently higher back injury rates than other industry sectors during 1992–2001.

Low back pain is the most expensive health care problem among the 30-50 year age group (Khalil, Abdel-Moty, Rosomoff, & Rosomoff, 1993). People with a medical history of low back pain experience eventual recurrence of symptoms in 85% of single episode cases (Rowe, 1969). Fifty to sixty percent of people that experience a reoccurrence are affected within the first year of treatment (Troup, Martin, & Lloyd, 1981).

Low back pain usually occurs early in life and peaks between the ages of 35-55 years. Although low back injuries generally occur equally between males and females, males file 75-80% of the workers compensation claims. However, women that do physically demanding jobs have a higher incidence of low back pain than those who work in jobs where less movement is required (Garg & Moore, 1992). Overall, three age

groups (25–34, 35–44, and 45–54) accounted for 78.5% of back injury cases, slightly more than the 75.2% reported for all nonfatal injury and illness cases (BLS, 2003a). Male workers accounted for 64.3% of back injury cases in 2001, slightly less than the 66.1% reported for all nonfatal injury and illness cases (BLS, 2003a).

The most common cause of low back pain is degeneration of the intervertebral disc. Vertebrae are divided into five groups: cervical, thoracic, lumbar, sacral, and coccygeal. The lumbar vertebrae are the largest and support the heavy loads of the upper part of the body. The number of people with degeneration of the disc increases with increasing age (Garg & Moore, 1992). However, structural abnormalities such as scoliosis, kyphosis, hyperlordosis, leg-length discrepancy, increased lumbosacral angle, spinal bifida, and osteoarthritis, do not seem to predispose someone to low back pain but can be a cause of low back pain (Rowe, 1969).

According to Garg & Moore (1992), the potential risk factors for low back injury are: age, gender, anthropometry, physical fitness and training, lumbar mobility, strength, medical history, years of employment, smoking, psychosocial factors, and structural abnormalities. In all jobs, there is a risk of low back injury. There is some contradictory research with respect to injuries associated with jobs that require the manipulation of heavy versus light materials. Garg & Moore (1992) stated that work activities that increase ones risk of lower back injury include: heavy physical work, lifting, bending, stretching, reaching, twisting, pushing, pulling, and prolonged sitting or standing. Rowe (1969) and Damkot, Pope, Lord, & Frymoyer (1984) reported moderate or no difference

in the frequency of low back pain between workers working with light or heavy materials.

With respect to the relationship between physical fitness/conditioning and prevention of low back injuries, there is little consensus in the research literature. Some have reported an effect on low back injuries (Garg & Moore, 1992; Astrand, 1987) while others (Cox, Shephard, & Corey, 1981) have reported no connection between physical fitness and low back injuries.

Low back pain is one major area of study in ergonomics. The word “ergonomics” is composed of two words, *ergon* meaning “work,” and *nomos* meaning “natural laws.” Khalil et al. (1993) stated, “Ergonomics is the scientific study of people and their work. Ergonomics helps people understand their abilities and limitations and teaches them how to perform safely, effectively, and comfortably within their environment” (p. 1).

A specific area of study within ergonomics is the human-machine system. It has three main components: the human component (anatomical, physiological, and psychological elements), the machine component (equipment, devices, and tools the human interacts with), and the environment component (heat, noise, vibration, family, job, organization elements) (Khalil et al., 1993). This study focused on the human component.

Efforts to prevent low back injury can be categorized into three methods. Primary prevention entails finding ways to prevent low back pain before occurrence. Secondary prevention, applied once an individual gets a low back injury, is a comprehensive rehabilitation program aimed at returning him or her to a productive lifestyle. The third

is tertiary prevention, which is focused on preventing re-injury by maintaining functional capacities safely at home and at work (Khalil et al., 1993).

Regardless of the method, it is prudent for employees to know their physical capabilities and limitations. Prevention and control of injuries through education and training should be provided for employees to use on the job and at home (Khalil et al., 1993).

One method for assessing risk of injury is evaluating the postures used by individuals. The Ovako Working Posture Analysis System (OWAS) (Karhu, Kansil, & Kuorinka, 1977) is a tool specifically designed to look at the posture of the back, feet, lower limbs, distance of the load from the surface, and distance of the load from the body. This study used the OWAS to examine the postures of the back, feet, and lower limbs.

One group of individuals that may be at risk for low back pain is those working with a Landscape Tree Crew. No research on this population has been found in the literature. Landscape Tree Crews use a wide variety of body movements in their job while lifting heavy power tools and tree branches. They use heavy tools at all levels and angles relative to their bodies and may have to work in tight spaces. They also experience vibration with the power hand tools used. Considering the number of high-risk factors involved in their work, Landscape Tree Crew employees may be at risk for low back injuries.

Statement of Purpose

The purpose of this study was to conduct an ergonomic analysis of posture among members of a Landscape Tree Crew. The secondary purpose was to make recommendations to the crew and management based on the findings.

Delimitations

The study was delimited to the following subjects:

- 1) Workers who were on the ground, rather than suspended in an aerial bucket.
- 2) Employees between the ages of 23-50 years.

The scope of the study was delimited to the following:

- 1) Information from the questionnaire.
- 2) The top three high-risk tasks performed by the tree crew as identified by the tree crew personnel themselves.
- 3) Information obtained using the Ovako Working Posture Analyzing System.
- 4) The use of a stopwatch to evenly space the recording of the OWAS data.

Limitations

The scope of the study was limited by the following:

- 1) The crew the employee was placed on for the day. There were three crews the employee's could have been assigned to in any given day but only one crew was studied at a time
- 2) The stopwatch used did not function well under loud conditions.
- 3) Responses from the task question on the questionnaire were subjective.
- 4) Not all employees took part in all the tasks.

Assumptions

The following assumptions were made for this study:

- 1) Employees gave truthful answers to questionnaire items with the understanding that the answers would be kept confidential.
- 2) The evaluator was alert and remembered to push the stopwatch start button after two minutes.
- 3) The data collected was an objective and accurate record of activities observed.

Definition of Terms

Body-Part Discomfort scale (BPD). This is a scale where participants indicate uncomfortable body parts on a body chart and rate the severity of discomfort. The rating of each body part on a scale of 1 to 10 indicates the level of discomfort.

Chipper. A machine that grinds trees for removal.

Manual Materials Handling (MMH). Manual material handling may involve lifting, lowering, carrying, pushing, pulling, shoveling, stacking, or some combination of these actions.

NIOSH. National Institute of Occupational Safety and Health. NIOSH is part of the Department of Health and Human Services and is in charge of research and education.

Ovako Working Posture Analyzing System (OWAS). OWAS is a classification system that codes posture using four back positions, three positions each for the feet and lower limbs, the distance of the load from the surface and distance of the load from the body. The OWAS is based on direct observation. A steel company developed OWAS for its work-study engineers. For more information, refer to Karhu, Kansi, & Kuorinka (1977).

Physical Work Capacity (PWC). The PWC is a measure of an employee's capacity to perform physically demanding work tasks.

Ratings of Perceived Exertion (RPE). This is a subjective rating that an individual assigns to the intensity of his/her exercise based on their perception of how hard the physical exertion was. Perceived exertion is how hard you feel your body is working. It is based on the physical sensations a person experiences during physical activity, including increased heart rate, increased respiration or breathing rate, increased sweating, and muscle fatigue.

Tree Crew. Employees responsible for maintaining and removing trees in the public areas throughout the city. This includes pruning and trimming the trees on a regular basis, removing trees or branches in the event that one is knocked over by a vehicle, accident, or storm.

Importance of the Study

Numerous physical factors within the workplace have the potential to cause low back pain and injury. The workplace geometry as well as the weight and/or sizes of objects being moved all have a potential influence on low back pain and injury. Employees need to be informed regarding ways a back injury can occur and ways to prevent injuries.

The Landscape Tree Crew may work at arm's length with equipment that can weigh up to 70 pounds. The employees are also repeatedly lifting, pushing, pulling, and shoveling objects such as tree branches. In addition, the employees can work in areas that are compact with insufficient maneuvering room. Using the equipment efficiently

and using good body mechanics can be difficult. Depending on the employee's equipment, they may or may not be able to keep a straight back or they may need to bend with the equipment to reach branches/limbs that are on the ground. An analysis of postures used would be valuable and could lead to recommendations with respect to preventing low back pain and injuries among Landscape Tree Crew employees.

CHAPTER II

REVIEW OF LITERATURE

Garg & Moore (1992) reported low back injury as one of the most frequent and disabling conditions affecting workers in their productive years. This section details the literature on the frequency and cost of low back injuries, potential causes of low back pain and injuries, measures likely to prevent low back pain/injury, workplace conditions related to back injuries, ergonomics and its contribution to workplace safety, and the Ovako Working Posture Analyzing System (OWAS).

Cost/Frequency of Back Pain/Injury

Mahone (1994) reported the average cost for a back injury to be \$24,000 according to the National Council on Compensation Insurers (NCCI). Straker, L.M. (1999) stated, "Work related back pain is the single largest occupational health issue in most jurisdictions accounting for around one quarter of all occupational health costs" (p.1). Daltroy et al. (1997) wrote that low back pain affects 70-80% of adults at some point and accounts for 30-40% of Workers Compensation payments. The authors pointed to back strains and overexertion while lifting and handling objects as being predominantly responsible for low back injuries. Dempsey & Hashemi (1999) studied workers compensation (WC) claims' relation to manual materials handling. The results were that 36% of the claims reported to a WC insurer during a 6-year period were identified as manual materials handling (MMH) claims. There were no increases or decreases in those 6 years. The results in 1994 were representative of recent years. In 1994, 225,000 MMH claims were made, which is 39% of WC claims and 35% of all

claims. The total cost of MMH claims was greater than \$750 million. When analyzing body parts that were being affected, the lower back area was the most frequent body part injured. Low back and upper extremities accounted for 70% of MMH-related claims. Strains and sprains were the most common accounting for 57% of the claims and 68.5% of the MMH related costs. Overexertion was reported as the primary root cause of the claims.

Kerr et al. (2001) stated low back pain remains the predominant occupational health problem in most industrialized countries, accounting for about 20-30% of all Workers Compensation claims and up to 50% of all direct compensation costs.

Material Handling and Back Pain

A useful place to begin a review of issues related to back pain is to examine information obtained from research regarding how various movements under load affect muscle activity. Gagnon, Plamondon, & Gravel (1993) studied nine male students in physical education class with little experience in manual materials handling. The mean age was 23.3 years, weight 167 lbs, height 69 in. (176 cm). They were physically active and had no previous experience with back pain. The task was to move a 36 lb load from a shelf on the left at a height of 27 in. (68 cm), pivot the load 90 degrees to the right to a height of 31 in. (80 cm). Three kinds of lifts were standardized for the subjects: 1) feet facing the final destination and the body twisted to the left and upper body flexed forward, 2) feet facing between the shelf on the left and shelf on the right, with the body twisted to reach the load on the left, and 3) the feet pivot and the body stays with the load

throughout the process. The hypothesis was that pivoting would produce smaller muscular movements and the full twist would produce higher muscular movements.

