HETA 93-0920-2548
December 1995
Kroger Grocery Warehouse
Nashville, Tennessee

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SUMMARY

On July 8, 1993, representatives from the National Institute for Occupational Safety and Health (NIOSH) undertook the first of three trips to a Kroger grocery warehouse in Nashville, Tennessee, in response to a confidential request for a health hazard evaluation. The request was prompted by employee concerns about the potential hazards of repetitive lifting and excessive work pace associated with a recent change in the performance standards for the job of grocery 'order assembler.' There were three objectives of this evaluation:

(1) Determine the prevalence and incidence of work-related musculoskeletal disorders (WMDs) associated with manual lifting activities of the grocery warehouse order assemblers.

(2) Document the presence of potential lifting hazards in the grocery warehouse.

(3) Develop recommendations for reducing the risk of injury associated with identified lifting hazards.

During two separate visits over a six month interval, the NIOSH team collected information at the Kroger work site to assess the extent and magnitude of the reported health hazards. During this and subsequent visits, we administered a questionnaire to the workers that included items designed to assess the workers' perceptions of physical workload and symptoms of musculoskeletal disorders. Bureau of Labor Statistics Log of Occupational Injury and Illnesses (OSHA 200 Logs) were reviewed to determine the extent of the recorded injuries and lost time. Ergonomic analyses were conducted on the following dates:

(1) On July 8, 1993, we conducted a preliminary analysis to determine variations in load weights and the types of stressful lifting postures that pose a risk to the worker.
(2) On October 14, 1993, we administered a questionnaire to all of the grocery assemblers working on that day and also collected videotape of assemblers completing several sample orders.
(3) On February 7 & 8, 1994, we returned and conducted a second-level of analysis on over 200 individual lifts. In addition to measuring load weights and postures, we used a lumbar motion monitor to measure trunk rotations. We also examined the effects of lifting frequency and work duration as they affected oxygen use and heart rate.

The results of our evaluation of the injury logs confirmed that back injuries among assemblers was the most important cause of lost workdays in the warehouse. According to the logs for the four-year period from 1989-1992, there was an average of 25 recordable back injuries per year.

A questionnaire was completed by 77% of the currently employed grocery assemblers, which represented 97% of assemblers working on the day of the survey. The work force was more than 95% male, and, on average, was younger, taller, and heavier than the majority of workers in the U.S. work force. More than 47% of the full time assemblers reported on the questionnaire significant physical discomfort in the region of the low back and 47% reported having a back injury during the previous year.

Based on a series of biomechanical and metabolic measurements of workers, NIOSH investigators were able to identify and quantify stressful work postures, motions, and levels of physical exertion that pose a significant risk of back injury. **According to recognized criteria defining worker capability and accompanying risk of low back injury, the job of order assembler at this work site will place even a highly selected work force at substantial risk of developing low back injuries. Our conclusion is based on the following findings from our work site analysis. Specifically, workers are required to:**

(1) Lift loads that exceed recognized weight limits,
(2) Lift loads that exceed recognized lifting rates,
(3) Lift loads from stock locations that are either too low (near the floor), too high, or too great a horizontal distance from the spine resulting in excessive biomechanical strain,
(4) Lift loads for work periods that sometimes exceed an 8-hr day, resulting in energy demands that exceed recognized capacities for a majority of workers.

The objective of the present investigation was to determine if the job of order assembler posed a substantive risk for development of musculoskeletal disorders, with particular reference to low back pain. The rate of OSHA 200 entries as well as workers' compensation claims for low back pain were elevated for order assemblers despite the highly selected nature of this work force.

Biomechanical and metabolic job analyses were performed to identify and quantify stressful work postures, heavy loads, and high frequency lifting motions. The order assemblers at the grocery warehouse lift loads that are too heavy at excessive lifting rates from stock locations that are either too low, too high, or too far away from the body for work periods that can exceed an 8-hr day. According to recognized criteria defining worker capability and accompanying risk of low back injury, the job of order assembler poses a substantial risk of low back injury for workers at this worksite. Recommendations for reducing lifting hazards are provided in Section VIII which include changes in work organization and methods.

Keywords: SIC 5411 (Grocery Stores, Warehouse), repetitive lifting, lumbo-sacral stress, back injury, ergonomics, biomechanical, physiologic, production standards, muscle fatigue.

INTRODUCTION

On July 8, 1993, representatives from the National Institute for Occupational Safety and Health (NIOSH) visited the Kroger Grocery Warehouse in Nashville, Tennessee, in response to a confidential employee request for a health hazard evaluation. The request was prompted by employee concerns about the potential hazards of repetitive lifting, and excessive work pace associated with a recent change in the performance standard associated with the job of "order assembler." During the initial meeting, NIOSH staff talked with the employer and worker representatives and discussed the objectives of the investigation and the level of effort required. The objectives of this investigation included:

(1) Determining the prevalence and incidence of work-related musculoskeletal disorders (WMDs) associated with manual lifting activities of workers in the nonperishable grocery warehouse who perform the job of "order assembler."

(2) Documenting the presence of potential occupational hazards in the warehouse, including ergonomic issues related to repetitive lifting.

(3) Developing recommendations for preventing or reducing the physical stresses associated with repetitive lifting.

BACKGROUND

A. Plant and Job Description

Kroger is a retail grocery food supplier with warehouses located in Nashville, Tennessee. Although the warehousing operation includes several buildings, this investigation was limited to the warehouse containing nonperishable grocery items.

