ERGONOMIC ANALYSIS OF WORKSTATION DESIGN FOR GALAXIE LIBRARY BOOKDROP, APPLE VALLEY, MN

by

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ABSTRACT

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The purpose of this study was to identify whether ergonomically related risk factors are present in the current workstation design of Galaxie Library's drive-thru bookdrop in Apple Valley, MN and compare probability of injury to proposed redesigned workstations. Redesign of the workstation to fit the workers and redesigning jobs to reduce or eliminate the amount of manual material handling has been recommended by various professionals, in the ergonomics field, to reduce job-related back pain. While none of the Galaxie Library employees has filed worker compensation claims for these ailments, human loss is occurring through their pain and suffering. Stover Snook points out that "…approximately 80 percent of the population experience low back pain sometime during life, yet treatment of these symptoms have not been very successful" (1987, p. 52).

Back problems are the single most costly workplace injury and represent 32 percent of all workers' compensation claims (Johnson, Baldwin, and Butler, 1998). Good work station design, mechanical aids, proper seating and appropriate object weights have reduced industrial low back pain by up to one-third (Snook, 1987). Job design analysis identifies individual tasks a worker is required to perform and then identifies the ergonomic risk factors associated with job task(s) (Armstrong, Radwin, Hansen, and Kennedy, 1986). If risk factors are identified, the observations, possibly combined with video observation, can lead to biomechanical monitoring and investigation to determines how the joint of interest is loaded during dynamic motion (Marras, 1992). The Risk Management Department for Dakota County decided to conduct a job analysis of assigned job tasks at Galaxie Library. Video-observation of the book return process was utilized to correctly ascertain the book collection process. To evaluate and monitor the information assistant’s lumbar position, while gathering materials, a Lumbar Motion was utilized to evaluate the current workstation to the proposed workstation design. For comparing the proposed workstation design to the present workstation design, there was a 69% decrease in sagittal motion and 60% decrease in the velocity of the movement. There was also a 69% decrease in acceleration / deceleration rate. As a result of this analysis process, it was determined that employees associated with the book collection/sorting process were at moderate risk of back injury. Study results combined with a literature review indicated that workstation redesign, an evaluated conveyor type system with spring loaded carts (or other non-manually bottom lifting cart), would decrease the amount of lumbar motion and potential of injury significantly This study was conducted Spring of 1999.

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Chapter 1

Statement of the Problem

Introduction

Ergonomics can be defined as designing the job to fit the capabilities and limitations of the worker (Snook, 1988). Traditionally, there has been a lack of appreciation for the dynamic variables during an ergonomic assessment (Marras, 1992). Redesign of the workstation to fit the workers and redesigning jobs to reduce or eliminate the amount of manual material handling has been recommended by various professionals, in the ergonomics field, to reduce job-related back pain. By job function, manual materials handling workers are at the greatest risk of developing back injuries (Frymoyer, & Cats-Baril, 1987).

Back problems have been found to be the single most costly workplace injury and represent 32 percent of all workers' compensation claims (Johnson, Baldwin, & Butler, 1998). Low back pain can be triggered by jobs which involve repetitive motion and tasks such as lifting, bending and stretching (Smith, 1996). Overexertion from reaching, twisting, pulling, throwing and light lifting significantly contribute to the back's gradual deterioration (Donajkowski, 1993). Therefore, the use of good work station design, mechanical aids, proper seating and appropriate object weights have reduced industrial low back pain by up to one-third (Snook, 1987).

Dakota County Minnesota Library systems were operating six libraries in 1999, with two more scheduled to open in 2000. While four of the libraries had conveyor style book return system, Galaxie Library did not have a conveyor-style book return. While Galaxie Library had not had worker compensation claims filed by its' library assistants, library assistants at the other Dakota Libraries had filed low back injury claims. The management at

Galaxy was receiving many complaints of back stiffness and back pain from employees working in the book return area. In a measure to ensure no injuries were incurred due to job tasks, the Risk Management Department for Dakota County decided to conduct a job analysis of assigned job tasks at Galaxie Library. As a result of this analysis process, it was determined that employees associated with the book collection/sorting process were at moderate risk of back injury.

Purpose

The purpose of this study was to identify whether or not ergonomically related risk factors are present in the current, and proposed, workstation designs of Galaxie Library's drive-thru bookdrop.

Goals of Study

1. Identify ergonomic risk factors associated with Galaxie Library's bookdrop.
2. Analyze predominate ergonomic risk factor associated with Galaxie Library's bookdrop.
3. Perform pilot implementation analysis to evaluate the effectiveness of new proposed workstation design solutions for the bookdrop area.

Background Significance

Dakota County Minnesota Library System operates eight libraries. It is estimated that these libraries serve a population of 312,868 people (Dakota County, 1997). Galaxie Library, located in Apple Valley, MN is one of Dakota County's libraries. Galaxie has a yearly circulation of 957, 048 items. Returned library materials are re-shelved by eight information assistants who work part-time or full-time, in four-hour or eight-hour shifts, respectively. The library information assistants at Galaxie Library have experienced low back pain associated with the collection of materials from the bookdrop. While none of the Galaxie Library employees have filed worker compensation claims for these ailments, human loss is occurring through their pain and suffering and may be causing the losses in efficiency and quality work. Due to the potential of severe loss from back injuries, Dakota County's Risk Management has targeted the bookdrop area for ergonomic analysis and probable workstation redesign.

Assumptions

The assumption is made that the back soreness and pain experienced by Galaxie Library assistants is the same type back pain and suffering experienced by other library assistants throughout Dakota County working in same conditions.

Limitations

This study pertained only to the Galaxie Library bookdrop area, Apple Valley, Minnesota and to those employees and tasks associated with materials return for the bookdrop. While this study may identify ergonomic risk factors other than those associated with the upper and lower back, only upper and lower back ergonomic risk factors with be measured through use of instrumentation.