The results showed that pivoting produced smaller muscular movements and the full-twist technique generated larger muscular movements. Gagnon et al. (1993) stated, “The maximal twisting moments were nearly twice as large for the half-twist technique and three times as large for the full-twist technique as compared to the pivoting technique” (p. 1521). Twisting to the left involved trunk flexion, bending, and twisting which all can lead to a back injury. The conclusion drawn in this study suggests that lifting loads with a full-twist and half-twist involves combined movement around the three axes of the trunk likely creating an imbalance in the muscles and spinal structure where people may be more prone to injuries.

Another set of motions potentially related to back pain includes folding and unfolding objects. A study by White & Kirby’s (2003) examined the hypothesis that health-care workers vary greatly in the methods used to fold and unfold manual wheelchairs and that many of the methods used include bent and twisted back postures that are known to be associated with a high risk of injury. The subjects were five nurses, five health-care aids, five occupational therapists, and five physical therapists. There were six men and 14 women. Inclusion criteria included an age range of 18-60 years old and previous experience folding a wheelchair, at least once during the month prior to the study. They excluded any one with low back pain.

The results showed that health-care workers did vary greatly in the methods used to fold and unfold manual wheelchairs and that many of the methods used include bent

and twisted back postures. These findings are cause for concern since Biering-Sorensen (1983) and Garg & Moore (1992) suggest that low back pain is the cumulative effect of a number of minor painless injuries, which eventually result in pain. Biering-Sorensen (1983) found that about half of the people surveyed reported a gradual onset of low back pain. These findings highlight the probable relationship between improper handling of objects and the development of low back pain.

Factors Affecting Back Pain/Injuries

The time of day may be one factor to consider with respect to activity and back pain/injury. Fathallah & Brogmus (1999) studied the hourly trends in workers compensation (WC) claims in 1999. A usual workday is between 7:00 a.m. to 5:00 p.m. Most of the injuries were reported in the morning (generally 9:00-10:00 a.m.) suggesting the possibility that the body is not warmed up yet. The spine is less flexible during the early morning hours than in the late afternoon. A confounding factor however, is that some employees report their injury before starting work or a little bit after and some may choose not to go to work because of pain they experience the previous night into the morning and call in to report it in the morning making it difficult to determine the “true time” that the injury/pain occurred.

Hand position is another variable to examine with respect to lifting and its potential impact on back pain/injury. Drury & Pizatella (1983) observed the hand positions on boxes among 27 subjects in nine industries. Information for pre-grasp, pickup, move/carry, put down, and adjust were consolidated into pre-grasp and pickup

for the start of the move, move/carry during the move, and put down and adjust for stopping the move. When using two hands on a box there were 81 possible pairs of hand

positions. Two-thirds of these were actually used. The positions 3:7 and 1:9 diagonal corner were used half of the time but positions 1:7 and 1:1 was used 47% of the time when adjusting boxes to put them next to each other. The positions 3:8 and 6:8 provided horizontal and vertical stability. Position 3:7 was associated with lowering while position 8:8 (hands are both under the box) was associated with holding the box at the same level. When raising the box or with movements far from the body the hand positions used were 7:9 and 4:4 while low movements used high hand position 2:2 and 2:8. For movements toward the person, the hand position used was 8:8 and the most frequent position when moving the box away from body was 3:7. The hand position used was related to the person's size and box size. Box width and distance carried had the least to do with hand position. In conclusion, in the handling of boxes, the handle positions should allow for both horizontal and vertical stability except for heavy lifting, where symmetrical handle placement may be best. Overall, handles should be used to help the workers hold the box against the body to protect the back from pain or injury.

Smith, Ayoub, & McDaniel (1992) studied non-standard postures, lifting, lowering, and twisting. The subjects in this study were college students between the ages of 18-30 years. Findings across the four experiments conducted were:

- Participants could handle more weight when lowering versus lifting and less weight while twisting versus non-twisting.
- Lifting capacities decreased with height of lift.
- More weight could be lifted if the box was lifted with two hands versus one hand.
- As ceiling height was lowered, the capacity with respect to the amount handled decreased.

Another study that examined constrained spaces was conducted by Ruckert, Rohmert, & Pressel (1992). They investigated aircraft luggage handlers engaged in manual load handling tasks in a German airport. Few studies have dealt with the ergonomic problems with height-restricted workplaces, which cause unfavorable working postures. This study had four parts: epidemiology, biomechanical, physiological, and psychophysical. The epidemiology study interviewed aircraft handlers (two years apart) regarding complaints related to the upper and lower back as well as other areas of the body. The physiological study evaluated the permissible load in manual load handling tasks on the basis of the resulting strain on the aircraft handler. The psychophysical study (n=4) was done in a mock-up aircraft compartment and evaluated the influence of the work height and weight of the work object on physiological strain. For the biomechanical study (n=6), maximum static forces were measured in manual load handling. The compressive forces on the intervertebral discs in selected areas of the lumbar section of the spinal column were calculated.

The results of the epidemiological study showed that most of the complaints (48%) with respect to pain were in the spinal column because of the ergonomically unfavorable working postures in the aircraft compartments. Thirty-six percent of the 44 aircraft handlers reported spinal pain after work. Sixteen out of 21 aircraft handles that had spinal column complaints had worked at the airport for up to five years. Fifty-two percent of the 21 aircraft handlers who had spinal column complaints were between the ages of 18-23 years old and 23-28 years old. The highest prevalence of spinal column complaints, $n = 11$ occurred at a height between 70-72" (178-183 cm). Seventy-six percent of subjects that had a body mass higher than 162 lbs (73 kg) complained of back pain. The epidemiological study showed long-term effects on the individual worker.

For the 28 subjects in the physiological study, a record of heart rate was examined to reveal the strain resulting from manual load handling during an eight-hour shift. The strain on the aircraft handlers also took into consideration the weights of the work objects manipulated. The average total weight per load (loading and unloading of one aircraft) was 1319 kg (2931 lb). There was a positive correlation between the average heart rate and the weight handled.

In the psychophysical study, as working height increased and weight of the object decreased, performance increased. The employee's were able to handle more work objects during the day.

In the biomechanical study, there was strain reflected in heart rate between the 100 cm (39 inches) and 140 cm (55 inches) working height. At both working heights higher than average heart rates, 119 beats/min and 116 beats/min respectively were

recorded and attributed to the static position in addition to the heavy dynamic muscular work. Since this biomechanical study had a limited number of subjects, Ruckert et al. (1992) felt that the biomechanical field study should be viewed as a pilot study. The conclusion, taking into consideration the findings from all four components of the study, was that excessive strain was experienced among aircraft handlers during manual load handling tasks in aircraft holds.

One of the more common activities in the workplace with the potential to result in back pain or injury is lifting. Winkelmolen, Landeweerd, & Drost (1994) evaluated patient lifting techniques with ten female volunteers that served as nurses. They had no musculoskeletal complaints and none had patient lifting experience. Age varied from 21 to 26 years. Two healthy volunteers served as the passive patients. The weights of the patients were 55 kg (122 lbs) and 75 kg (166 lbs). The five lifting techniques were all two-person lifting techniques to move a patient upwards (towards the head of the bed) in a hospital bed.

Flexion, lateral flexion, and rotation of the back were assessed at the start and end of the lifting task. Three out of ten lifts were analyzed, third, sixth, and ninth. The compressive forces at the L5-S1 disc were assessed. Three evaluations of perceived stress were also obtained: Ratings of Perceived Exertion (RPE), Body-Part Discomfort scale (BPD), and Paired Comparison Analysis. For the paired analysis, nurses were asked to choose the most stressful out of each pair after they completed all techniques. .

The results showed that there was a significant difference between the techniques with respect to compressive forces when the 55 kg patient was lifted. The Australian,

orthodox, and barrow lift had more flexion and significantly less lateral flexion than the other two. The barrow lift caused significantly more stress on disc L5-S1 than the Australian lift and the orthodox lift. With respect to perceived stress, there were RPE differences between the techniques in the case of the heavier patient. The orthodox and barrow lift produced more stress on the back than the under-arm or through-arm lift. When analyzing the body-part discomfort scores, the left and right side were combined which reduced the number of areas to four (upper trunk, arms, back, and legs). Significant results were observed for the back. The orthodox lift and the barrow lift were rated as significantly more stressful than the through arm lift. The paired comparison analysis showed that the barrow lift and orthodox lift were the most stressful for the nurses. The Australian lift overall was the least stressful on the body while the barrow and orthodox lift were found to be more strenuous. The Australian lift called for the nurses to put one hand under the patient's thighs and their shoulder in the patient's axilla to support the lifting. The other hand was placed on the back but did not have a function in the lifting process. The patient was sitting up. The orthodox lift had the nurses' hands symmetrically placed under the patient's bottom and thighs. The patient crossed their arms in front of themselves while sitting up. The barrow lift was where the nurses grasp each other's hand under the patient's waist. One nurse puts his/her other hand under the thighs; the other nurse supported the patient's head with her free hand. The patient was lying down. While each person may have his/her own way of lifting, the findings confirm the importance of adequate training and lifting instructions.

Prevention of Back Pain/Injuries

With respect to prevention of back pain/injury, how a load is handled may be important. Smith & Jiang (1984) studied the psychophysical and physiological responses of nine male college students between the ages of 18-33, mean age 25 years, mean height was 69 in. (176.3 cm), and mean weight was 169 lbs. as they lifted bags of different levels of fullness with or without handles. There were two experiments done in the study. Experiment A measured heart rate and oxygen consumption while bag lifting. The independent variables were fullness (70% and 95%) and handles (with or without handles). Oxygen consumption, heart rate, and percent of physical work capacity were used as the dependent variables. Controlled variables were weight of the load, frequency of the lift, height of the lift, the size of the bag, location of the bag, and level of bag fullness. The subjects were allowed to lift in the manner that they felt was most comfortable and least stressful. The data was collected for six to 10 minutes to make sure a steady state had been achieved.

In experiment B, the participant adjusted the weight of the bag to the maximum amount they could lift without strain or discomfort. They repeated Experiment B twice for each of the two levels of fullness and for the handles/no handle condition. The subjects worked at their maximum acceptable level for 30 minutes. The subjects were given 10-15 minutes to establish the maximum weight they were willing to lift and then continue that lift for 15-20 minutes. Heart rate and oxygen consumption was recorded at the last six-to 10 minutes of lifting.

The conclusion was that providing handles and filling the bags to their capacity increased productivity from the psychophysical standpoint. The fullness of the bag reduced the load shifting that occurs during handling and handles make it easier to control the bags with the palm of the hand and reduce finger fatigue. Also, handles provided a firm, secure grip so as to insure safe handling.