1. Work force

The entire warehouse operation employees slightly over 200 hourly workers. The warehouse is divided into buildings that contain perishable and non-perishable items. The non-perishable grocery warehouse employees approximately 42 workers who move the cases from the shelves to pallets and who are referred to as "order assemblers." The order assemblers all work on the day shift and for at least a full 40 hours per week, although they frequently work an additional 5 to 10 hours of overtime per week.

2. Job Activity

The job of an order assembler involves selecting cases of grocery items from supply pallets and loading the cases on an electrically-driven pallet jack. The selection or "picking order" is dictated by a computer-generated list that contains the items and quantities of groceries to be picked, the order for picking these items, and their locations (aisle and slot numbers). The cases of grocery items are stored on wooden supply pallets located on either side of the aisle, and may include a one or two item pick (two grocery items stored in the same slot at different heights). The total weight of the order and the total number of items per order may vary considerably.

3. Job Cycle

A job sequence for the order assembler, hereafter referred to as a job cycle, typically involves the following steps: (1) Walking or riding on an electric jack to the dispatcher window to receive a picking order for grocery selection; (2) driving to the empty pallet stacks and lifting or sliding two empty pallets onto the fork lift; (3) driving to the slot on the first picking label, walking to the grocery item to be picked, lifting the case from the slot, carrying it to the pallet jack, and lowering or lifting it on the pallet jack to build the load on the pallet jack; and finally, (4) peeling the label from the order and applying it to the case (item picked). This work sequence is continued until the entire order is picked. When the order is completed, the assembler wraps the order in plastic wrap and then drives to the loading dock area and places the loaded pallets into the appropriate truck for shipping. The order assembler returns to the dispatcher office with the end sticker, receives his performance rating, and is given another order. This work sequence continues throughout the course of the workday.

4. Performance Standard

The company had recently begun phasing in a performance evaluation standard developed by an industrial engineering consulting firm. Time standards for performance were set based on “Master Standard Data” (MSD), a procedure which analyzes the basic motions required to perform a task and assigns to each motion a predetermined time standard. The MSD approach is a simplified approach to the “Methods Time Measurement” (MTM) system that was developed in 1940. The standard is set based on the number and location of items to be picked during the order assembly operation. The goal of the performance standard was to establish a "fair amount of time" to complete a trip. A trip was defined as "the selection and filling of a 2-pallet cube." Each motorized jack could carry two pallets. During the phase in period, workers were required to achieve 85% of the standard, with the eventual goal of 100%. At the time of the study, there was no incentive pay for working above the standard, but workers would be disciplined if they did not meet the standard.

Prior to implementation of the MSD-based performance standard, a worker's performance was judged to be acceptable if they met a lifting rate equal to their "qualification rate." The qualification rate was based on the number of cases handled per hour and was determined according to the labor agreement in effect at the time they were hired.

Garg (1986b) previously reported that physiological limits were typically exceeded when performance standards based on motion-time-methods were used to set the work pace for grocery assemblers. In addition, Garg et al., 1986, found that performance standards force workers to maintain high lifting rates that result in excessive heart rates and oxygen consumption that may result in increased incidences of injury and illnesses.

B. Incidence and Costs

The job of order assembler has been previously identified as physically demanding, primarily because of the frequent and heavy manual lifting demands associated with these jobs (Garg et al., 1983; Garg, 1986a and 1986b; and, NIOSH, 1993). One of the most frequent complaints associated with heavy manual lifting is back pain. As an occupation, "stock handlers" have an annual estimated prevalence of back pain caused by "activities at work" of 17.8%. More specifically, for males working in the wholesale grocery industry, the estimated annual prevalence of back pain caused by "activities at work" is 16.4%. This industry is one of the 15 industries with the highest prevalence of work-related back pain (Guo et al., 1993).

One study has shown that warehousemen averaged nearly 10 claims for workers' compensation per 100 workers during a given year (Klein et al., 1984). Moreover, others have shown that the majority of the back claims identify manual lifting as the primary cause (Bigos et al., 1986; Snook et al., 1978). Unlike many occupational diseases, these disorders do not wait until the worker is older to appear, but occur most frequently in otherwise young and healthy workers. The average age of workers filing compensation claims is 34 years. Costs per case in 1986 averaged over $6,800. In today's economy, the average cost can easily exceed $10,000 per case (Webster and Snook, 1990).

Workers' compensation data, supplied by the National American Wholesale Grocers' Association and the International Foodservice Distributors Association for the years 1990 to 1992, revealed that back sprains/strains accounted for 30% of all injuries for warehouse workers (NAWGA and IFDA, 1992). Data from the same report indicated that more than a third of all workers (34.6%) experience an annual injury in warehouse operations, accounting for an hourly cost of $0.61 per worker-hour. Moreover, manual lifting is identified as the cause of the back injury in 54% of the cases, followed by "push and pull" as a cause in only 15% of the cases. A previous study by NIOSH found that in another grocery warehouse there was a 16% rate of back-related workers compensation cases (NIOSH 1993). In summary, it is evident that grocery warehouse workers face a substantial risk of lifting-related low back disorders that include low back pain, overexertion, and strains and sprains.

EVALUATION DESIGN AND METHODS

A. Medical Evaluation Methods

1. OSHA 200 Logs

The Bureau of Labor Statistics Log of Occupational Injuries and Illnesses (OSHA 200 logs) were obtained from the company for the period 1989-1992. These logs are the official report of occupational injuries and illnesses and are required by the Occupational Safety and Health Administration. Information from the logs was reviewed and rates of injuries and numbers of lost workdays were calculated for grocery assemblers. The company also provided summary data on rates of recordable injuries and illness for the entire warehouse work force.