Definitions

1. <u>Anthropometry</u> - Measurement and collection of body measurements for use of design criteria to improve functioning, efficiency and safety of humans in the work environment (Finder, 1999).
2. <u>Bookdrop return tasks</u> - Activities associated with the removal of library materials from the bookdrop area to circulation desk.

3. <u>Ergonomics</u> - The science dedicated to the study of the relationship between the worker and the work environment to achieve an optimum in efficiency, safety, health and well-being between the two (Finder, 1999).
4. <u>Extension</u> – movement that increase the angle between two adjacent bones (Putz-Anderson, 1988).
5. <u>Flexion</u> - movement that decrease the angle between two adjacent bones (Putz-Anderson, 1988).
6. <u>National Institute of Occupational Safety and Health (NIOSH)</u> - A government association which evaluates available research data and criteria and recommends standards for safe work practices and occupational exposure to toxic substances.
7. <u>Occupational back injuries</u> - Any incidence of pain occurring to the back which is caused by work-related activity and results in loss of efficiency and effectiveness of the employee.
8. <u>Occupational Safety and Health Administration (OSHA)</u> - A government regulatory agency, which enforces standards concerning occupational safety and health, conditions, exposures, and procedures.
9. <u>Risk Factors</u> - Job attributes or exposures that increase the probability of the occurrence of injury or illness to the employee.
10. <u>Workstation</u> - The workspace with in the direct reach of the individual and includes all relevant work fixtures, such as the work table, stools or chairs as well as any supply and output containers (Armstrong, Radian, Hansen, and Kennedy, 1986).

Chapter 2

Review of Literature

Introduction

The specific causes of low back pain are unknown although the condition has been around for hundreds of years. Many practitioners, safety and health experts as well as those in general industry believe that low back pain is a result of multiple "incidents" rather than one acute accident that cause changes to the spine as a person gets older. None of the common musculoskeletal disorders is uniquely caused by work exposures (NRC, 2001). The World Health Organization calls these musculoskeletal back disorders "work-related conditions" because they can be caused by work exposures as well as non-work factors (World Health Organization, 1985). Stover Snook points out that "…approximately 80 percent of the population experience low back pain sometime during life, yet treatment of these symptoms have not been very successful" (1987, p. 52).

Epidemiology

Back problems are the single most costly workplace injury and represent 32 percent of all workers' compensation claims (Johnson, Baldwin, and Butler, 1998). Good work station design, mechanical aids, proper seating and appropriate object weights have reduced industrial low back pain by up to one-third (Snook, 1987). A great number of epidemiological studies have shown that the risk of occupationally related low-back disorder (LBD) significantly increased during manual material-handling activities (Marras, 1992).

Workers' Compensation Claims & Low Back Injury

Studies of workers' compensation data have suggested that low back pain (LBP) represents a significant portion of morbidity in working populations: data from a national insurer indicate that back claims account for 16% of all workers' compensation claims and 33% of total claim costs (Snook, 1982). Routinely collected source of occupational injuries and illnesses of U.S. workers is the Annual Survey of Occupational Injuries and Illnesses conducted by the Bureau of Labor Statistics reports in 1999 private industry experienced 424,251 back injuries and illness that resulted in days away from work (BLS, 1999). 211,131 cases were injuries or illnesses associated with the lumbar region (BLS, 1999). These types of numbers and the costs associated with these injuries and illness gives credence to employers redesigning jobs, job task and especially work stations to decrease the exposure and possibility of injury to employees.

Ever since evidence began to point toward ergonomics as a prevention technique for low-back pain, various industries have begun to look at job design and workstation redesign as methods to decrease low-back disability and to cut the workers' compensation costs. Job design analysis identifies individual tasks a worker is required to perform and then identifies the ergonomic risk factors associated with job task(s) (Armstrong, Radwin, Hansen, and Kennedy, 1986).

Ergonomic Risk Factors

Ergonomic risk factors are those physical exposures of force, repetition, posture, loading, speed of movement, vibration, and temperature (Keyserling, 1999). The following table lists Risk Factors and References identified by Armstrong, Radwin, Hansen, and Kennedy.

Table 1 *Reported Risk Factors of Repetitive Trauma Disorders*

Factor	*Reference*
Repetitive Exertions	Cannon, Bernacki and Walter, 1981;Hagberg, 1982; Kelly and Jacobson, 1964; Kuorinka and Koskinen, 1979; Kurppa, Waris and Rokkanen, 1979a; Lupajarvi, Kuorinka, Virolainen, and Holmer, 1979; Muckart, 1964; Phalen, 1966; Simon, 1975;Sperling, 1951; Thompson, Plewes, and Shaw, 1951; Tichauer, 1976; Wilson and Wilson, 1957; Wright 1945
Posture:	
1) Shoulder	DePalma and Callery, 1954; Herberts, Kadefors, Andersson, and Petersen, 1981; Lippmann, Simon, 1975; Wright, 1945
2) Forearm Inward or outward rotation with a bent wrist	Hoffmann, 1981; Kurppa, Waris, and Rokkanen, 1979b; Goldie, 1964; Tichauer, 1976.
3) Wrist: Palmar flexion or full extension and/or Ulnar or radial deviation	Armstrong and Chaffin, 1979; Phalen, 1966; Smith Sonstegard, and Anderson, 1977; Tanzer, 1959; Tichauer, 1976; Loomis, 1951; Muchart, 1964; Younghusband and Black 1963
4) Hand: Pinching	Armstrong, 1979, 1982; Smith Sonstegard and Anderson, 1977; Swanson, Matev and Groot, 1970
Mechanical Stress Concentrations:	
1) Over the base of palm	Armstrong, 1983; Kendall, 1960
2) On the palmer surface of the fingers	Quinnell, 1980; Sperling, 1951; Tichauer, 1976
3) On the sides of the fingers	Dobyns, O'brien, Linscheid, and Farrow, 1972 Kisner, 1976; Tichauer, 1976
Vibration	Cannon, 1961; Seppalainen 1970
Cold	Clark, 1961; Dusek, 1957; Fox, 1967; Lockhart and Kiess, 1971; Mackworth, 1955; Morton, and Provins, 1960; Scheifer, Kok, Lewis and Meese, 1984; Stevens, Green and Krimsley, 1977; Williamson, Chrenko, and Hamley, 1984
Gloves	Hertzberg, 1955; Lyman, 1957; Sperling, 1980