Ruckert et al. (1992) recommended three biomechanical principles essential for designing lifting and carrying tasks: 1) decrease forces on the intervertebral discs and muscles of the back by bringing the center of gravity close to the spinal column, 2) avoid uneven compressive forces on the intervertebral disc by keeping the spine straight, and 3) decrease the stress on the back muscles by using the larger muscles in the body, especially the thighs.

Andersson, Ortengren, & Nachemson (1976) examined the myoelectric back muscle activity, intra-abdominal pressure, and the disc pressure on the back when lifting in different ways. In this study, there were four subjects (3 female, 1 male), age 26-34 years, height 66-70 in., (169-177 cm), weight 114-152 lbs, with no history of back pain or previous back injuries.

For static loading, the subjects pulled on a handle with a force of 400 Newtons (N) at three different heights using both hands. At each height, one pull was done with the back straight and the knees flexed (leg lifting) and another was done with the back bent and the knees straight (back lifting). Six repetitions were performed lasting 12 seconds with one-minute breaks between repetitions.

For dynamic loading, 100N were lifted from 18 in. (45 cm) above the floor to the height of freely hanging hands. Another experiment entailed lifting a 50 Newton weight from a table with outstretched arms and then brings the box into the body and back out. A third experiment had participants lift a 50 Newton weight from a height of 26 in. (65 cm) table at different paces. The subjects used both hands, lifted the weight quickly (in less than one second) and then slowly (in five seconds).

For the static loading with legs engaged in lifting, the results indicated that electrical activity was high no matter the height of the handle from the floor. When the handle was 16 to 20 in. (40-50 cm) off the floor, there was less electrical activity when the back was primarily lifting. Intra-abdominal pressure differed with leg and back lifting at 16 in. (40 cm), with the leg lifting producing more pressure.

With respect to dynamic loading, there was more disk pressure with back lifting versus leg lifting. Andersson et al. (1976) stated:

For back lifting, it (higher disc pressure values) can be caused by the flexed position of the spine, which in itself is accompanied by high disc pressure values. For leg lifting it (higher disc pressure values) can be explained by the high activity of the longitudinal muscles of the back, which increase the compressive stress on the disc. (p. 183)

When flexing to pick up an object, there was a large amount of activity in the back until fully flexed and then on the way up there was activity; no activity occurred when the back was fully flexed. The distance between the body and object is important in looking at the load on the spine. When the weight was moved away from the body, there was an increase in electrical activity in all muscle groups. These results support the

recommendation that lifting with the legs (rather than back) is more appropriate and less stressful.

Additional perspectives in the area of prevention consider training and workplace conditions. Andersson et al. (1976) stated that workspace design along with decreasing the weight and size of the objects to be lifted should be studied versus the provision of lifting instructions.

With respect to training, Straker, L. (1999) reviewed the problem of teaching different lifting techniques. Four main techniques for lifting are: squat, semi-squat, stoop, and freestyle. Most people choose the semi-squat or stoop technique but many change their technique depending on the task at hand. For example, they bend their knees but when they have the object in their hands they extend the knees producing full flexion in the trunk, which is a stoop lift. There was little evidence to support that by teaching lifting techniques, there would be fewer injuries. Straker, L. (1999) stated, “Probably the most useful training to provide workers is how to participate in the design and redesign of safe work systems” (p. 4).

The internationally favored approach to preventing work-related back pain involves the four steps of hazard identification, risk assessment, risk control, and follow-up evaluation (Straker, L.M. 1999). The problem is most of the literature rarely uses this language and is more likely to talk about an intervention such as an educational program.

Three approaches are commonly used to prevent work-related back pain: 1) Selecting workers unlikely to report work-related back pain, 2) Training workers to reduce the occurrence of work-related back pain, and 3) Re-designing workplaces to

reduce work-related back pain. The selecting and training options tend to focus on the worker while the design option tends to focus on changing the work. Straker, L.M. (1999) noted that there were only a handful of articles that evaluate the efficacy of an intervention. The following issues may explain this:

- Back pain is not a simple phenomena.
- Limitations in the risk assessment model (researchers do not know what hazards to look for, what constitutes risk, and how to measure them).
- Large budgets are required.
- Interventions used may have been inadequate (for example, lifting techniques may have been taught inappropriately).
- Intervention effects may be small and interact in complex way, which means it is difficult to measure them.
- The site of research is typically real world and outside researcher control.

Daltroy et al. (1997) studied the effect of education on low back (LB) injuries.

The authors developed a back school for the primary prevention of low back injury and evaluated all employees in two facilities. Four thousand U.S. postal workers at two mail processing facilities were studied. For this population, 70% of low back injuries in the five years before the study began were related to lifting and handling. Thirty-four work units (an administrative grouping of employees, usually on the same shift, working under a common general supervisor in a shared work environment) were arranged into 17 pairs, matched on the basis of clerk or mail handler and job characteristics (machine or manual work). One unit of each pair received training and the other served as a control group. Before the study, LB injury occurred at a rate of 2.4% per year and accounted for 17% of Workers Compensation injuries and 35% of Workers Compensation payments. Mail handlers and some maintenance workers who did heavy lifting (16-32 kg bags) and clerks who did light work such as manual or mechanized mail sorting were studied. The

intervention was an employee-education program. Workers and supervisors in groups of 10-12 were taught principles of back safety, correct lifting and handling, posture, exercises, and pain management. The instructors were Physical Therapists. The therapist examined each workstation with workers and supervisors and suggested physical and procedural modifications such as the adjustment of shelf heights and the use of lumbar supports for chairs. The results suggest that back schools are not by themselves an effective intervention for the primary prevention of low back injuries. Workers that were assigned to the training group were not found to have lower rates of primary low back injury, time off from work, costs associated with injury, or time elapsed prior to a further injury.

Daltroy et al. (1994) stated: "Back schools are not by themselves an effective intervention for the primary presentation of industrial low back injury." Programs that focus on educating injured workers before their return to work and programs emphasizing exercise for workers after their return may be more useful. An important question to examine is whether or not exercise programs that are implemented in the workplace for every employee and those who are new to the company are effective in reducing the incidence of back pain/injury.

Determination of what constitutes a manageable load is an interesting question. Equations developed in 1981 and 1991 by the National Institute for Occupational Safety and Health (NIOSH), were intended to calculate the recommended weights for manual lifting tasks. Based on the 1981 equation, 10% of industrial lifting jobs were classified as dangerous. The revised equation in 1991 suggested that 73% of the industrial lifting jobs

were high risk however, Auguston (1995) suggested that the equation incorrectly assessed half of the jobs as high risk when in fact they were low risk jobs.

According to Auguston (1995), researchers at Ohio State University (OSU) conducted a study in 1995 to challenge the NIOSH equation since the equations did not measure motions of the trunk, angular position, velocity, and acceleration during lifting tasks. To address this, a lumbar motion monitor was strapped to workers to track the motions of the trunk while lifting and OSU came up with their own model for classifying jobs and predicting risk of injury. Professor William Marras, who headed the research effort said, "Our model was on the order of three to four times more predictive than NIOSH" (Auguston, 1995, p. 51). They found that by varying the trunk motion in addition to other risk factors, they were able to decrease the odds that a job would fall into the high-risk category. Tom Waters, biomechanical engineer at NIOSH, said that the current 1991 NIOSH equation is part of a progression. The work done by OSU and other institutions helps increase the body of knowledge about lifting to improve future equations. Professor William Marras stated:

The NIOSH equation is a perfectly appropriate tool for straight forward lifting tasks, but you can only go so far with a static model. I think what our study has shown is that we can do better than NIOSH in evaluating certain types of lifting tasks for which dynamic forces are an issue. (p. 53)

Tom Waters explained, "The NIOSH equation cannot tell you if a specific individual is at risk, but it can tell you whether you might want to improve the job" (Auguston, 1995, p. 53).

Wang et al. (1998) supported the NIOSH 1991 equation. They studied medical cases from a national Taiwan University Hospital and Provincial Hsinchu Hospital

relating to lower back pain, which was collected over the preceding year. Wang et al., (1998) stated:

No epidemiological study has evaluated the revised NIOSH equation. Therefore, this study is aimed at applying the revised NIOSH lifting guide to evaluate the relation between the lifting indexes (Lis) of the assessed jobs and the severity ratings of low-back discomforts of 97 manual material handling workers in Taiwan. (p. 510)

The workers' average age was 39 years, job experience more than 6 years, and the weights of objects lifted were between 4–110 lbs (1.8 to 50 kg). Only 10 of 97 participants had experienced no lower back discomfort. Thus, 90% of the MMH workers in this study had experienced various degrees of low back discomfort. Eighty percent had sought some form of medical treatment. Results indicated that the likelihood of having low back pain was low for MMH workers with jobs considered acceptable by the NIOSH lifting guide. Workers who were experiencing pain, were experiencing pain from moderate to severe and working in jobs characterized by NIOSH as having greater potential for LB injury.

Contributions of Ergonomics to Workplace Safety

Back pain affects people of all ages. When people experience back pain, they cope with more than the pain as mobility and function are also challenged. Just leaning forward over a sink can exacerbate the pain. When the worker cannot cope with back pain, it becomes a back injury. Back pain is exacerbated by what we do. Determining the correct lifting technique remains the focus of efforts to reduce the incident of back injuries. Ergonomics is the study of getting people situated in their workplace based on their pain or discomfort. Hadler (1997) states, "The solution to the conundrum of

backache in the workplace is straightforward. There must be a national mandate to provide workplaces that are comfortable when we are well and accommodating when we are ill” (p. 939). Comfortable means the employee is not expected to perform any task against his or her will, including any physical task that is too demanding to the employee. “Ergonomics must turn from the quest to prevent back ‘injuries’ to the quest for enhancing the ability of a person with a backache to cope” (Hadler, 1997, p. 939). Ergonomics is about preventing injuries before they happen but injuries will still occur. Therefore, ergonomics needs to focus not only on how to prevent injury, but also how to make the person comfortable in their workplace once they have sustained an injury.

Ovako Working Posture Analyzing System (OWAS)

One of the widely used methods of observation in working posture studies is the Ovako Working Posture Analysis System (Karhu et al. 1977). It is used to identify and evaluate harmful working postures. There are 84 different posture combinations from four back postures, three arm postures, and seven leg postures. The method facilitates the investigation of the frequency and relative proportion of time spent in various positions and assesses on a four-grade scale the harmfulness of the postures. Appendix A lists the areas observed when using the OWAS system.

In the Karhu et al. (1977) article, working postures were collected from photographic material taken in several divisions of one steel factory. The classification of the pictures taken yielded 72 postures, the main grouping being based on general features (sitting, standing, etc.) and the position of the back and arms. Twelve engineers spent one week learning the system. They then analyzed 28 tasks in the steel plant. The

results were encouraging and the authors proceeded to the next phase of evaluating the reliability of the method. During the reliability evaluation, 52 tasks were analyzed and a total of 36,240 observations were made. In general, the reliability (consistency) of the observations was fairly good between the two work-study engineers (93%) and between the morning and afternoon observations (86%). The two workers who were observed doing the same job used different postures the majority of the time.