2. Questionnaire

On October 14, 1993, a questionnaire was distributed to all grocery assemblers who were at work that day and was completed in a single group during work hours. This questionnaire (Appendix A) included items that asked workers about the perceived physical workload of their job, symptoms of pain associated with musculoskeletal injuries, and whether they had experienced an injury during the previous year. Questions were also included concerning the overall workload and the workers' perceived control over their workload. A more complete description of these indicators is provided below:

<u>Assessment of Perceived Physical Workload</u>

The Borg scale was used to illicit an overall assessment of the perceived physical workload of the assemblers' job. This scale consists of a 15-point numerical list, anchored by adjectives describing increasing levels of physical effort (Question 13, Appendix A). The Borg scale was initially developed through laboratory experiments using exercise bicycles and has subsequently been used at the worksite to assess the perceived physical effort of persons performing manual tasks. Studies have shown a good correlation between perceived workload and objective measures of physiologic workload such as heart rate (Borg 1982, Borg 1990).

Assessment of Reported Discomfort

Several investigations have used questionnaires to determine the prevalence of musculoskeletal disorders among working populations. A particularly descriptive method for determining the location and severity of complaints is the Corlett-Bishop (1976) body parts map diagram (Question 14, Appendix A). A number of studies have documented the relationships between complaints of discomfort and inadequate ergonomic work conditions. These questionnaires are useful in identifying which parts of the body are under the greatest stress. (Kuorinka et al. 1987, Silverstein et al. 1986, Viikari-Juntura 1983). For this study, a worker was considered to have significant discomfort if he reported pain that was "very or extremely uncomfortable," the top half of a 4-point scale, in one of the areas of the body shown in Appendix A, question 14.

Assessment of Injuries and Missed Workdays

Workers were asked about injuries at work and lost workdays due to those injuries. Although these cases probably represent the more severe problems, they provide another indicator of the magnitude of the problem.

Employees Perception of Job Demands and Job Control

A series of questions was included to determine assemblers' perception of their job demands and control (Questions 15 and 16, Appendix A). These questions were chosen based upon a decision latitude model of job stress. This model suggests that a combination of high-job demands and low-job control will produce high job strain and could lead to problems such as stress and job dissatisfaction (Landsbergis, 1988).

Questionnaires containing similar questions have been administered to thousands of workers employed in a variety of occupations, thus allowing a comparison of this job to a range of other occupations (Hurrell and Linstrom, 1992).

Control: Control was measured using a scale factor analytically derived (McLaney and Hurrell, 1988) from work originally conducted by Greenberger (1981). This seven item scale (Question 16, Appendix A) measures task related control and includes items assessing individual control over the variety, order, amount, pace, and quality of work performed. The scale has been shown to be highly internally consistent (McLaney and Hurrell, 1988)

Quantitative Workload: This four item scale (originally developed by Caplan et al., 1975) contains items which assess the quantity of work required of the job incumbent (Question 15, Appendix A). The scale has also been shown to have high internal consistency (Caplan et al., 1975).

B. Ergonomic Assessment

1. Risk Factor Identification

To assess the musculoskeletal stresses associated with repetitive manual lifting among order assemblers in the Kroger grocery warehouse, the NIOSH team collected information on the following factors, each of which is a recognized risk factor for overexertion and low back pain:

(1) Load or weight of the objects to be lifted (Chaffin and Ayoub, 1975);

(2) Posture of the worker in reference to the position of the load to be lifted (Chaffin et al., 1977);

(3) Dynamics of the lifting motion that affect spinal forces, i.e., dynamic trunk rotations (Marras et al., 1993); and

(4) Frequency and duration of manual lifting activities, i.e., the temporal pattern of manual lifting, including work-rest cycles (Chaffin et al., 1977).

A main advantage of organizing our data collection by risk factor is to ensure that the (1) appropriate information is collected, and (2) the information that is collected can be readily evaluated against known criteria to determine what constitutes low-risk or high-risk jobs for a majority of healthy workers.

2. Established Criteria

Three sets of criteria are commonly used to evaluate the potential risk associated with manual lifting tasks: biomechanical, psychophysical, and physiological (NIOSH 1981). Biomechanical criteria limit the mechanical stress on the musculoskeletal system resulting from lifting, while metabolic criteria limit the physiological stress imposed by the workload of the lifting job. Psychophysical criteria provide limits based on an integration of the biomechanical and physiological stress as perceived by workers. Researchers have developed assessment models which utilize these criteria to estimate the likelihood that a particular lifting job poses a significant risk of a work-related low back injury (Waters et al., 1993, Marras et al., 1993). Two of these models were used in this study: The Revised NIOSH Lifting Equation (NLE) and Marras' Lumbar Motion Model. Physiological data were also collected and compared to acceptable metabolic limits published in the literature.

3. Revised NIOSH Lifting Equation

The Revised NIOSH Lifting Equation, which is described in Appendix B, is a tool for assessing the physical demands of two-handed manual lifting tasks. Input data include measurements of the location of the load relative to the worker, the lifting frequency, duration, and other task-related factors. The principal results from the NLE are the Recommended Weight Limit (RWL) and the Lifting Index (LI). The RWL is that amount of weight that nearly all healthy workers should be able to lift safely for a specified lift. The LI, which is defined as the ratio of actual weight lifted to the recommended weight limit (i.e., LI=L/RWL), provides an index of the level of physical stress for a job. As the LI increases, the level of physical stress increases and the risk of injury increases. According to the NLE developers, it is likely that lifting tasks with a Lifting Index > 1.0 pose an increased risk for lifting-related low back pain for some fraction of the work force and that many workers will be at elevated risk if the Lifting Index exceeds 3.0 (Waters, et al., 1993).