(Armstrong, Radwin, Hansen, and Kennedy, 1986)

In order to understand the frequency as well as the severity of the risk factors that may be present the physical demands, or exposures, of each task performed in a job must be analyzed. The different available approaches to estimate these physical exposures include worker self-report, bioinstrumentation, and direct observation (NRC, 2001). In highly repetitive work, where a worker repeats the same task over and over, identification of exposure can be a simple process. In non-routine work and job rotation, exposures to risk factors may be a more lengthy and thought intensive process. Job description alone is not enough to determine exposure for every employee. Job title may indicate homogenous exposure groups for some stressors, such as repetitiveness and force demands, while other features such as posture may vary widely among workers in the same job (Punnett and Keyserling, 1987; Silverstein, Fine and Armstrong, 1986).

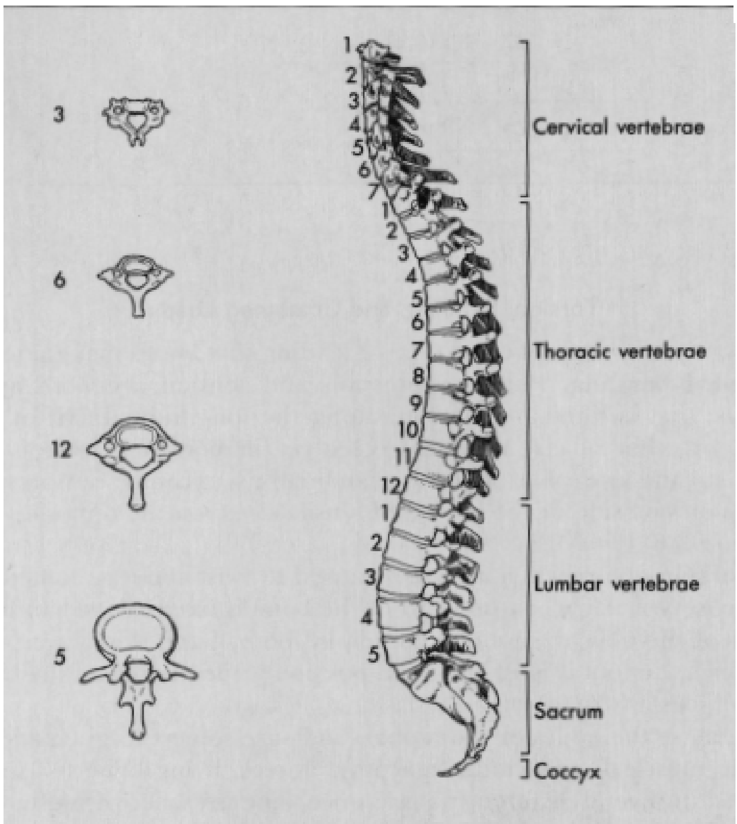
Worker self-reporting can address both task-specific exposures within jobs and the distribution of tasks performed by each worker (NRC, 1999). The self-reports permit assessment of exposures in the past as well as the present (NRC, 2001). Direct observation does not allow for past exposure interpretation. Bioinstrumentation provides quantifiable results, but can be invasive and may alter work practices the same may be true of observation (NRC, 1999).

There are also psychological and physiological ergonomic risk factors that should be given due note. The nature vs. nurture theory comes into play for psychological ergonomic risk factors. How a person was raised/trained to perform certain tasks, and how they handle stress by increased workload are examples of psychological risk factors (NRC, 2001). Interference in work demands, by that of the observer or person performing biomechanical instrumentation, may skew results in identifying ergonomic risk factors. Examples of physiological factors are how tired the person is performing the task, how fatigued muscles are, personal reactions to temperature and the mechanical strain placed by each task, varies from person to person (NRC, 2001). Studied and identified risk factors have been directly linked to anatomy and physiology of the portion of the body being observed.

Back Anatomy and Physiology

The form and functioning of the back, especially the spinal column, is quite unique. It is designed to be incredibly strong and flexible, while providing protection to the central nervous system. The design of the spinal column provides a many planes of mobility, but its' design also allows it to deliver high levels of pain. First, in discussing the design structure of the spine, there are five major sections: the coccygeal, the sacral, the lumbar, the thoracic, and the cervical spine (Hall, 1991).

Figure 1. *Picture of Spinal Column and Vertebral Joint*



(Hall, 1991)

As indicated in Figure 1 above, each section is composed of individual bones called vertebrae. There are three to five vertebrae in the coccygeal, five fused vertebrae in the sacral, five vertebrae in the lumbar region, twelve in the thoracic, and seven in the cervical region (Hall, 1991). The main weight-bearing region of each vertebral body provides a resting-place for a vertebral disc. Each disc acts like a shock absorber. The outer layer of the disc is called the annulus, which surrounds a soft pliable inner layer termed the nucleus

(Adams, 1983). When a disk “herniates” or ruptures, the soft nucleus spurts out through a tear in the annulus and can compress a nerve root (Adams, 1985). The amount of perceived pain depends on how much of the nucleus breaks through annulus and how much nerve compression and nerve irritation occurs. Other physiological structures that can contribute to back pain are the large muscles groups supporting the spine (Hall, 1991).