In order to evaluate each posture from the point of view of the discomfort caused and the effect on health, a rating system was designed with 32 experienced steel workers evaluating each position twice during the same session. For each posture the workers were shown a male manikin properly positioned and a schematic drawing. From the workers' ratings a mean rating was calculated for each posture. In order to give greater credibility to these ratings, a small group of international ergonomists also rated them. The final rating of each posture was formed from the workers' ratings weighted by the evaluation of the specialists. After each of the postures had been rated, they were re-classified into four categories according to the results. The categories were broken down into classes. Class 1 was for employees that were using the correct posture, Class 2 was for employees that were using postures that might injure the employee and should be checked the next time the engineers did their walk around the company, Class 3 was for employees that were using postures that might injure the employee and should be looked at soon, and Class 4 was for employees using postures that need to be changed because they could result in injury.

The Ovako Working Posture Analyzing System (OWAS) was used for two years in the steel company, which developed it. The results of the research led to improvements in comfort in individual jobs and have greatly contributed to the reconstruction of some production lines. OWAS has proved to be effective and easy to use. Observations can be made rapidly on postures so they can be classified into various groups and then evaluated in terms of their desirability and need of attention.

In an article by Bruijn, Engels, & van der Gulden (1998) the inter-and intra-observer reliability of the OWAS method was examined. Subjects were observed during a full shift to make a proper count of the nature and frequency of awkward working postures and movements during their day. Slides showing nurses in different working postures were used to evaluate the reliability of the OWAS observations. The results were expressed in percentages of agreement (inter-observer and intra-observer reliability). Since the measurements can be affected by chance, the kappa (κ) statistic was used since it reflects the actual agreement beyond chance (Altman, 1991). The aim was to arrive at a percentage of agreement of at least 85% and a kappa over 0.6, which is considered “good” agreement (Altman, 1991). In all the comparisons, percentages of agreement were over 85% and kappa was over 0.6. For the back, the inter-observer reliability was 87% with a kappa of 0.78 while the intra-observer reliability (short-time interval – 4 weeks) was 91% with a kappa of 0.85. The intra-observer reliability (long-time interval – 3.5 months) was 90% and the kappa was 0.83.

Possibilities exist for automatically recording and assessing working postures as specified in the OWAS method using video and computer techniques. A study by Pinzke

(2001) showed promising results regarding the use of image analysis for tracking and assessing working postures. The computer neural network used in experiment two had the ability to correctly identify 62% of the studied images. However there are pluses and minus with using video recording. It reduces interference with the workers to a minimum and there is a possibility of a more detailed analysis while reducing observation errors. A disadvantage is the limited area of observation. If a person works outside of the area observed by the camera, they cannot be analyzed. Kilbom (as cited in Pinzke & Kopp, 2001) stated that postures are likely to be recorded more accurately by direct observation since human vision is three-dimensional whereas a video recording is reduced to a two-dimensional image.

“The OWAS method is most suitable for targeting and identifying hazardous working postures in dynamic occupations where the workers move around their workstation” (Pinzke & Kopp, 2001, p. 469). The OWAS method is a time-lapse sampling method, where the observations are performed at a regular interval. A 30-second time-lapse sampling for direct observations in the field is recommended (Mattila, Karwowski, & Vilkki, 1993).

Workplace Conditions

A study done by Kuorinka, Lortie, & Gautreau (1994) was conducted in two medium-sized retail warehouses for grocery items. Sixteen professional manual handlers were followed for one working day to observe the various aspects of the job. The main means of analysis of the lifting actions was photography. Serial photographs of lifting actions (a sequence comprised of lifting and lowering a single load) were taken so the

beginning and the end of the action were covered. Along with photographs, a video recording of the same photographed sessions was made. The purpose of the video was to support the photographs and give a picture of the working conditions in general, and of the events occurring simultaneously near the lifting task. The classification system used included four back positions, three feet positions, lower limbs, and distance. The criterion for each category was the same as in the OWAS method (Karhu et al. 1977).

The results showed that in the initial posture, feet were apart (58%), lower limbs straight (68%), back bent (92%), and the back was twisted in more than half of the cases. In this posture, they were lifting a load that was located 20 in. (50 cm) or less from the floor and the distance of the load from the body was less than 20 in. (50 cm). In the final position, the feet were apart (47%), lower limbs extended (92%), back straight (27%), back bent (58%), and/or twisted (45%). The typical lift was a “back lift”. The back was bent and twisted. The load was close to the body when lifting more than 33 lbs but if the body did not support the load the load was less than 20 lbs. The lifting was seldom done with the back straight and knees bent as is typically recommended for a correct lift.

Hagen, Magnus, & Vetlesen (1998) looked at neck, shoulder, and low back disorders in the forestry industry. Forestry work is traditionally recognized as one of the hardest types of physical work. This study looked at manual workers (use chainsaws, exposed to hand and arm vibration and spinal loading), machine operators, and administrative workers (office work, sedentary work). Low back and neck/shoulder disorders were considered as present if they had lasted for more than 30 days during the

previous 12 months. Participants were divided into three groups: 645 manual workers, 66 machine operators, and 124 administrative workers.

The results of this study showed that 197 workers (23.6%) reported low back pain. The prevalence of low-back disorders increased significantly with age. Low back disorders were more common among the manual workers than among the administrative workers. There was no difference found in low back disorders between the machine operators and the manual workers. Psychosocial job stress and musculoskeletal disorders were measured at the same time but it was not possible to determine whether the disorders resulted from the stress or vice versa.

Similar workplace conditions exist for tree crew employees. Given the wide array of potentially challenging positions and workplace constraints on movement, these employees were selected for observation in the present study. In addition, the OWAS system was selected as the tool for recording postures for subsequent analysis.

CHAPTER III

METHOD

The purpose of this study was to conduct a descriptive ergonomic analysis of postures observed among members of the City of San Jose Landscape Tree Crew. Selection of participants used in this study, instrumentation used to collect data, procedures used to conduct the study, and data analysis procedures are outlined in this chapter.

Participants

An entire Landscape Tree Crew (11 male employees) between the ages of 23-50 years participated in this study. Information regarding their hours and what was done in a typical day were obtained at a meeting with the Landscape Tree Crew supervisor on February 19, 2004. There were 14 questionnaires (one extra than evaluator thought would be needed) passed out with a number on the top right corner. Nine of the employee's filled out the questionnaire at this time. Two additional employees, not present at the meeting on the 19, filled out the questionnaire on the first day of the study. Originally, the evaluator thought there would be 13 employees being evaluated but two of them were managers and did not work in the field, but in the office. This study studied the 11 employees in the field since the tasks involved outside activities.

Description of Instrumentation

Ovako Working Posture Analyzing System (OWAS)

The OWAS is a coding system that facilitates coding the frequency of the feet, lower limbs, and back in various positions. Bruijn et al. (1988) reported a proportion of

agreement value of 93% using the OWAS across multiple observers or “evaluators.” The OWAS is designed to reduce the infinite variety of possible angles for the back, lower limbs, and feet positions. For example, back straight or bent is recorded versus estimating the angle the back is bent. Furthermore, the OWAS reduces observations to a finite set of all possible combinations of positions included in the coding system. For example, in this study, the back, feet, and lower limbs were coded into one of three or four positions each involving 36 combinations (Table 1).

Table 1*OWAS Position Combinations for the Back, Feet, and Lower Limbs*

Back	Feet	Lower Limbs	no.
Back straight 1	Feet side by side 1	Both limbs straight 1	1
		Both limbs flexed 2	2
		One limb flexed 3	3
	One behind 2	Both limbs straight 1	4
		Both limbs flexed 2	5
		One limb flexed 3	6
	Other position 3	Both limbs straight 1	7
		Both limbs flexed 2	8
		One limb flexed 3	9
Back bent 2	Feet side by side 1	Both limbs straight 1	10
		Both limbs flexed 2	11
		One limb flexed 3	12
	One behind 2	Both limbs straight 1	13
		Both limbs flexed 2	14
		One limb flexed 3	15
	Other position 3	Both limbs straight 1	16
		Both limbs flexed 2	17
		One limb flexed 3	18
Back straight, twisted 3	Feet side by side 1	Both limbs straight 1	19
		Both limbs flexed 2	20
		One limb flexed 3	21
	One behind 2	Both limbs straight 1	22
		Both limbs flexed 2	23
		One limb flexed 3	24
	Other position 3	Both limbs straight 1	25
		Both limbs flexed 2	26
		One limb flexed 3	27
Back bent, twisted 4	Feet side by side 1	Both limbs straight 1	28
		Both limbs flexed 2	29
		One limb flexed 3	30
	One behind 2	Both limbs straight 1	31
		Both limbs flexed 2	32
		One limb flexed 3	33
	Other position 3	Both limbs straight 1	34
		Both limbs flexed 2	35
		One limb flexed 3	36

Questionnaire

A questionnaire (Appendix B) was used to gather additional information about the participants in this study. Data obtained from the questionnaire included age, training for the job, equipment they used, work schedules, extra curricular activities, and medical information such as known histories of back pain, injuries, and surgeries. The questionnaire also included the item, "Name the three most common tasks that you think can cause back injuries in your job." Fourteen numbered questionnaires were given out to the employees.

Informed Consent

An informed consent form (Appendix C) was given to each of the employees, which contained information about the study from which they could determine if they wanted to volunteer to participate. The supervisor of the crew encouraged all of his employees to take part in the study.

Stopwatch

A digital kitchen timer was used to keep the time intervals between each data entry in the study consistent.

Research Procedures

The City of San Jose Landscape Tree Crew supervisor was first contacted concerning this study on February 19, 2004. The supervisor agreed to permit employees to participate in the study and offered his own additional input after being briefed on the proposed purpose and methods of this study. Prior to any contact with participants, approval to conduct this study (Appendix D) was obtained from the Human Subjects

Review Board at San Jose State University on August 26, 2004. The evaluator met with the employees and supervisor at their staff meeting on August 27, 2004 in their break room. The supervisor introduced the evaluator to the subjects, and she gave them a summary of the study. The employees filled out a Questionnaire (Appendix B) and signed an Informed Consent (Appendix C). Only nine employees filled out the questionnaires the first day because two of the employees were absent. The two remaining employees filled out the questionnaire the following week. Originally, there were 13 employees but two of the employees were managers and did not work in the field but in the office. This study was designed to observe employees in the field since the tasks that were selected involved outside activities.

To select the tasks to be evaluated, questionnaire responses were reviewed to identify the top three tasks the employees felt could lead to back injury. Some of the tasks the employees listed were very general, such as lifting or pulling, but others mentioned lifting logs or pulling limbs. The evaluator grouped tasks with similar descriptions together. For example, pulling brush and pulling limbs were categorized in the same group. The tasks selected were lifting logs, pushing and pulling brush, and shoveling debris.