Procedure: Four experienced male grocery assemblers were chosen to participate in this phase of the investigation. The four workers, referred subsequently to as participants, were healthy and conditioned for work. Participants were informed of the investigative procedures before data collection began.

For this analysis, load weights and body postures were systematically recorded and a videotape recording was made for ten representative lifting tasks that were judged by both the workers and investigators as having a high potential for injury. These ten lifts were subsequently analyzed with the Revised NIOSH Lifting Equation (NLE). Participant 1 performed Tasks 1-3, Participant 2 performed Tasks 4-6, Participant 3 performed Tasks 7-9, and Participant 4 performed Task 10. Each participant was instructed to perform the lifts using the same technique he would use when actually assembling a grocery order.

By examining a sample of the potentially most hazardous jobs with the NLE, the maximum severity of the lifting hazards can be estimated.

4. Trunk Motion Measures

The purpose of the trunk motion evaluation was to further define the level and extent of the biomechanical hazards associated with the job of order assembler. Because the lifting jobs at the worksite were repetitive and paced through an incentive system, a second-level analysis was designed to focus on the **dynamic properties** of manual lifting to determine the probability that the lifting tasks posed a significant risk for low back injury. To accomplish this, we used a commercial Chattanooga Corporation Lumbar Motion Monitor™ (LMM) that was worn by the worker (Marras et al. 1993). The LMM is capable of measuring the asymmetrical pattern of tri-axial spinal motion (rotation) around the L5/S1 intervertebral joint that occurs as a lift is performed.

Procedures: Four experienced male grocery assemblers (same as for the NLE procedure) were randomly chosen to participate in this phase of the investigation. Each participant was informed of the procedures before we began the data collection.

Each of the four participants was fitted with the LMM and monitored for one complete trip (two full pallets). For each lift and lowering motion recorded with the LMM, the vertical height at the origin and destination of the lift was determined. Based on these vertical height measurements, each lift was categorized into one of three types, either low, medium, or high (L, M, or H), with low defined as below 30 inches, medium defined as between 30 and 50 inches, and high defined as above 50 inches. Each participant was also video-taped as they performed the order selection. The videotape was used as an independent verification of which grocery items were selected and how they were lifted. To ensure an adequate sample of lifts and lower motions for each of the three vertical height categories, more than 170 individual lifts were evaluated.

5. Metabolic Measures

To characterize the metabolic risk factors during the third and final assessment visit, the NIOSH team measured heart rates and oxygen consumption during lifting to assess the energy demands of order selection. Oxygen consumption measurement provides a relatively objective assessment of the energy demands posed by the work load of the job, whereas heart rate monitoring is an indirect procedure for assessing metabolic load, inherently less accurate, but somewhat easier to use.

Procedure: Three male grocery assemblers were randomly chosen for this phase of the investigation. (For this phase of the investigation, different individuals participated.) All participants were informed of the procedures before the data were collected.

For our testing trials, a management representative selected the grocery orders for each assembler-participant. The order was judged to be of average size and difficulty. Each participant was fitted with an Oxylog portable oxygen consumption meter (Morgan Instruments, Inc.) and a Polar portable heart rate monitor (Polar USA Inc.) (Ballal and Macdonald 1982). Heart rate data were collected from a combination electrode-transmitter band that was worn on the chest and a watch-like receiver that was worn on the wrist. The receiver was able to store more than 8-hours of heart rate data for subsequent down-loading into a computer for analyses. The oxygen consumption values were automatically stored in a data logger attached to the oxygen consumption meter and later downloaded to a computer. Oxygen consumption and heart rate were allowed to stabilize for approximately five-to-ten minutes before the grocery order was selected. Each of the three participants were instructed to work as they normally would and to maintain a work pace approximately equivalent to 100% of the existing performance standard.

To assist in the metabolic analysis, a printout of the order showing the items to be selected, was provided by management. The printout listed the total number of items to be selected, as well as the weight and volume (size) of each item.

6. Psychophysical Measures

As mentioned previously, psychophysical criteria provide weight limits for lifting that are based on the workers perception of the integration of the biomechanical and physiological demands of a job. Psychophysical databases of maximum acceptable weight limits for lifting have been developed from laboratory studies of workers' strength and capacity for a wide range of task conditions. In these studies, workers' maximum-acceptable-weight-of-lift (MAWL) for specified combinations of task characteristics are defined as the amount of weight a person determines they can lift repetitively, working as hard as they can without straining themselves, or without becoming unusually tired, weakened, overheated, or out of breath. Typically, data are collected from a series of criterion tasks that are then used to generate normalized distributions of maximum weights that are acceptable to 10, 25, 50, 75, and 90% of the male and female population. Researchers have shown that back injuries increased for lifting tasks rated acceptable by less than 75% to 90% of the workers (Snook 1978, Herrin et al. 1986).

Procedure: The data obtained from the trunk motion and NIOSH lifting equation components of the study were used to determine averages for the amount of weight lifted, horizontal location, lifting frequency, vertical displacement, and vertical height of lift for the 173 lifts discussed previously. These averages were then used to develop a table of weight limits for various percentages of males that would find these tasks acceptable based on the psychophysical database (Snook and Ciriello 1991). According to Snook and Ciriello, the weight values in the database should be reduced 15% when handling boxes without handles; and by approximately 50% when handling smaller boxes with extended horizontal reaching. The average weight handled for the 173 lifts was then compared to the psychophysical data for lifts with similar characteristics to determine the potential risk of back injury associated with the manual lifting.