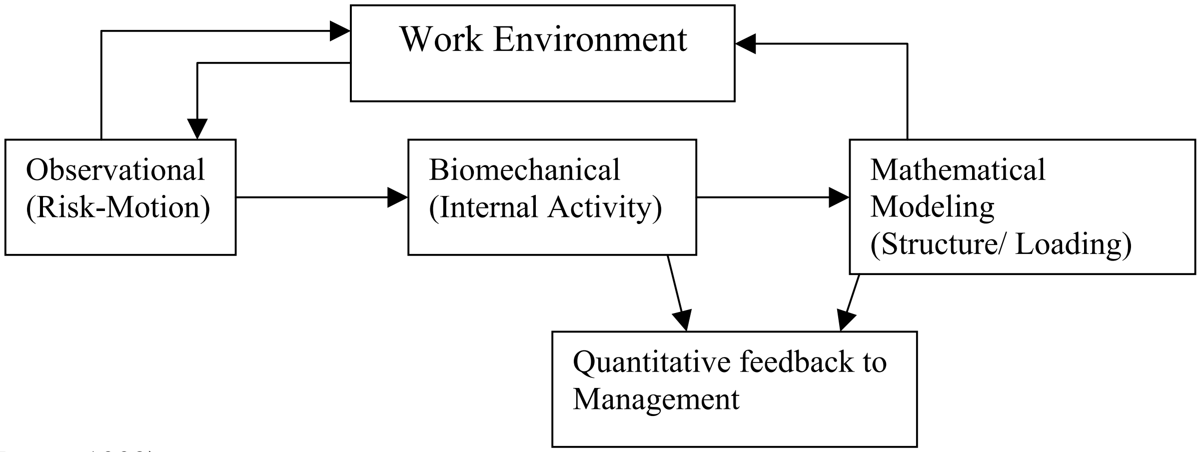
Large muscle groups, which support the spine, give the back its’ range of motion, allowing for extension, flexion, rotation and lateral bending. There are three major groups of muscles of the back that are broken into further subcategories. These three groups are the superficial, the intermediate, and the postvertebral. The postvertebral layers directly support the spine and are made up of to subgroups, the erector spinae and transversesospinalis. These postvertebral muscles are postural muscles that hold the back erect and allow for the varying dynamic movements on a day to day basis. When any of these three major groups muscles are injured, the injured tissue becomes inflamed, causing a dull aching, almost deep boring, pain (Hall, 1991).

The postvertebral muscles support the lumbar region of the back. The lumbar region of the back is located between the sacral region and the thoracic, also known as the torso region of the back. This low back/lumbar region is prone to more injuries because of high degrees of spinal stress. More flexion and rotation occur in this area of the back. These muscles must be strong to control the torso about the pelvis and thus are frequently overworked and injured (Hall, 1991). A recent monograph published by the National Institute for Occupational Safety and Health (NIOSH) summarizes several key findings of the 1994 ASOII: Approximately 530,000 lost work-time cases were associated with manual materials handling activities such as lifting, pushing, pulling, and carrying (NIOSH, 1997). The low back was the most common site of injury associated with materials handling activities; over 60% of these cases involved back pain (Keyserling, 2000). Overexertion from reaching, twisting, pulling, throwing and light lifting significantly contribute to the back's gradual deterioration (Donajkowski, 1993). While a variety of movements can be performed with a healthy back, biomechanical monitoring is one way to identify the amount of stress placed on a person by performing job tasks.

Biomechanical Instrumentation Monitoring

Research efforts involving dynamic activities generally can be divided in three classes: surveillance studies, biomechanical laboratory studies and mathematical modeling (Marras, 1992). Observation of job tasks associated within the work environment provides initial determination if ergonomic risks factor exist. If risk factors are identified, the observations, possibly combined with video observation, can lead to biomechanical monitoring and investigation. Research, into job analysis, is now beginning to not only utilizes observational studies, and biomechanical laboratory studies, but also real-working conditions biomechanical studies in combination with mathematical modeling to determines how the joint of interest is loaded during a dynamic motion (Marras, 1992). Observation, biomechanical investigations along with mathematical modeling provide an understanding of how the body responds to real-world working conditions. They are useful in the work environment by giving management a quantifiable probability of injury of employees actually performing real-world job tasks. The relationship between these efforts and the workplace are shown in the flow diagram in Figure-2.

Figure 2 *The Relationship Between Dynamic Variable Research Efforts and the Workplace*



(Marras, 1992).

Biomechanics is the study of forces acting on and generated within the body and of the effects of these forces on the tissues, fluids, or materials used for diagnosis, treatment, or research purposes (NRC, 1999). This biomechanical linkage can be brought back to the workplace so that ergonomic recommendations can be justified with both statistical as well as biomechanical findings (Marras, 1992). One of the ergonomic areas that can be investigated using biomechanical model is that of back injuries using an instrument called the Lumbar Motion Monitor (LMM). Ergonomic risk factors have lead to back injuries and other musculoskeletal disorders. These injuries and potential for injury have been investigated in a number of epidemiological studies, and have been studied previously using the LMM.

Video Analysis and Goniometry

Posture is an important consideration in the design of work procedures and equipment, portable videotape cameras are often used at the worksite to record the workers movements and posters during a series of job cycles (Armstrong, Caffin & Foulke, 1979). Later the recorded work activity can be analyzed to determine the speed, angle and frequency of worker movement (Armstrong, Caffin & Foulke, 1979). Video analysis allows individual job elements to be identified, broken down into separate tasks and analyzed in slow motion or still frame (Armstrong, Radwin, Hansen & Kennedy, 1986). The time to taken to perform each task can then be measured with a stopwatch without observer interference (employees feelings of "being timed" could be a psychological influence) with tasks being performed (NRC, 2001). A manual goniometer can measure any joint angle or range of motion quickly and accurately. It has a range of 0 to 360 degrees and is accurate to +/- 1 degree (Norkin & White, 1995). The manual goniometer can then be combined with still frame video analysis to identify abduction/adduction risk factors while employees perform job tasks. Observed joint angles can then be compared to identified angles/joint loading risks.