The first task was lifting logs. The evaluator evaluated employees as they lifted large logs and lifted large bundles of branches. The second task was shoveling debris. Not many of the employees did this task and if they did, it was for a short period of time. The third task was pushing and pulling debris. This is a broad task. Pushing and pulling debris encompassed pushing debris into the chipper, using the broom for raking the

debris, and pulling branches to the chipper. Participants engaged in additional manual activities such as manipulating heavy power tools, and activities in an elevated position (“cherry picker” bucket) that were not evaluated. Only lifting, pushing/pulling, and shoveling activities performed on the ground were evaluated.

Employees were observed for three 6-hour days and three 4-hour days. A different three-person team was evaluated each day. The evaluator followed the team each morning out to the site(s) they were working at for the day. The employees started their day at 7:00 a.m., got their trucks ready, left the yard between 7:30-8:00 a.m., and arrived at their first job by 8:30 a.m. They took breaks at 10:00 a.m. and noon, and then finished up after 2:00 p.m. They headed back to the yard before 3:00 p.m. During the time of the study, the evaluator rode in one of the trucks to the job site and then was dropped off at the yard at the end of the day. The first day of data collection was September 7, 2004.

The employees generally did not remember their numbers (on the questionnaire and informed consent form). Therefore, the evaluator asked each of the employees their name and then looked up their participant number, which was recorded on the OWAS worksheet. Participants were instructed to do their job in a normal fashion, disregard the presence of the evaluator, and continue normal business conduct during the evaluation. “Normal business conduct” for the City of San Jose Landscape Tree Crew involves handling fallen trees from accidents or storms, zone trimming around utility lines and other city property features, and emergency removal involving, for example, trees falling on cars or houses.

The evaluator used the OWAS to focus on the position of the back, feet, and lower limbs. Postures were recorded for each employee at two-minute intervals over a span of one hour of normal working conditions. Once the employee started the job, the stopwatch was started and it counted backward from two minutes. At the two-minute mark, the evaluator began coding the feet, lower limbs, and back for one of the three tasks. The stopwatch was then started again for the next two minutes. The stopwatch ran the length of the job stopping every two minutes until the job was done. A job could take ten minutes or an hour depending on what crew (complaints crew, tree removal crew, and pruning crew) the employee was working with for the day.

The *complaints crew* worked on small jobs generated by day-to-day reports of needed work throughout the city, (e.g., a tree branch blocking traffic). The employees took care of the complaint, then moved on to the next job. They may have six to eight jobs to be done within the four or six-hour observation time during the day. The *tree removal crew* is normally on a job for a longer period of time to cut down large dead trees. This crew was the easiest crew to observe due to the length of their tasks; however this crew spent considerable time elevated bringing large branches down from overhead cuts. The *pruning crew* worked on cosmetic pruning jobs throughout the city, typically of short duration. This crew might complete six to eight jobs per day.

It often took several hours to obtain one hour of data for a participant. The time frame used for observation was two minutes since this was the typical amount of time that it took to repeat the task of picking up branches and moving them to the chipper. This was similar to the White & Kirby (2003) wheelchair study where the amount of time

to do the task was based on how long it took the employee to walk to the wheelchair, complete the task, and walk back to the start position.

Between the time trials, the evaluator took additional notes as necessary. The evaluator observed each employee for a one-hour period, collected data every two minutes, recorded information on the OWAS worksheet (Appendix E) by putting an “x” in the box of the position the employee was using for the back, feet, and lower limbs while conducting one of the tasks. Continuous notes were taken pertaining to the employee’s activities, tools, equipment, and environment. The evaluator also made note of times when the employees performed tasks that were not one of the three key tasks being studied. Refer to Appendix F for the notes while out in the field. Neither travel time between job assignments nor any breaks was counted as part of the one-hour evaluation period.

The evaluator was required to stand a safe distance from the working crews as determined by the lead supervisor for that crew. The evaluator was positioned perpendicular to or behind the worker for the most unobstructed view, depending on each task’s layout.

Analysis of Data

All data resulting from this study was entered into a Microsoft Excel spreadsheet for subsequent analysis and evaluation.

Questionnaire

Information from the questionnaire was summarized. Percentages were calculated for the number of employees with pre-existing back injuries, those with back

pain while working, and the number that received training for their job. Additionally, responses regarding what equipment was used on the job were tabulated. Central tendency and variability were calculated to summarize the information on age. The last item on the questionnaire was for the employees to identify the top three tasks that might cause back pain or injury on the job. Based on the frequency with which each task was reported, the top three tasks to be observed in this study were identified: lifting logs, shoveling debris, and pushing and pulling debris.

Ovako Working Posture Analyzing System (OWAS)

The OWAS was used on three tasks performed by the tree crew. The tasks were lifting logs, shoveling debris, and pushing and pulling brush. Summary information (frequencies) were obtained at the end of the study for each of the three tasks on the posture and combination of postures (e.g., back bent, feet side by side, and both limbs flexed) used by the group as a whole and separately for employees in two age groups and for employees with back pain and those without back pain.

CHAPTER IV

RESULTS

This chapter presents the results from the questionnaire, tasks observed, and description of the equipment used on the job. Second, it conveys the summary results from observations of employee postures and posture combinations across the three tasks. Third, it presents results separately for those with and without back pain/ injury and by age group.

Questionnaire Results

This section contains summary information from the questionnaire, which included three sections: employee demographics, employee reported tasks, and employee reported tools used during the job. It also presents the information obtained on age, back pain, job training, and back injury.

The mean age of the 11 employees was 35 years old. The range of ages was between 24 years and 43 years. Eight-two percent (9 out of 11) of the employees received training for their job consisting of proper lifting techniques, miscellaneous training on equipment, and chainsaw and chipper operation classes. Only one person responded he had a back injury that has kept him off the job. Five employees (45%) reported working with back pain daily. In addition, employees noted other injuries such as knee or neck injuries that took them off the job. Table 2 summarizes the questionnaire demographics.

Table 2*Tabulated Results of the Questionnaire*

Employee #	Age	Training	Back Injury	Back Pain
1	36	Y	N	N
2	34	Y	N	Y
3	40	N	N	N
4	40	N	N	N
5	28	Y	N	Y
6	26	Y	Y	Y
7	40	Y	N	Y
8	33	Y	N	N
9	43	Y	N	N
12	40	Y	N	Y
14	24	Y	N	N

An item at the end of the questionnaire asked participants to, identify three common tasks that could cause back injuries in their job. The answers given were not very specific; there was a lot of room for subjective interpretation of the answers. For example, one employee wrote lifting, pulling, bending whereas another employee wrote lifting logs, pulling branches to the chipper, and bending down to pick up branches. From the responses provided by the employees, the researcher selected the three most frequently mentioned tasks. They were lifting logs (31 %), pushing and pulling brush (16%), and shoveling debris (13%). A complete set of responses is provided in Appendix G.

Another questionnaire item was “What equipment do you use on the job?” Table 3 lists tools used but not how often they used the tools. The chainsaw was the tool most often used by the employees according to this survey, but was not identified as one of the top tasks that might cause back pain/injury. The chipper was second.

Table 3*Equipment Use Survey Results*

Tools used	Number of responses
Chainsaws	8
Chipper	7
Pole pruner	3
Blowers	2
Hand tools	1
Shovels	1
Rakes	1
Brooms	1
Saws	1
Wenches	1
Boom truck	1
Stump grinder	1
Trucks	1

Postures and Combinations of Postures Across Three Tasks

The following section presents summary information regarding the individual postures and combinations of postures that the 11 employees used for each task: lifting logs, shoveling debris, pushing and pulling brush.

Task 1: Lifting logs

The first task was lifting logs. Data for this task was obtained from observations of six of the 11 employees. Out of the 36 possible combinations of back, feet and lower limb positions, the employees used eight combinations. A total of 24 observations were recorded for lifting logs. They are summarized in Table 4.

The two most frequently observed combinations at 33% each were:

- Back bent, one foot behind, both limbs flexed – combination 14
- Back bent, feet side by side, both limbs flexed - combination 11

The only difference between the two combinations was if one-foot was behind or the feet were side by side. In contrast to what was observed, the employee should be keeping their back straight while lifting logs versus bending their backs.

Table 4*Posture Combinations Observed While Lifting Logs*

Combination #	Combination	Number ^a	Percentage
14	Back bent, One foot behind, Both limbs flexed	8	33%
11	Back bent, Feet side by side, Both limbs flexed	8	33%
23	Back straight, One foot behind, Both limbs flexed	2	8%
10	Back bent, Feet side by side, Both limbs straight	2	8%
5	Back straight, One foot behind, and Both limbs flexed	1	4%
4	Back straight, One foot behind, Both limbs straight	1	4%
15	Back bent, One foot behind, One limb flexed	1	4%
12	Back bent, Feet side by side, One limb flexed	1	4%

^aTotal number of observations for the lifting task = 24

Table 5 presents the information on lifting logs separately for each component (back, feet, lower limbs) of the combination postures. The most frequently observed back posture while lifting logs was back bent (83%), the most frequently observed position of the feet was one foot behind (54%), and for lower limbs the most frequent posture was both limbs flexed (79%). While the position of the back (bent) is not

optimal, the positions for the feet and lower limbs are good, one foot behind (feet side by side is good as well) and both lower limbs flexed.

Table 5*Position of Back, Feet, and Lower Limbs Observed While Lifting Logs*

Posture	Number ^a	Percentage
Back bent	20	83%
Back straight and twisted	2	8%
Back straight	2	8%
One foot behind	13	54%
Feet side by side	11	46%
Both limbs flexed	19	79%
Both limbs straight	3	13%
One limb flexed	2	8%

^aTotal number of observations for the lifting task = 24*Task 2: Shoveling Debris*

The second task was shoveling debris. Five of 11 employees were observed doing this task. There were eight combinations used by the employees for this task across the 10-recorded combinations. They are presented in Table 6. The most frequently observed combination (#14) at 30% was back bent, one foot behind, and both limbs flexed.

Table 6*Posture Combinations Observed While Shoveling Debris*

Combination #	Combination	Number ^a	Percentage
14	Back Bent, One foot behind, Both limbs flexed	3	30%
13	Back bent, One foot behind, Both limbs straight	1	10%
31	Back bent and twisted, One foot behind, Both limbs straight	1	10%
4	Back straight, One foot behind, Both limbs straight	1	10%
22	Back straight and twisted, One foot behind, Both limbs straight	1	10%
17	Back bent, Other position, Both limbs flexed	1	10%
12	Back bent, Feet side by side, One limb flexed	1	10%
11	Back bent, Feet side by side, Both limbs flexed	1	10%

^aTotal number of observations for the shoveling task = 10

Table 7 presents observations for the back, feet, and lower limbs postures while employees were shoveling debris. The most frequently observed back posture was back bent (70%), the most frequent observed position for the feet was one foot behind (70%), and the most frequently observed lower limbs position was both limbs flexed (50%).