RESULTS/DISCUSSION

A. Medical

1. Recordable Injuries and Illnesses

Table 1 summarizes the rates of recordable injuries according to the OSHA 200 logs for grocery assemblers between 1989 and 1992. The first column shows the rate for all injuries while the last column shows the rates for back injuries alone. These rates were based upon a population of 42 day grocery assemblers as indicated by the company. The data provided in Table 1 also shows the rate of injuries associated with lost or restricted work time and the rate of lost or restricted workdays per 100 workers. The average rates of injuries over the four-year period from 1989-1992 were: 73 total recordable injuries per 100 workers, 45 lost or restricted-time injuries per 100 workers, and 25 back injuries per 100 workers. According to the Kroger safety personnel, the average rate of recordable injuries for the entire warehouse operation (about 205 workers) between 1989 and 1992 was 44 per 200,000 man hours or 44 per 100 full-time workers.

2. Questionnaire

Of the 42 grocery assemblers, 33 were working on the day of the survey and of those 32 (97%) completed a survey. Of these 32 assemblers, 13 had been hired during the previous six or seven months, while the remaining 19 were longer-term workers with at least one and a half years of seniority. All questionnaire results are presented with the short-term and long-term workers separated.

<u>Demographics</u>

Table 2 shows the demographics of these two groups of workers. Those completing the questionnaire were all male, although there is one female assembler. As a group they were young by national standards, with a combined average age of 29 as compared with the national average age of the workforce of 35.8 years (BLS, 1992). Moreover, the average work experience in warehouse work was less than 5 years. In terms of physical size, the workers were of average weight (180 pounds) but taller than the average American male (71 inches), falling in the 75th percentile for height (Kodak, 1983).

<u>Reported Injuries and Missed Workdays</u>

Among the longer-term workers, 12 of 19 (63%) reported an injury at work during the previous year (Table 3). Back injuries were the most common injury, with 9 of 19 (47%) reporting a back injury and 7 of 19 (37%) reporting a back injury which was associated with missed workdays. Among the 13 shorter-term workers there were no reported back injuries, and therefore including all 32 workers the rate of all self-reported back injuries was 9 of 32 (28%) and lost-workday back injuries was 7 of 32 (22%). Assuming that the lost workday injuries are those most likely to be officially reported to management and be recorded on the OSHA 200 logs, this later number agrees well with the average rate of recordable back injuries reported in Table 1 (i.e., average recordable back injury rate of 25 per 100 workers between 1989 and 1992).

Reported Symptoms

Table 4 shows the rate of "very or extremely uncomfortable pain" in each of the four-body part areas. For the long-term workers, over 47% reported significant back pain in the past year, while the rates for the other body parts ranged between 5 and 11%. These findings suggest that in addition to the 20-30% of workers with recorded back injuries, there is a considerable proportion of assemblers who continue to work with substantial back pain.

Borg Scale

The longer-term workers reported an average Borg score (Appendix A, Question 13) of 18.6 (very hard physical effort), with a range of 15-20. The shorter-term workers reported an average of 16.7 (very hard physical effort), with a range of 13-19. These findings correlate well with those found using heart rate and oxygen consumption monitoring, described below which found this job to be physiologically demanding.

Job Demand and Control

Average demand and control scores were computed from each of the two scales. Only the 19 longer-term workers were included in this analysis. These results were then compared to the results from a previous NIOSH investigation of 2300 male public employees working in a wide range of occupations. The average demand score for the warehouse workers was 4.6 (fairly-very often demanding), while the average for the public employees was 3.4 (sometimes-fairly often demanding). The average control score for the warehouse workers was 1.7(little control), while the average for the public employees was 3.7 (moderate-much control). All of these differences were statistically significant at the p=.001 level or better.

These findings suggest that the order assembler job is a high-demand low-control job, as compared to a large diverse group of public employees. In particular, the assemblers reported a much lower level of control over their job activities. During an informal interview with assemblers, a common concern was the effect of the work standards on the workers’ ability to control the pace and content of their job.

Researchers have shown that this combination of high demand and low control could lead to problems such as stress and job dissatisfaction (Landsbergis, 1988).

B. Ergonomic

1. Workplace Layout Analyses:

Grocery items were separated into individual slots and stored on pallets on the floor or on raised shelves. The slots were generally arranged as a single-height or double-height pick. The single-height slots were approximately 51" wide and 48" deep and held a single pallet of one product stacked to a height of up to 70". The double-height slot is also approximately 51" wide and 48" deep, but held two products, one on a pallet on the floor and one on an upper shelf. The upper shelf was usually 38" to 60" above the floor. Cases are stored on wooden pallets which raise the products 3-4 inches above the floor or shelf.

Most workers under 6' were able to stand up in the single-height slots, but workers typically had to squat or bend at the waist to reach the items in the lower tier of the double-height slot. Workers were observed kneeling and crawling to reach some objects in the lower tier. Selecting grocery items from the top tier, located at a height above 70", could also pose a stress for many workers, since 70" is the maximum recommended vertical reach height for manual lifting (Waters et al, 1993). This effort is increased when the workers have to reach for objects which are located further back in the slot. Although a hook (tool for pulling items down from the upper tier) was provided, workers rarely used the tool because heavy items would tend to roll down and fall on the worker. Thus, workers were observed climbing on cases in the lower tier to reach items in the upper tiers, particularly if they were not near the front edge.