Lumbar Motion Monitor

The Lumbar Motion Monitor (LMM) is a device that is used to capture three - dimensional motion of the lumbar region of the torso (NexGen Ergonomics, 2001). It was designed to help identify, monitor and document the three-dimensional motion components experienced by the spine during performance of industrial manual material handling (MMH) work associated with various risks of low back disorders (LMM, 1994). The LMM is an exoskeleton of the spine that measures the position, velocity, and acceleration of the spine in the sagittal, lateral, and twisting (NexGen Ergonomics, 2001). LMM is an tri-axial lumbar motion monitor which facilitates on-the-job motion assessments and documentation (Marras, 1992). MMH tasks can require workers to lift, bend forward, bend laterally, twist, maintain static postures, carry heavy loads, or perform combinations of these activities (Snook et al., 1978; Andersson, 1981; Kelsey et al., 1984; Marras et al., 1993, 1995). This is why the LMM is one of the great tools for assessing spinal loads and stress while performing MMH tasks as well as predictor of back injury possibly resulting from over loading and stressing the lumbar region of the back.

Workstation Redesign

Anthropometry is the study of weight, height, body mass index (BMI), and obesity used in studies for determining potential risk factors for certain Musculoskeletal Disorders (MSD) (Putz-Anderson, 1988) and is often used in workstation redesign. Redesign of the workstation to fit the workers and redesigning jobs to reduce or eliminate the amount of manual material handling has been recommended by ergonomists to reduce job related back pain. By job function, manual materials handling workers are at the greatest risk of developing back injuries (Frymoyer & Cats-Baril, 1987). Excessive rotation or rapid movements at the low back during manual materials handling (MMH) may significantly increase a worker's risk of developing a LBD (Akron, Putz-Anderson, Barron, 1998). Certain stresses [can be] totally eliminated as a result of minor job changes, such as altering the location of the work or changing a tool (Armstrong, Radwin, Hansen & Kennedy, 1986). Pat McDermott-Caire, president of Ergoworks, Inc., Medford, OR, suggests when a workstation is used by several different shifts [or employees] making workstation adjustable so that the work surfaces can be raised or lowered and equipment and tools moved to different locations (Smith, 1996). In designing workstations for MMH the following should be considered; 1) avoid manual materials movement particularly lifting from the floor or lowering to the floor, 2) reduce weights and forces required to a minimum 3) keep objects close to the body, 4) reduce the distance that the objects must be moved, 5) keep all movements in front of the trunk, 6) move objects horizontally, not vertically (Kroemer, 1980). Marras *et al*. (1993,1995) determined the importance of trunk kinematics in assessing LBD risk. Using a logistic regression model Marras *et al*. found that two workplace factors, external moment and lifting rate and three trunk kinematics factors – maximum sagittal flexion position, average twisting velocity and maximum lateral velocity (1993, 1995). The combination of kinematics information provided by Marras *et al*. and Kroemer's workstation redesign recommendations are based on basic concepts in physics, Newton's first, second and third laws of motion. Newton's first law is known as the *law of inertia* – A body will maintain a state of rest or constant velocity unless acted on by an external force that changes the state (Hall, 1991). Just like it requires muscle to begin the movement of materials, it requires muscles to stop that movement because if Newton's first law. Newton's first law is incorporated into Kroemer's (1980) first, fourth, fifth and sixth workstation redesign recommendations and affects Marras *et al.* (1993, 1995) work factors of external moment and lifting rate. Newton's second law is the *law if acceleration* – A force applied to a body causes an acceleration of that body of a magnitude proportional to the force, in the direction of the force, and inversely proportional to the body's mass (Hall, 1991). Newton's second law is taken into consideration with Kroemer's second and third workstation recommendations. Newton's third law is the *law of motion* – For every action there is an equal and opposite reaction (Hall, 1991). Marras *et al.* observations of LBD risk being related to maximum sagittal flexion position, average twisting velocity and maximum lateral velocity (1993, 1995) is based heavily on Newton's first and third laws. Once the object is in motion and that motion is stopped, there is an equal and opposite reaction by the body's muscles, thus the velocity affects how the muscles are affected by the material handling load (Hall, 1991).

In approaching a job for redesign, performing a job analysis is required. Job analysis consists of two steps: (1) a work-methods analysis, based on traditional techniques of time-and-motion study to determine the work content of the job; and (2) a systematic analysis of risk factors (Armstrong, Radwin, Hansen, and Kennedy, 1986).

Additional indicators that job redesign might be called for include the following:

1) Apparent trends in accidents and injuries

2) Incidents of cumulative trauma disorders

3) Absenteeism, high turnover rate

4) Temporary or seasonal hiring patterns

5) Employee complaints

6) Employee generated changes in the workplace (i.e. tool modification)

7) Incentive pay systems

8) High overtime or increased work rate

9) Poor product quality

10) Manual material handling and repetitive motion tasks
(Putz-Anderson, P., 1988, p.48)

Summary

Ergonomic risk factors are identified through observation of the physical demands, or exposures, of each task performed in a job. One objective and quantifiable method to monitor and identify risk factors is through the use of biomechanical instrumentation monitoring. Video monitoring provides a minimal invasive monitoring method that allows job task time analysis and goniometric measurements to be made. After the higher risk factors in job tasks are identified, biomechanical monitoring provides a 3-D method to measure risks by comparing known anthropometric data, force requirements, joint loading and torque associated with individual job tasks. With an understanding of human anatomy and physiology along with possible physiosocial influences, workstation redesign can take place to reduce workplace injuries, illness and complaints.

Chapter 3

Methodology

Purpose

This purpose of this chapter is to provide the reasoning behind why and how this study was performed. Items to be considered are the literature review, research design, instrumentation, and population vs. sample.