This task occurred at the end of the job for cleanup purposes, perhaps reflecting fatigue.

Table 7*Position of Back, Feet, and Lower Limbs Observed While Shoveling Debris*

Posture	Number ^a	Percentage
Back bent	7	70%
Back straight	1	10%
Back straight and twisted	1	10%
Back bent and twisted	1	10%
One foot behind	7	70%
Feet side by side	2	20%
Other position	1	10%
Both limbs flexed	5	50%
Both limbs straight	4	40%
One limbs flexed	1	10%

^aTotal number of observations for the shoveling task = 10*Task 3: Pushing and Pulling Brush*

The third task was pushing and pulling brush, which was the only task that all 11 employees were observed doing. There were 36 possible combinations; the employees used 22 combinations. This task involved more than one activity. The activities evaluated in this task were pushing branches into the chipper, raking brush, using the broom to clean up brush, and pulling branches to the chipper. Data for all of these brush removal activities are aggregated in Table 8. When pushing and pulling brush, the most

frequently observed combination (#14) was back bent, one foot behind, and both limbs flexed (19%).

Table 8*Pushing and Pulling Brush Combinations*

Combination #	Combination	Number ^a	Percentage
14	Back bent, One foot behind, Both limbs flexed	18	19%
13	Back bent, One foot behind, Both limbs straight	9	9%
32	Back bent and twisted, One foot behind, Both limbs flexed	8	8%
28	Back bent and twisted, Feet side by side, Both limbs straight	7	7%
31	Back bent and twisted, One foot behind, Both limbs straight	5	5%
15	Back bent, One foot behind, One limb flexed	5	5%
5	Back straight, One foot behind, Both limbs flexed	5	5%
4	Back straight, One foot behind, Both limbs straight	5	5%
10	Back bent, Feet side by side, Both limbs straight	5	5%
8	Back straight, Other position, Both limbs flexed	4	4%
16	Back bent, Other position, Both limbs straight	4	4%
1	Back straight, Feet side by side, Both limbs straight	3	3%
22	Back straight and twisted, One foot behind, Both limbs straight	3	3%
11	Back bent, Feet side by side, Both limbs flexed	3	3%
17	Back bent, Other position, Both limbs flexed	3	3%
6	Back straight, One foot behind, One limb flexed	3	3%
19	Back straight and twisted, Feet side by side, Both limbs straight	2	2%
30	Back bent and twisted, Feet side by side, One limb flexed	1	1%
29	Back bent and twisted, Feet side by side, Both limbs flexed	1	1%
9	Back straight, Other position, One limb flexed	1	1%
20	Back straight and twisted, Feet side by side, Both limbs flexed	1	1%
33	Back bent and twisted, One foot behind, One limb flexed	1	1%

^a Total number of observations for the pushing/pulling task = 97

Observations for the separate back, feet, and lower limb postures, are presented in Table 9. The most frequently observed back posture was back bent (48%), the most frequent observed position for the feet was one foot behind (64%), and the most frequently observed lower limbs position was both limbs flexed or both limbs straight (44% each).

Table 9

Position of Back, Feet, and Lower Limbs Observed While Pushing and Pulling Brush

Posture	Number ^a	Percentage
Back bent	47	48%
Back bent and twisted	23	24%
Back straight	21	22%
Back straight and twisted	6	6%
One foot behind	62	64%
Feet side by side	23	24%
Other position	12	12%
Both limbs straight	43	44%
Both limbs flexed	43	44%
One limb flexed	11	11%

^aTotal number of observations for the pushing/pulling task = 97

Posture Across All Three Tasks

Table 10 summarizes the number of observations and percentages for the positions of the back, feet, and lower limbs across the three tasks. Looking at the data as a whole across all three tasks, the most frequent position for the back was back bent for lifting logs (83%), shoveling debris (70%), and pushing and pulling brush (48%). The most frequent position of the feet was one foot behind for lifting logs (54%), shoveling debris (70%), and pushing and pulling brush (64%). The most frequent lower limbs position was both limbs flexed for lifting logs (79%), shoveling debris (50%), and pushing and pulling brush (44%). For the task of pushing and pulling brush, there was a tie for the most frequent lower limbs posture (44%) for both limbs straight or flexed. Across the three tasks, the employees used the back bent position (56%), one foot behind (63%), and both limbs flexed (51%).

Table 10*Back, Feet, and Lower Limbs Posture for All Three Tasks*

Position of the back	Lifting		Shoveling		Pushing		Overall	
	no.	%	no.	%	no.	%	no.	%
Back straight	2	8%	1	10%	21	22%	24	18%
Back bent	20	83%	7	70%	47	48%	74	56%
Back straight and twisted	2	8%	1	10%	6	6%	9	7%
Back bent and twisted			1	10%	23	24%	24	18%
Position of the feet								
Feet side by side	11	46%	2	20%	23	24%	36	27%
One foot behind	13	54%	7	70%	62	64%	82	63%
Other position			1	10%	12	12%	13	10%
Position of the lower limbs								
Both limbs straight	3	13%	4	40%	43	44%	50	38%
Both limbs flexed	19	79%	5	50%	43	44%	67	51%
One limb flexed	2	8%	1	10%	11	11%	14	11%

Combinations Across All Three Tasks

Appendix H presents detailed information regarding the combinations of postures for the three tasks.

There were 131-recorded observations (24 for lifting logs, 10 for shoveling debris, and 97 for pushing and pulling brush) in this study. When reviewing the combinations of postures across all the tasks, the most frequent combination (#14) was back bent, one foot behind, and both limbs flexed (22%). The next closest was combination (#11): back bent, feet side by side, and both limbs flexed (9%). The only difference between the two combinations was the position of the feet, feet side by side or one foot behind.

Back Pain Injury Across Three Tasks

There were a total of five employees that had back pain. Employees with (24%) and without (21%) back pain were observed predominantly using combination 14, back bent, one foot behind, and both limbs flexed. Overall, no matter the task or if the employee had back pain or not, the favored combination was number 14, back bent, one foot behind, and both limbs flexed. Additionally, for the one employee with a back injury, again, combination 14 was the dominant combination observed.

Age Group Comparisons

Positions used were summarized by age group for those under 40 (n=6) and 40 or older (n=5). For each task, the information from individuals in these two groups is presented.

Lifting Logs and Age

Six employees were observed lifting logs. Table 11 shows summary information on combinations used based on age group while lifting logs. In summary, most of the employees observed lifting were under 40 years old. Employees, regardless of age group, predominantly used combinations 11 and 14.

Table 11

Combinations Observed During the Task of Lifting Logs

no.	Combination	Age Group			
		Under 40		40 and Up	
		no.	%	no.	%
4	Back straight, One foot behind, Both limbs straight			1	20%
5	Back straight, One foot behind, Both limbs flexed	1	5%		
10	Back bent, Feet side by side, Both limbs straight	2	11%		
11	Back bent, Feet side by side, Both limbs flexed	6	32%	2	40%
12	Back bent, Feet side by side, One limb flexed	1	5%		
14	Back bent, One foot behind, Both limbs flexed	6	32%	2	40%
15	Back bent, One foot behind, One limb flexed	1	5%		
23	Back straight and twisted, One foot behind, Both limbs flexed	2	11%		
Total		19	100%	5	100%

Shoveling Debris and Age

Five employees were observed shoveling debris. Summary information on combinations used based on age group while shoveling debris are presented in Table 12. In summary, with so few observations, little can be inferred from the comparison. What was observed was that employees under the age of 40 used four combinations, combination 11, 12, 14, and 17 equally. Employees 40 years and older used combination 14, back bent, one foot behind, both limbs flexed (33%).

Table 12

Combinations Observed During the Task of Shoveling Debris

Combination no.	Age Group			
	Under 40		40 and Up	
	no.	%	no.	%
4 Back straight, One foot behind, Both limbs straight			1	17%
11 Back bent, Feet side by side, Both limbs flexed	1	25%		
12 Back bent, Feet side by side, One limb flexed	1	25%		
13 Back bent, One foot behind, Both limbs straight			1	17%
14 Back bent, One foot behind, Both limbs flexed	1	25%	2	33%
17 Back bent, Other foot position, Both limbs flexed	1	25%		
22 Back straight and twisted, One foot behind, Both limbs straight			1	17%
31 Back bent and twisted, One foot behind, Both limbs straight			1	17%
Totals	4	100%	6	100%

Pushing and Pulling Brush and Age

Eleven employees were observed pushing and pulling brush. Summary information on combinations used based on age group while pushing and pulling brush are presented in Table 13.

Table 13*Combinations Observed During the Task of Pushing and Pulling Brush*

Combinations		Age Group			
		Under 40		40 and Up	
no.		no.	%	no.	%
1	Back straight, Feet side by side, Both limbs straight	2	4%	1	2%
4	Back straight, One foot behind, Both limbs straight	2	4%	3	7%
5	Back straight, One foot behind, Both limbs flexed	3	5%	2	5%
6	Back straight, One foot behind, One limb flexed	1	2%	2	5%
8	Back straight, Other position, Both limbs flexed	1	2%	3	7%
9	Back straight, Other position, One limb flexed			1	2%
10	Back bent, Feet side by side, Both limbs straight	2	4%	3	7%
11	Back bent, Feet side by side, Both limbs flexed	3	5%		
13	Back bent, One foot behind, Both limbs straight	4	7%	5	12%
14	Back bent, One foot behind, Both limbs flexed	7	13%	11	26%
15	Back bent, One foot behind, One limb flexed			5	12%
16	Back bent, Other position, Both limbs straight	4	7%		
17	Back bent, Other position, Both limbs flexed	3	5%		
19	Back straight and twisted, Feet side by side, Both limbs straight	1	2%	1	2%
20	Back straight and twisted, Feet side by side, Both limbs flexed			1	2%
22	Back straight and twisted, One foot behind, Both limbs straight	2	4%	1	2%
28	Back bent and twisted, Feet side by side, Both limbs straight	6	11%	1	2%
29	Back bent and twisted, Feet side by side, One limb flexed	1	2%		
30	Back bent and twisted, Feet side by side, One limb flexed	1	2%		
31	Back bent and twisted, One foot behind, Both limbs straight	5	9%		
32	Back bent and twisted, One foot behind, Both limb flexed	6	11%	2	5%
33	Back bent and twisted, One foot behind, One limb flexed	1	2%		
Totals		55	100%	42	100%

Overall Tasks and Age

Summary information for the 11 employees on combinations used based on age group is presented in Table 14. In summary, employees favored combination 14 (18% under age 40; 28% 40 years and older).