Pallet heights on the jack were observed to be as high as 90" near the end of the trip. Workers were observed climbing on their jacks to build their load to accommodate the size of the order. Also, workers often had to remove the upper portion of the load on the loading dock because the pallet would not fit through the door of the truck. This required them to lift a number of items to the ground from above shoulder height, move the pallet into the truck, and then lift the items from the floor to the top of the pallet. Many of these lifts required that the worker carefully orient objects and hold them in place above shoulder height to fit them onto the pallet at the top of the stack. These type of lifts are very stressful because they require near maximum muscle use in awkward postures, which produces high levels of shoulder stress to maneuver heavy items above one's head. The handling of heavy loads at the top of the pallet also poses a risk of falling and dropping heavy loads.

2. Biomechanical Data

a. NIOSH Lifting Equation

Table 5 displays the results of the evaluation of ten sample lifting tasks that were selected for analysis with the Revised NIOSH Lifting Equation. The column labeled RWL in Table 5 refers to the Recommended Weight Limit, and the column labeled LI refers to the Lifting Index. The LI is computed by dividing the actual load by the RWL. Lifting tasks recognized by NIOSH as posing a low level of risk for the majority of workers will have LI < 1.0. A LI that exceeds 1.0 increases the risk of low back injury for an increasing number of individuals. Many researchers believe that a LI greater than 3 poses a risk of back injury for many workers (Waters et al, 1993).

Two of the ten lifting tasks shown in Table 5 (Tasks 2 and 5) required horizontal reach distances that exceed the maximum allowable distance of 25 inches. In order to make the calculation comparable for all 10 tasks, the maximum distance (25 inches) was used in the calculation. For all ten of the tasks, the weight lifted (L) far exceeded the RWL, which resulted in LI values ranging between 2.7 and 9.1.

If the basic design of the warehouse racks and the size and weight of grocery cases remain the same, only two of the factors in the lifting equation can readily be reduced: 1) the frequency of lifts and 2) the duration of exposure. Therefore, the LI can be brought closer to 1 by decreasing the required lifting rate or by providing additional recovery periods during the work day. For example, examination of Table 6 reveals that, by providing a 30 minute light duty job every two hours, the LI values will be reduced by an average of 40%.

b. Dynamic Trunk Motion Analysis

<u>Lift Distribution</u>

Of the 606 lifts that were performed by the four participants during the observation period, the LMM was used to successfully record data on 173 individual lifts (29%). Following data collection, each of the 173 sampled lifts were then classified as either low, medium, or high, depending upon the vertical height at the origin or destination of the lift. A lift was defined as "Low" if either the origin or destination was below 30 inches; "Medium" if both the origin and destination were between 30 and 50 inches; and "High" for all other conditions. Of the 173 lifts, 58% were categorized as low, 27% were categorized as medium, and 15% were categorized as high. The lumbar motion monitor data was then used to obtain the average trunk motion for all of the lifts in each of the three categories. From a biomechanical perspective, lifts originating and ending in the medium height range are considered desirable from a biomechanical perspective. It is important to note that in this study, only 27% of 173 lifts observed during our visit started and ended within the medium height range. This finding indicates that a significant portion of the lifts observed in this study (73%), required lifting motions that are undesirable from a biomechanical perspective.

Lifting Rate/Maximum Moment

The average lifting rate for the 173 tasks was 4.9 lifts/minute (294 lifts/hour). Load weights were obtained for the 173 lifts that were analyzed with the LMM. The average weight of the load for those lifts was 29.2 pounds [129.9 Newtons (N)]. The horizontal distance of the load from the spine was obtained for the 173 lifts analyzed with the LMM. The average horizontal distance at the origin of the lift for those lifts was 22.3 inches [0.57 meters (m)]. Thus, for an average lift, the estimated peak static spinal moment was 651 in·lbs (74 N•m).

The values shown for maximum moment in Column 3 of Table 7 are based on the LMM data set, but were combined and averaged by lift height category. For the low height category (below 30 inches), the maximum moment averaged 84 N·m; for the medium height category (30-50 inches), the maximum moment averaged 72 N·m; and, for heights above 50 inches, the maximum moment averaged 48 N·m. The magnitude of the spinal moment created during a lifting activity is directly related to the compressive force on the intervertebral disc in the spine. Maximum moments such as those found in this study are likely to generate compressive forces in the spine that are above 3400 N, which is the acceptable limit proposed by NIOSH in the revised lifting equation (Waters et al, 1993).

Lumbar Rotation Angles

As the height of the lifts increased from low to high, there was a significant decrease in the average peak sagittal lumbar flexion angle. The average maximum sagittal flexion angle recorded for the low, medium, and high categories was 65, 30, and 9 degrees, respectively (Column 4, Table 7). There were only small differences in lateral and transverse ranges of motion between the three height categories.

The average transverse rotation velocity also was determined for each lift. The means for the average transverse rotation velocity for each of the three height categories were 8, 10, and 9 degrees/second for the low, medium, and high height categories, respectively (Column 5, Table 7).

As with the lateral and transverse range of motion components, there were only small difference in the average peak lateral or transverse velocities between the three height categories. The average peak lateral velocity was 32, 31, and 32 degrees/second, for the low, medium, and high height categories, respectively (Column 6, Table 7).

Marras' Risk Assessment Model

Marras et al. (1993) developed a statistical risk model, based on several measures of trunk motion, that quantifies the probability that a job would be classified as having a high risk of developing low back disorders. According to Marras, "high risk" is defined as a job with more than 12 back injuries per 100 workers. Marras' model is based on measurements of five variables that were found to be most effective in predicting which jobs were associated with a high rate of back disorders. These five variables include three trunk motions which are obtained from the LMM (the peak lateral velocity of the trunk, the average twisting velocity of the trunk, and the peak sagittal flexion angle of the trunk during forward bending), and two workplace variables which are measured during the lift (the average lifting rate, and the maximum L5/S1 moment). The maximum moment is defined as the product of the maximum moment arm (horizontal distance between the worker and the center of the load) and the weight of the load.