The purpose of the study was to identify and measure significant ergonomic risk factors associated with the workstation design of Galaxie Library's bookdrop. The library information assistants at Galaxie Library have experienced back pain, specifically lower back pain, associated with the collection of materials from the bookdrop. While none of the Galaxie Library employees has filed worker compensation claims for these ailments, human loss is occurring through their pain and suffering. To decrease the potential for injury, the bookdrop area was selected to undergo an ergonomic analysis.

Objectives

1. Identify the potential ergonomic risk factors associated with Galaxie Library's bookdrop materials return task.
2. Measure and analyze the identified predominate ergonomic risk factor(s).
3. Perform post implementation analysis to measure and evaluate the effectiveness of proposed solution(s) for the bookdrop workstation design.

Research Design

The design of this study is based upon studies performed by Marras, Lavender, Leurgans *et al*, 1995 and Armstrong, Radwin, Hansen, and Kennedy, 1986. The basic premises were:

- Performed initial observation and video analysis of workstation / employee interaction
- Determined risk factors associated with task
- Selected worst (or most probable to cause greatest injury or loss) risk factor(s) using goniometric measurements
- Selected ergonomic instrumentation to measure risk factor (in this case lumbar motion monitor)
- Performed on-the-job lumbar motion assessment and documentation
- Analyzed collected data for probability of injury
- Performed analysis on a post-implementation setting similar to integration of new workstation design.

Instrumentation

The identified observed risk factors were lumbar motion, shoulder abduction/ adduction and forces exerted on the knees and ankles. NIOSH (1997) concluded that there was evidence for a relationship between repeated or sustained shoulder postures, with greater than 60 degrees of flexion or abduction, and shoulder musculoskeletal disorders of shoulder tendinitis and non-specific shoulder pain. To narrow the study, the more predominant risk factor of lumbar motion was analyzed using ergonomic instrumentation. The instrumentation used was a Lumbar Motion Monitor (LMM). The LMM allowed for a three dimensional study of lumbar motion, sagittal, side bending and rotational forces (Marras, 1992). The LMM required the weight of the material moved as well as number of repetitions per hour to be entered into the computer program prior to a trial being performed. Video analysis, using a Sony Video Camera, allowed for an average measurement of times per hour that each separated task was performed. A Wagner FDL Force dial was selected to measure, in pounds, the average weight of the materials transferred from the floor to the cart. When the necessary data was entered, which included workstation description and task description, a trial may be performed. Analysis was only performed on two of four on duty library information assistants at Galaxie Library, where the bookdrop area is located. This method of library assistant random selection ascertained, the data collected was applicable to the needs of this study and that of Galaxie Library located in Apple Valley, MN.

Population vs. Sample

The population to be analyzed is that of Galaxie Library's Information Assistants during the time frame of January through June 1999. There are eight library information assistants at Galaxie Library, Apple Valley, MN, four on duty at a time. The library information assistants are the persons who perform the materials return task from the bookdrop area. In order to sample the lumbar motions involved in the book return process, two of the library information assistants were randomly selected to participate in lumbar motion assessment after signing an informed consent form. The two information assistants were selected by who was assigned to the book return area on the date the analysis was performed. The date of the analysis was decided upon by when the researcher and Galaxie Library's manager were able to meet. The Galaxie Library manager does not make out, or assign, which information assistants perform the book return tasks. The next chapter will discuss the results of the study performed.

Data Presentations

The results of the study will be reported in separated components: The tasks will be broken down. The results presented in tabular format. The lumbar motion monitor allows data to be presented on lumbar motion velocity, sagittal flexion and side bending along with the ability to compare the monitored tasks to LMM's database of benchmarks associated with high incidence of low-back disorders. High incidences, or likelihood of injury, are presented as percent probability of injury.

Chapter 4

Results

Purpose

This purpose of this chapter is to provide the reasoning behind why and how this study was performed. Items to be considered are the literature review, research design, instrumentation, and population vs. sample.

The purpose of the study was to identify and measure significant ergonomic risk factors associated with the workstation design of Galaxie Library's bookdrop.

Objectives

1. Identify the potential ergonomic risk factors associated with Galaxie Library's bookdrop materials return task.
2. Measure and analyze the identified predominate ergonomic risk factor(s).
3. Perform post implementation analysis to measure and evaluate the effectiveness of proposed solution(s) for the bookdrop workstation design.

Video Analysis and Goniometric Measurements

Video observation of the book return process was utilized to correctly ascertain the book collection process. During the book return process, the books are dropped into a chute 40" from the ground. The books exit the shoot 13" from ground and spread out in a large pile on the floor. The library information assistants are then required to gathered these books, video and audio tapes from the floor and place them on a two-shelved, double-sided cart (see Figure 3).

Figure 3 *Materials Gathering Cart*

The desk workers either kneel on the floor (using a generic 3/4" knee pad), reaching far in front of them to gather materials, or use a stool (Zag 18" X 15" X 8"), which requires them to reach down and out in front of themselves. After putting materials into piles, the library information assistant picks up the pile, twists and puts the books on the cart. When all of the materials are gathered from the floor the cart is wheeled back to the check-in room, where they are sorted by categories. Depending on the amount of books returned, the gathering of materials takes approximately ten to fifteen minutes. The books are gathered once an hour, with the library being open ten and half -hours a day.

The greatest ergonomic risk factor observed was the back position required to gather the materials off of the floor. While other risk factors were observed during the initial analysis, (possible injuries to the rotator cuff due to shoulder abduction/ adduction see Table 3 and possible injury to ankles and knees due to kneeling on the floor) these risk factors were not chosen to undergo further analysis in this study.