Table 14*Combinations Sorted By Age Across the Three Tasks*

no.	Combination	Age Group			
		Under 40		40 and Up	
		no.	%	no.	%
1	Back straight, Feet side by side, Both limbs straight	2	3%	1	2%
4	Back straight, One foot behind, Both limbs straight	2	3%	5	9%
5	Back straight, One foot behind, Both limbs flexed	4	5%	2	4%
6	Back straight, One foot behind, One limb flexed	1	1%	2	4%
8	Back straight, Other position, Both limbs flexed	1	1%	3	6%
9	Back straight, Other position, One limb flexed			1	2%
10	Back bent, Feet side by side, Both limbs straight	4	5%	3	6%
11	Back bent, Feet side by side, Both limbs flexed	10	13%	2	4%
12	Back bent, Feet side by side, One limb flexed	2	3%		
13	Back bent, One foot behind, Both limbs straight	4	5%	6	11%
14	Back bent, One foot behind, Both limbs flexed	14	18%	15	28%
15	Back bent, One foot behind, One limb flexed	1	1%	5	9%
16	Back bent, Other position, Both limbs straight	4	5%		
17	Back bent, Other position, Both limbs flexed	4	5%		
19	Back straight and twisted, Feet side by side, Both limbs straight	1	1%	1	2%
20	Back straight and twisted, Feet side by side, Both limbs flexed			1	2%
22	Back straight and twisted, One foot behind, Both limbs straight	2	3%	2	4%
23	Back straight and twisted, One foot behind, Both limbs flexed	2	3%		
28	Back bent and twisted, Feet side by side, Both limbs straight	6	8%	1	2%
29	Back bent and twisted, Feet side by side, Both limbs flexed	1	1%		
30	Back bent and twisted, Feet side by side, One limb flexed	1	1%		
31	Back bent and twisted, One foot behind, Both limbs straight	5	6%	1	2%
32	Back bent and twisted, One foot behind, Both limbs flexed	6	8%	2	4%
33	Back bent and twisted, One foot behind, One limb flexed	1	1%		
Total		78	100%	53	100%

CHAPTER V

DISCUSSION

This section examines the questionnaire, how the evaluator used the OWAS, problems with the OWAS system, results obtained using the OWAS system, problems encountered while conducting the study, and recommendations for future research.

Questionnaire

Interpreting the task descriptions from survey responses proved subjective. Employees described various work tasks in many different ways (see Appendix G) and the evaluator had difficulty interpreting the descriptions until after gaining experience with the crew in the field. For example, one employee wrote “bending over”; is this bending over to pick up branches or the chainsaw? Another employee wrote “moving branches to the chipper”; does this mean a small branch lifted then thrown into the chipper or pulling branches to the chipper. Another meeting with the tree crew to define work tasks would have been helpful. In addition, a validity check on the final categories selected would have been useful.

For future research, when asking a similar question of participants, “Name the three most common tasks that you think can cause back injuries in your job”, the evaluator should list some tasks the evaluator feels would cause back injuries or list the tasks the employees conduct in their day (after taking time to observe their work). The employees could then mark the top three tasks they think can cause back injury and provide a second response that would identify the most frequent tasks. Another

suggestion is for questions to be discussed as a group and a consensus reached by the participants working together.

Evaluator's Use of the OWAS

The OWAS studies referenced in the review of literature used the OWAS in different ways. Some videotaped their employees so they could observe them but also be able to review the videotape and break down the postures. One study, done by Bruijn et al. (1998) stated that it is more difficult to observe workers in a dynamic profession (those that move around from one area to another) versus administrative workers who stay at their desk. In the study done by Kuorinka et al. (1994) the employees were in motion but the beginning and end of the movements were evaluated. Similar to the Karhu et al. (1977), this paper evaluated the employees posture and combination of postures at specific time intervals during their day.

In this study, each employee was studied for one hour and positions were recorded every two minutes. Recording information on the employees every two minutes turned out to be too long a period of time. Many postures and combination of postures were being done during that time since they were constantly moving. In the future, the decision on a time frame should be made only after observation of the varied activities. Subsequently a pilot testing of the selected protocol should be completed and modifications made as needed before final observations are made.

The OWAS coding system was found to be very general for the back posture. At what point is the back bent? The same position was recorded if the employee was bending their back 45 degrees or 10 degrees. In addition, when employees were walking

backwards and forwards, it was difficult to determine the appropriate position to record for the feet and lower limbs.

The OWAS seems to be a coding system better used for employees that are stationary, rather than for employees that are in motion. Activities were completed quickly in this study, which made it difficult to code all three areas: back, feet, and lower limbs. However, since some of the motions were repetitive, the evaluator was able to catch what was missed.

For future evaluations, there is an updated model of the OWAS called the Rapid Entire Body Assessment (REBA) that might be more useful. The REBA approach defines angles for the positions and gives them a code number. However, the higher accuracy data possible with the REBA test takes longer to obtain, and may be too complex depending on the activity being observed.

Posture and Combinations Across the Three Tasks

When lifting, regardless what the object is, employees should use their legs to lift. The back should be straight, knees bent, and feet side by side or one foot behind. Ideally, employees should squat, bending at the knees, and keep the back in proper alignment. They should lift by using the leg muscles and not the back. Additionally, employees should not twist as they lift. Instead, employees should pivot with the hips and shoulders in line and shift their weight. The employees in this study were lifting with the back bent but the lower limbs and feet were in an appropriate position.

Typically when shoveling anything, the employee should keep a straight back (but often this is not feasible), bend at the knees, and pick up small amounts at a time. In this

study, employees shoveled debris and though they used a bent back, the posture was not sustained over long periods of time and the weight (leaves, small branches) was minimal.

When pushing and pulling objects, the back should be straight and the body should stay close to the object and not lean forward. In addition, it is better to push objects than pull. The employees that were observed pushed a broom, pushed branches and logs into the chipper, and pulled branches to the chipper. Most of the time, the back was bent when conducting this task.

There were many empty cells within the tables. There were only three employees that conducted all three tasks, three employees that conducted two tasks, and five employees that only conducted one task. There were many times when the employee was not performing any of the tasks while the evaluator was observing them. For example, one employee used a stump grinder, and for the entire hour he worked the controls for the machine to grind the stump. In this case, the evaluator obtained six minutes of information over the course of an hour. Also, some employees worked in the basket but the evaluator was not studying tasks involving the overhead basket. Given the observations of this study, a broader range of tasks for observation is recommended. For example, employees used many postures that could potentially cause back injuries, such as leaning out of the basket or reaching above the head with the chainsaw.

Finally, the evaluator also encountered logistical problems in collecting the data. These included the chipper truck breaking down and waiting for another truck to come, waiting for tree branches to fall from the basket, set-up time to put out cones, time spent directing the employee in the basket, or watching for pedestrians walking under the trees.

This resulted in large gaps in the OWAS worksheet, in the posture tables, and combination tables since there was no information to gather while waiting for things to happen.

Back Pain and Age Across the Three Tasks

Employees were predominantly observed in combination 14 (back bent, one foot behind, and both limbs flexed) or combination 11 (back bent, feet side by side, both limbs flexed) regardless of whether or not the employees had back pain, back injury, or the age of the employees. Employees over 40 years old used combination 14 slightly more often than the younger group (28% versus 18%).

Conducting the Study

The evaluator noticed after a week of observations, only two employees, not three, could be observed in a six hour day when observing them one at a time. Field observations were subsequently performed on two employees simultaneously, observing one employee on the even minute counts, and the other employee on the odd minute counts. Some of the jobs took 45 minutes, some 10 minutes; it depended on the crew the employees were working with that day since the jobs varied in complexity and duration. If the employee was on the complaints crew, then it would take 6-8 jobs to get an hour of data but if the employee was on the tree removal crew, it would take 2-4 jobs to get one-hour of data since the employee was at the job site for a longer period of time.

Throughout the six days of the evaluation, members of the public occasionally approached the evaluator regarding tree crew business because they mistook the evaluator as a member of the tree crew. Twice the stopwatch went off prompting

homeowners to ask questions. In addition, some bystanders wanted to know what the evaluator was doing and if the evaluator was a city employee. Some thought the evaluator was the safety officer. Though a distraction, these interruptions did not happen frequently enough to interfere with the collection of data.

Stopwatch Issues

The stopwatch was used as follows: 1) evaluator pushes start, 2) wait two minutes, 3) push the start button to turn the stopwatch off, and 4) push the button again to start the stopwatch. There were times when the evaluator forgot to push the button the second time to set the two minutes so several seconds would pass before the evaluator realized the stopwatch had not been started. There were other times when the evaluator would not hear the stopwatch go off because of the noise of the chainsaw or chipper and again several seconds would pass before the evaluator noticed the problem. The evaluator on both occasions started the stopwatch and continued with the study. For future studies, the researcher should have a vibrating stopwatch or one that you push once and it counts down and beeps every two minutes.

Future Studies

From the results and discussion of the present study, several recommendations may be made for future research involving ergonomic analyses and lower back pain. The Landscape Tree Crew Supervisor provided these suggestions: 1) conduct an evaluation of the employee's posture and effects of vibration in the truck seat while traveling between job sites, 2) investigating the availability of grip and anti-vibration gloves for the tree crew's equipment, 3) an ergonomic evaluation of the break room chairs, and 4) an

ergonomic evaluation of exercises using equipment in the mini-gym to strengthen the body specifically for this kind of work.

Another idea is to study a different crew using the OWAS. Many of the employees asked the evaluator why she was studying the Landscape Tree Crew versus the Paving crew or Gardening group. These are other groups researchers could observe using the OWAS. Both of these groups can be expected to engage in motions that might result in back injury. In addition, comparison of observations across the three-crew types could prove interesting.

Additional recommendations specifically for tree crew personnel and managers include:

- 1) The employees can do their own task analysis of their jobs and brainstorm ways to maintain safe postures during work. Tasks can be analyzed by breaking down the task into their various components and subcomponents. For example, lifting logs involves bending the legs, keep the back straight, use your legs when lifting, walk to the chipper, and throw the log in the chipper.
- 2) Exercise/training should focus on back, legs, abdominal, and stretching. An athletic trainer or fitness expert could give classes on the equipment and exercises they can use in their mini gym that will work the back, legs, and abdominal. Stretching exercises will need to be emphasized since their job involves a lot of heavy physical work.
- 3) Hold training information sessions periodically to reinforce information on best practices with respect to movement.
- 4) Supervisors should be trained, informed with respect to ergonomics, and responsible for oversight (in the context of OWAS) that includes feedback to employees regarding posture and injury prevention. Proper lifting techniques should be emphasized. Explain the OWAS system and consider having the employees conduct the OWAS with their coworkers and observe various tasks especially using the chainsaw. Train the supervisor what to look for when they do periodic checks on their employees.

All of these recommendations have the potential to reduce medical costs, reduce time off the job, and result in fewer incidents of back pain/injury. In conclusion, combination 14, (back bent, one foot behind, lower limbs flexed) was most frequently used by employees across three tasks. When observing the employees, they had plenty of room to conduct the tasks so the back could have been straight. The feet and lower limbs were in the correct position. The back straight position is recommended and should help reduce the amount of back pain the crew experiences.