Table 7 lists the measurements obtained for the five variables needed to use Marras' risk model for each of the three lifting categories. Figure 1 shows the results of the prediction of high risk group membership obtained from the model. The horizontal bars of the histogram represent the percent probability associated with each of the individual factors, by height category. The heavy vertical arrows represent the average percent probability that the grocery order assembler tasks would be categorized as high risk jobs based on the average for all five factors. The average probability of high risk group membership for each of the three height categories was 71%, 73%, and 49% for the low, medium, and high height categories, respectively. Therefore, according to Marras' model, there is a high probability that these jobs would result in more than 12 back injuries per 100 workers, which is consistent with the injury rates obtained from the OSHA 200 logs (Table 1). It should be noted that other investigators may classify "high risk" at a lower level than 12 injuries per 100 workers (Waters et al., 1993).

3. Metabolic Data

Table 8 displays a summary of the physiological demands for three cycles of order selection. The table provides information on the total cases per order, total weight per order, allowed time per order, average weight handled per minute, worker's performance index, measured metabolic working rate, and measured average heart rate. The length of time required to complete each of the orders varied from 38 to 51 minutes, depending on the size of the order and the worker's pace.

As noted previously, there can be extreme differences between orders, including differences in the total amount of weight and number of cases lifted per order, as well as the time allowed and the amount of weight lifted per minute (i.e., average work load). As can be seen from Table 8, the average work loads for the three participants observed in this study were 48, 75, and 114 lbs per minute. These work loads correspond to estimates of peak energy expenditures of 3.5, 5.5, and 9 kcal/min, and average working energy expenditures of 2.6, 4.0, and 6.3 kcal/min for the three participants[1]. A value above 5.0 kcal/min is considered excessive for an eight-hour work shift. Work loads as high as 216 lbs per minute were observed, and an average work load of 87.4 lbs per minute was determined for a sample of 25 typical orders from the grocery warehouse.

The average working heart rates for the three participants was 140, 146, and 138 beats per minute, which exceeds the criterion of 110 beats per minute, recognized as acceptable for most workers (Astrand and Rodahl, 1986).

Although significant variation between orders was observed, the measured heart rate data and energy expenditure values for workers performing tasks with these work loads would be defined as "heavy" to "very heavy" work for individuals of average capacity (Eastman Kodak, 1986, Table 26-24). Thus, we have concluded that these jobs would result in excessive physical fatigue for a majority of healthy workers, and we believe that this excessive physical fatigue increases the risk of lifting-related low back pain (Waters, et al., 1993).

4. Psychophysical Comparison

Table 9 displays the maximum-acceptable-weight-of-lift for various percentages of the male industrial work force for lifts similar to those performed by the grocery selectors. In most cases, the grocery selectors used extended reaches and the boxes lacked handles. Therefore, according to Snook and Ciriello (1991), the values in the table should reflect a 57.5% reduction from those originally listed in the database.

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[1] Energy expenditure is predicted from oxygen consumption measurements according to the following equation: 5 Kcal/min = 1 liter of oxygen consumed per minute.

The values shown in Table 9 were adjusted from the corresponding values in Snook and Ciriello (1991) (Table 2, p. 1202). For comparison purposes, the values in Table 9 correspond to a box width of 20 inches (51 cm), and a vertical displacement of 19.3 inches (49 cm). In most of the observed lifts, the vertical displacement exceeded 19.3 inches, which would result in even lower acceptable weight limits than shown in Table 9.

Comparing the average weight of 29.2 pounds lifted at a rate of 4.9 lifts/min for the 173 lifts mentioned previously to the values in Table 9, it is clear that the lifts are acceptable to less than 10% of the male industrial work force. According to Snook (1978), lifting tasks should be designed so that at least 75% of the population find them acceptable. Therefore, the average weight lifted by grocery selectors for lifting tasks with these characteristics should not exceed between 11.2 and 15.8 pounds.

CONCLUSIONS

The objective of an ergonomic job analysis is to fit the job to the worker so that one can work without excessive physical stress, fatigue, or harm to one's health. This investigation clearly showed the importance of obtaining quantitative data on biomechanical, physiological, and psychophysical responses of workers as they are actually performing their job. The collection of this data has allowed us to make conclusions about the risk of low back injury among grocery assemblers in the Kroger grocery warehouse.

In summary, the order assemblers have an elevated risk for musculoskeletal disorders, including low back pain, because of the combination of adverse job factors all contributing to fatigue, a high metabolic load, and the workers' inability to regulate their work rate because of the work requirements. According to recognized criteria defining worker capability and accompanying risk of low back injury, the job of order assembler at this work site will place even a highly selected work force at substantial risk of developing low back injuries. Moreover, in general, we believe that the existing performance standards encourage and contribute to these excessive levels of exertion.

These overall conclusions are based upon the following specific findings from our quantitative evaluation.

(1) Based on the revised NIOSH lifting equation, a significant proportion of the lifting tasks that were sampled during our visit exceeded the RWL by significant margins or exceeded maximum limits set for individual task parameters, such as the horizontal reach factor, indicating that the tasks were highly stressful to the musculoskeletal system, particularly the low back.