Table 2 *Manual Goniometric measurements of tasks performed*

Task	*Observation*			
	Participant Alpha (63" ht.)		Participant Beta (68" ht.)	
	Angle of Shoulder Anterior Motion	Angle of Hip Flexion	Angle of Shoulder Anterior Motion	Angle of Hip Flexion
Kneeling while gathering books from floor	80°	130°	N/A[1]	N/A
Keeling and lifting books, placing on cart directly in front of library assistant	75°	125°	N/A	N/A
Kneeling and lifting of books, placing on cart to side of library assistant [2]	85°	125°	N/A	N/A
Sitting while gathering books from floor	43°	95°	48°	97°
Sitting and lifting books, placing on cart directly in front of library assistant	43°	115°	78°	120°
Sitting and lifting books, placing on cart to side of library assistant	45°	125°	59°	115°
Reaching overhead to return books to shelves	140°	3°	98°	5°

Footnote

1 Participant Beta indicated they never knelt to perform book return process

2 Both participants exhibited approximately 30° to 90° of shoulder abduction while returning books to a cart located to the side, depending on shelf height

Bioinstrumentation Monitoring (LMM)

To evaluate and monitor the information assistant's lumbar position, while gathering materials, a Lumbar Motion Monitor (LMM)(Chattanooga Group, INC., serial number 1035, calibrated March 9, 1999) was utilized. The LMM was attached to two randomly selected library information assistant's backs as seen in figure 4. The LMM allowed for a three dimensional analysis of lumbar and trunk rotational movements and the determination of LBD risks associated with combined changes in the motion.

Figure 4 *Demonstration of How LMM is Worn*

(NexGen Ergonomics, 2001)

The video observation identified gathering of materials for book return process as the first process, the participants were asked to repeat this procedure. Due to the limitations of the LMM, monitoring required breaking the task into two separate tasks. First, the desk workers were asked to gather the books into piles. The weight of each of the piles of materials needed to be entered into the computer to determine joint loading. Books, audio and videotapes were the types of materials being gathered from the floor. A Wagner FDL Force dial was selected to measure, in pounds, the average weight of the materials transferred from the floor to the cart. LMM monitoring was performed during this phase.

Table 3 *Weight of Materials gathered from floor to be placed on cart*

	Participant Alpha	*Participant Beta*
1.	6.7	9.8
2.	7.3	6.7
3.	8.3	9.0
4.	7.8	9.2
5.	7.0	9.6
6.	7.4	11.0
7.	6.3	9.4
Ave. Wt. of materials	7.25	9.25

As a second task the video observation identified the employees picked up the pile and placed it on the cart, sometimes located directly in front of them or sometimes located to the side of the employee. LMM monitoring was also performed during this activity. Average postural-related data for the back movements, during initial workstation design, was compared with a database of characteristics contributing to risk of back injury. This comparison gives a probability of injury readout.

Table 4 *Current Workstation Design Probability of Lumbar Injury*

Task	*Participant Alpha (63" ht.)*	*Participant Beta (68" ht.)*
Kneeling while gathering books from floor	27%	N/A[1]
Keeling and lifting books, placing on cart directly in front of library assistant	28%	N/A
Kneeling and lifting of books, placing on cart to side of library assistant [2]	42%	N/A
Sitting while gathering books from floor	48%	60%
Sitting and lifting books, placing on cart directly in front of library assistant	28%	24%
Sitting and lifting books, placing on cart to side of library assistant	40%	58%

1 Participant Beta indicated they never knelt to perform book return process

For the task of gathering books for both sitting or kneeling (performed by Test Participant Alpha) neither side bending or rotational motion significantly contributed toward potential injury, but sagittal flexion (bending forward from the hips) was found to contribute a 90% probability of injury while performing this task. An overall potential for injury equal to 29% while sitting and 27% potential for injury while kneeling was found.

For the task of gathering books while sitting (performed by Test Participant Beta) neither side bending or rotational motion significantly contributed toward potential injury, but sagittal flexion was found to contribute a 90% probability of injury while performing this task. An overall potential for injury equal to 27% was found if test participant performed this task sitting. NOTE: Test Participant Beta prefers not to perform this task while kneeling.

For the task of gathering books while kneeling (performed by Test Participant Beta) it was found that sagittal flexion and side bending contributed to a 90% each, respectively, to the probability of injury, with an overall probability of injury score of 60%. NOTE: The observable difference between the participants performance of this task was that Beta stretched and reached further, by kneeling, for books located on the floor than Alpha did while sitting on the stool or floor.

For the task of picking up books both test participants Alpha and Beta had an increased risk of injury. This increased risk again was contributed by sagittal flexion (90%) with too much forward bending increasing their potential of injury (Range = 24-27%).

For the task of picking up books (and placing them on a cart located to the left side, thereby requiring rotational trunk motion = w/ torque) both participants experienced markedly increased potential for injury. The probability of injury ranged from 40-58%. Both participants had increases in average rotational, sagittal and side bending moments, thereby increasing their risk of injury.

Workstation Redesign

In addition, recorded back movements of the initial workstation design can be compared to readings from the average postural-related data of a new workstation design. Comparing new workstation to the old design allows for an objective view as to whether an improvement has been made in the station design. The new workstation design was simulated to match the height of bottom spring loaded cart (the type of carts that bring materials up to working height, as the cart is unloaded). This post analysis was performed to compare present workstation design to that of the proposed design. While examining the probable new workstation design, it was found that the job of gathering the books from the floor would be eliminated all together. The books would no longer be located on the floor, but rather in spring loaded carts that could be easily wheeled to the check-in area.

Table 5 *Workstation Redesign Probability of Lumber Injury*

Task	*Participant A (63" ht.)*	*Participant B (68" ht.)*
Placing item from proposed design ht. to shelves with no rotation	9%	8%
Placing item from proposed design ht. to shelves **with rotation**	31%	24%

The proposed redesigned workstation design was compared against the present workstation to determine the difference in probability of injury and find if notable improvements were made. The following is a list of results:

For the first task of gathering the books from the cart and placing them directly on a shelf in front of the cart, the potential for injury was found to be only 9%. For the second task of standing beside the cart, gathering the books and placing them on the shelf located to the test participant's left (requiring the participant to rotate/torque the back in order place the books on the shelf) the potential for injury was found to be 31%. This is a definite decrease in back sprain / strain potential of injury from the task of picking up the books from the floor, twisting and putting them on the cart (Range of 40-58% probability of injury).