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Appendix A

OWAS Coding System

Posture	Description
Position of the feet	Feet side by side
	One foot behind
	Other position
Position of the lower limbs	Both limbs straight
	Both limbs flexed
	One limb flexed
Position of the back	Back straight
	Back bent
	Back straight and twisted
	Back bent and twisted
Distance of the load from the surface	On the floor, pallet or < 50cm
	50-100 cm
	100-150 cm
	>150 cm
Distance of the load from the body	Close: < 50 cm
	Far: > 50 cm

Appendix B

Demographic Questionnaire

Workers Component:

Age: _____

Height: _____ (optional)

Weight: _____ (optional)

Did you receive training for your job? Yes/No

If yes, what kind?

Do you work out at the gym or do some form of exercise outside of work? Yes/No

If yes, what do you do?

Do you have back pain periodically while working? Yes/No

If yes, how often?

Have you had a back injury that has taken you off the job for some time? Yes/No

If yes, how long were you off work?

Have you had back surgery? Yes/No

If yes, what was the nature of the surgery?

Have you seen a doctor, physical therapist, or chiropractor regarding back pain or injury?

Circle all that apply.

Task Component:

What equipment do you use on the job?

How many trees do you maintain in one day? _____

Is there a rotation of equipment used at the worksite? Yes/No

How many hours do you work? _____

Do you get breaks? Yes/No

Name the three most common tasks that you think can cause back injuries in your job.

1.

2.

3.

Appendix C

Informed Consent

Responsible Investigator: Kim Granata-Clark

Title of Protocol: Ergonomic Analysis of the Landscape Tree Crew

You have been asked to participate in a research study investigating the ergonomic analysis of the Landscape Tree Crew. You will be asked to fill out a demographics questionnaire and the information will be kept confidential. The study will occur at the workplace. The evaluator will be observing your postures while you use equipment to conduct your job.

There are no known risks to you in this study. You may benefit from this study by knowing the most common position you use with the equipment on different tasks compared to your coworkers. There is no compensation for your participation.

Although the results of this study may be published, no information that could identify you will be included. Questions about the research and/or research procedures may be addressed to the evaluator Kim A. Granata-Clark (408) 378-3322. Complaints about the research may be presented to Dr. Ted Butryn (408) 924-3039. Questions or complaints about research, subjects' rights, or research related injury might be presented to Nabil Ibrahim, Ph. D., Associate Vice President, Graduate Studies and Research, at (408) 924-2480.

No service of any kind, to which you are otherwise entitled, will be lost or jeopardized if you choose to "not participate" in the study. Your consent is being given voluntarily. You may refuse to participate in the entire study or in any part of the study. If you decide to participate in the study, you are free to withdraw at any time without any negative effect on your relations with San Jose State University or with any other participating institutions or agencies.

At the time that you sign this consent form, you will receive a copy of it for your records, signed, and dated by the investigator.

- **The signature of a subject on this document indicates agreement to participate in the study.**
- **The signature of a researcher on this document indicates agreement to include the above named subject in the research and attestation that the subject has been fully informed of his or her rights.**

Signature

Date

Investigator's Signature

Date

Appendix D

IRB Approval

San José State
UNIVERSITY

Office of the Academic
Vice President
Academic Vice President
Graduate Studies and Research

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To: Kim Granata-Clark
3200 Payne Avenue, Apt. #701
San Jose, CA 95117

From: Pam Stacks,
Interim AVP, Graduate Studies & Research

Date: August 26, 2004

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"Ergonomic Analysis of a Landscape Tree Crew."

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Pam Stacks, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subjects portion of your project is in effect for one year, and data collection beyond June 18, 2005 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

cc: Dr. Ted Butryn, Ph.D.

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Appendix E

OWAS Worksheet

Action: Lifting logs		Employee #X																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
Position of the back																															
Back straight																															
Back bent																															
Back straight, twisted																															
Back bent, twisted																															
Position of the feet																															
Feet side by side																															
One behind																															
Other position																															
Position of the lower limbs																															
Both limbs straight																															
Both limbs flexed																															
One limb flexed																															
Combinations																															

Action: Shoveling debris																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
Position of the back																															
Back straight																															
Back bent																															
Back straight, twisted																															
Back bent, twisted																															
Position of the feet																															
Feet side by side																															
One behind																															
Other position																															
Position of the lower limbs																															
Both limbs straight																															
Both limbs flexed																															
One limb flexed																															
Combinations																															

Action: Pushing and pulling brush																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
Position of the back																															
Back straight																															
Back bent																															
Back straight, twisted																															
Back bent, twisted																															
Position of the feet																															
Feet side by side																															
One behind																															
Other position																															
Position of the lower limbs																															
Both limbs straight																															
Both limbs flexed																															
One limb flexed																															
Combinations																															

Appendix F

Notes from the Field

These are notes from the field of tasks that were not considered in the study but probably influence back pain/injuries. Also, there are notes regarding the employee's actions or the tools they used on the job.

Chipper activities

Pushing wood into chipper with broom
Throwing wood/branches into chipper
Chipper broken, needed to get another one
Could not use chipper because the basket was being used
Hooking up trucks with chipper
Moving truck and chipper
Throwing brush and wood into chipper
Lifting tailgate on chipper
Cutting inside the chipper with the saw
Using rake and leg to get brush into the chipper
Pushing into chipper with hands
Using foot to push brush into chipper
Pushing brush into chipper from the side versus in front
Steady wood into chipper
Build up branches and pull them into the chipper
Push bar on chipper to grind wood
Push wood in chipper and use bar
Use controls on mechanical lift/chipper

Winch activities

Pulling winch
Equipment lifting logs
Winch and carry into truck/guide it
Wrapping tree with metal rope for winch to pull
Controls – Winch and roller
Undo winch

Basket work

Hold onto branches and then drop from basket

#12 was in the basket cutting branches
Leaning out and over the bucket
Cut and hold onto branch
Reaching high

Activities/tasks

Picking up debris
Pushing wood into truck
Pulling branches from ground or in tree
Broom debris
Raking leaves
Use the blower
Picking up debris with rake and foot
Shovel debris and throw it into the large truck by throwing it over their shoulder
Rake dirt
Shovel the mulch to the street for pick up
Kicking debris
Walked away to get branches
Picking up branches
Reaching for controls
Prune trees with pole pruner

Chainsaw activities

Bend knee to cut branches with the chainsaw
Long chainsaw
Small chainsaw
Starting the chainsaw
Kneeling with chainsaw
Long saw
Chainsaw above the head
Reaching with the chainsaw
Trimming tree
Reach overhead with saw in basket
20" small chainsaw
46" large chainsaw
66" extra large chainsaw
Pull saw - long saw

Chainsaw at knees, shoulder, above the shoulder

Climb tree with chainsaw

Rope activities

Rope gathering

Tie wood with rope, when cut, let's tree down safely versus branches all over the ground and blocking traffic

Pulling ropes

Untangling ropes

Holding onto rope, while pulling in tree

Holding rope, leaning back, spread legs

Holding tension in rope on ground, spread legs, back straight

Lean back and side, one foot behind, straight leg

Other observations

Employee use hand signals to talk to their coworkers in the basket

There was a lot of waiting for trees to be cut

Leaning on right leg for 10-15 minutes

Controls at hip level and shoulder level (when getting to the back of the stump)

Controls – up and down, side to side, forward and back

Take phone calls

Standing, twisting to right, look over glass to the right

Stand for 10-15 minutes running the controls, standing in one spot, looking through the glass

Suggestions – chair for employee, conveyer or blower to throw the mulch into the truck.

Employee wants an umbrella.

Straight leg, bending at hips, no eye protection

Neck extension to see top of tree

Appendix G

Tasks Noted on the Questionnaires

Task	Number of responses
Lifting logs	7
Pulling brush	2
Shoveling debris	4
Cutting big wood with the large chainsaw	1
Holding the chainsaw	1
Bending over	1
Move wood around	1
Pulling ropes	1
Working out of the bucket	1
Lifting	1
Pulling	1
Bending	1
Chipping branches	1
Bending down to pick up small brush	1
Moving branches to the chipper	1
Cutting logs on the ground	1
Picking up wood	1
Pulling limbs	1
Using chainsaw	1
Heavy lifting	1
Twisting	1
Walking on and off curbs	1
Pushing and pulling brush	1

Appendix H

Combination Postures Observed Across Three Tasks

Back	Feet	Lower Limbs	#	Lifting		Shoveling		Push/Pull		Overall	
				No	%	No.	%	No.	%	No.	%
Back straight 1	Feet side by side 1	Both limbs straight 1	1					3	3%	3	2%
		Both limbs flexed 2	2								
		One limb flexed 3	3								
	One behind 2	Both limbs straight 1	4	1	4%	1	10%	5	5%	7	5%
		Both limbs flexed 2	5	1	4%			5	5%	6	5%
		One limb flexed 3	6					3	3%	3	2%
	Other position 3	Both limbs straight 1	7								
		Both limbs flexed 2	8					4	4%	4	3%
		One limb flexed 3	9					1	1%	1	1%
Back bent 2	Feet side by side 1	Both limbs straight 1	10	2	8%			5	5%	7	5%
		Both limbs flexed 2	11	8	33%	1	10%	3	3%	12	9%
		One limb flexed 3	12	1	4%	1	10%			2	2%
	One behind 2	Both limbs straight 1	13			1	10%	9	9%	10	8%
		Both limbs flexed 2	14	8	33%	3	30%	18	19%	29	22%
		One limb flexed 3	15	1	4%			5	5%	6	5%
	Other position 3	Both limbs straight 1	16					4	4%	4	3%
		Both limbs flexed 2	17			1	10%	3	3%	4	3%
		One limb flexed 3	18								
Back straight, twisted 3	Feet side by side 1	Both limbs straight 1	19					2	2%	2	2%
		Both limbs flexed 2	20					1	1%	1	1%
		One limb flexed 3	21								
	One behind 2	Both limbs straight 1	22			1	10%	3	3%	4	3%
		Both limbs flexed 2	23	2	8%					2	2%
		One limb flexed 3	24								
	Other position 3	Both limbs straight 1	25								
		Both limbs flexed 2	26								
		One limb flexed 3	27								
Back bent, twisted 4	Feet side by side 1	Both limbs straight 1	28					7	7%	7	5%
		Both limbs flexed 2	29					1	1%	1	1%
		One limb flexed 3	30					1	1%	1	1%
	One behind 2	Both limbs straight 1	31			1	10%	5	5%	6	5%
		Both limbs flexed 2	32					8	8%	8	6%
		One limb flexed 3	33					1	1%	1	1%
	Other position 3	Both limbs straight 1	34								
		Both limbs flexed 2	35								
		One limb flexed 3	36								
Totals				24		10		97		131	