For comparing the proposed workstation design to the present workstation design, there was a 69% decrease in sagittal motion. A 60% decrease in the velocity of the movement. There was also a 69% decrease in acceleration / deceleration rate. This decrease in velocity might have been a concern indicating that the employee might be decreasing his or her work rate. The velocity here is referring to how fast the back motion is made. It was found that not only did participant place the books on the shelf at a faster rate (60 vs. 50 repetitions per hour), they had more pounds of books (9.16 vs. 7.25 lbs.) in their hands as they placed the books on the shelf. The 69% decrease in acceleration / deceleration rate will most probably decrease the forces acting upon the muscles and ligaments associated with the spine, thereby decreasing the potential for injury.

Chapter 5

Conclusions & Discussion

Purpose

This purpose of this chapter is to provide the reasoning behind why and how this study was performed. Items to be considered are the literature review, research design, instrumentation, and population vs. sample.

The purpose of the study was to identify and measure significant ergonomic risk factors associated with the workstation design of Galaxie Library's bookdrop.

Conclusions

Initial observation and video analysis of workstation and employee interaction determined risk factors associated with library assistant job tasks were;

1) the extended back positions required to gather the materials off of the floor;
2) the possible injuries to the rotator cuff due to shoulder abduction/ adduction and;
3) and possible injury to ankles and knees due to kneeling on the floor.

The most prominent risk factor that could cause greatest injury and/or loss, and a direct issue with employees, was back pain while performing the book return process. A Lumbar Motion Monitor was selected to measure and analyze probability of injury due to current and proposed workstation designs. Collected data for probability of injury was a 69% decrease in sagittal motion and a 60% decrease in the velocity of the movement. There was also a 69% decrease in acceleration / deceleration rate. Utilizing the proposed workstation design, incorporating a conveyor type system with spring loaded carts and placing materials on a shelf in front of the cart, the potential for injury was decreased from an average of 90% down to 9%.

Recommendations

Study results combined with a literature review indicated that workstation redesign, an evaluated conveyor type system with spring loaded carts (or other non-manually bottom lifting cart), would decrease the amount of lumbar motion. It would also decrease the velocity of the back's motion and the rate of acceleration/deceleration. The lumbar motion monitor results indicate significant potential for injury with present workstation design.

The task of gathering the books and placing them on the cart took on average 10 to 15 minutes (every hour), depending on the amount of materials returned. If the new workstation was implemented this task would be eliminated, freeing up the library information assistant's time to perform other job functions. Eliminating this task would save the library $6,300.00 a year. This is a low estimate based on only 10 minutes (0.1666 of an hour) to perform the task as figured below. The average, full-time library information assistant made $20,000 a year, roughly $10.00 an hour.

$10.00 / hr.
<u>x 0.16 of an hour saved</u>
$1.66 / hr saved in labor
<u>x 10.5 hrs / day</u>
$17.50 / day saved in labor
<u>x 30 days / month</u>
$525.00 / month saved in labor
<u>x 12 months / year</u>
$6,300.00 a year saved in labor

There are a few concerns that should be addressed when considering the type of conveyor system to be installed:

1) The capacity of the bins vs. the number of times emptied per day (or even when closed on holidays).
2) Bins must be wheeled through a public area, thus the proper appearance & ease of mobility of these devices must be considered. Wheels should be serviced regularly to decrease wear on carpet and limit "squeaking" tires. The mechanical lift inside the bins must be properly maintained, this will limit employees needing to bend into bin to retrieve materials.
3) A protective shield with heat sensing device should be considered to protect against vandalism (i.e. Cherry bombs). The time materials remain in the shielding area should be long enough to prevent damage to the collection room. Emergency procedures should be evaluated (and put into place) for heat sensing alarm. Biohazard cleanup kits should be available if vandalism does occur

An ergonomic program will allow worker participation in identifying tasks/procedures that could cause musculoskeletal injury (Bioswick & Golias, 1996). Following this advice an additional recommendation based on employee video observation, is implementation of employee safety education program. Test participant Beta noted he never knelt while performing the materials gathering task. Video analysis showed greater reach and greater angles of abduction for test participant Alpha. An educational safety program would allow top level management to communicate with employees the increased risks associated with certain lifting and manual material handling tasks. This education program would also be a two way street. It should allow employees to identify other areas of safety concerns, besides just back safety and manual material handling. Employees were the ones who brought it to the researcher's attention about the cherry bomb incidents at other Dakota County Libraries.

Errors

Time constraints prevented a larger sample of library assistants from being monitored with the LMM. Greater sample size would provide for greater statistical reliability and interpretation.

Further Research

Jobs that require the worker to habitually reach and work with the arms above the shoulder level are not only fatiguing, but have been associated with a range of disorders such as shoulder tendinitis or thoracic outlet syndrome (Neviaser, 1983). Further research should be performed regarding lowering the top shelf height of where books are re-shelved.

One of the greatest limitations of this study was the small sample size thus the statistical “ n-power” was low. Had the sample size been larger, other statistically significant differences between the current and proposed workstation designs may have appeared. Future studies should focus on using larger populations of library workers to determine if significant improvement in discomfort and awkward postures occur while using the ergonomically designed workstation. Similar studies should be conducted to determine if further equipment re-design is necessary. The use of EMG data, particularly in a controlled laboratory setting, might add greater depth to this type of study. Future studies are needed to identify the impact that better workstation redesign has on productivity, error rates and job satisfaction of librarians.

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