(2) The results indicate that movements in the sagittal plane (forward bending) required the greatest spinal movement, regardless of the height of the lift. In particular, the low height lifts were associated with the greatest sagittal flexion angle (i.e., 65 degrees) and highest velocities and accelerations.

(3) Based on the fact that spinal forces increase as the flexion angle increases, the results here indicate that a significant proportion of lifts (those included in the low category) would be associated with the greatest biomechanical spine loading, especially when the increased accelerations are considered.

(4) Analysis of the results of Marras' lumbar motion model indicates a high probability that warehouse grocery assembler tasks would be categorized as "high risk" jobs. This would suggest that it is likely that there would be more than 12 injuries/200,000 hours of work exposure for grocery assemblers, a prediction borne out by the company's OSHA logs and the questionnaire survey.

(5) Based on average measured heart rates, the job of order assembler exceeded the physiological criterion of acceptability for an 8-hr day (110 beats per minute), which is recognized as heavy to very heavy work for a majority of healthy workers (Kodak, 1983). The average heart rate of 141 beats per minute found in this study is equivalent to an oxygen uptake of more than 60% of an average males maximum aerobic capacity (Astrand and Rodahl, 1986). Energy expenditure should not exceed about 33% of a workers maximum aerobic capacity for an 8-hr day, nor should it exceed about 50% of a workers maximum aerobic capacity for one-hour of continuous work (Waters et al., 1993).

(6) The order assemblers' physiologic energy demands from continuous lifting at a rate of 4.9 lifts/minute (294 lifts/hour) would probably result in fatigued muscles, especially when extended shifts of more than 8 hours are considered.

(7) Ergonomic evaluations showed that the racks were very deep, and the stacking arrangement resulted in many grocery items being located either too high or too low. In addition, the order assemblers are required to lift heavy and bulky loads to a vertical height which exceeds the reach limit for most people, and at a horizontal distance which is close to the functional reach limit.

(8) Data collected from OSHA 200 logs and employee questionnaires all found a high rate of back injuries amongst the order assemblers.

(9) Workers in the warehouse reported significantly less control over their work compared to other workers. Much of this lack of control was attributed to the production standards.

Finally, the results of this study are comparable to the results of a previous NIOSH field study of grocery warehouse assemblers (NIOSH, 1993). In the earlier study, reported back injury rates, physiological demands, biomechanical forces, low back motions, and weights handled were nearly identical. This extreme similarity would suggest that the physical demands and risks of low back injury would be comparable in other grocery warehouses with similar layouts and performance requirements.

LIMITATIONS

This investigation performed a number of assessments of the physical characteristics of specific job tasks performed by order assemblers. Since these investigations were performed during a portion of only three days it is difficult to know whether our assessment is representative of the usual assembler workload. In some of these evaluations we focused on job tasks which were considered to be most hazardous although fairly common. As a result, some of our analyses are not necessarily representative of average job tasks. However, the job analyses do provide an accurate description of ergonomic hazards at this warehouse. Because the job tasks are highly repetitive, short sampling periods should yield data representative of usual job tasks. The conclusions of this investigation are supported by the consistency of the results of different exposure assessments and analysis of the health information from the OSHA logs and the questionnaire survey.

RECOMMENDATIONS

A. Ergonomic

The assemblers' current workload requires excessive metabolic and biomechanical demands even for a highly select population. These hazards are not the result of unique characteristics of the work methods or workplace layout, but rather result from a combination of the amount of weight lifted per hour, number of lifts per hour, and lifting of objects from floor level and above waist height. Substantial changes in work organization and methods are needed in order to reduce the hazard. These changes can be accomplished in a variety of ways and should be done though the consultation of a trained ergonomist. Some of the specific recommendations are:

(1) Ergonomic principles should be used in the design of racks, physical layout, size of the order, and arrangement of grocery items. This should minimize the physiological cost of work, reduce injury and illness to order assemblers, and may even improve productivity.

(2) Jobs should be analyzed using the NIOSH lifting equation to identify highly stressful tasks and evaluate alternate methods or workplace layouts.

(3) Since both the physical strength and endurance requirements for the order assembler's job are very high, even with the recommended changes, certain administrative changes will be necessary, such as worker rotation, to reduce the future risk of injury and illness among the order assemblers.

(4) Performance standards, if they are to be used, must be based on objective measures of physical effort, such as heart rate and oxygen uptake, in order to determine reasonable workloads which will not place the worker at an excess risk of injury.

(5) Light duty jobs should be made available for injured workers in order to encourage and facilitate their return to work.

(6) Overtime should be kept to a minimum, as the energy requirements for the job are very high. Further, overtime should be made voluntary so that a tired worker with a limited aerobic capacity is not forced to maintain a certain level of performance after an 8-hr work day.

(7) Warehouses should develop a better system to monitor injury and illness profiles of the workers. This system can be useful in preparing injury and illness statistics and monitoring the effectiveness of workplace intervention programs.

(8) The heaviest objects should be stored in slots with the bottom raised to knee height. Less heavy items should be stored in the bottom slot of a two slot configuration, rather than in the top slot and only light and non-breakable items should be stored in the top racks.

(9) The size of an order should be restricted so that the pallet load heights do not exceed 60 inches.

(10) Using single pallet rather than double pallet orders is one method to decrease the cycle time and increase the frequency of recovery periods between orders.

(11) The use of computer-generated orders should be modified to ensure that order selections for each worker is balanced with respect to the "load difficulty." A heavy or difficult load should be followed by a less difficult load to allow the worker an opportunity for some recovery. Factors which appear to affect load difficulty were well-known to the workers including: weight, number of items, location, and type of items to be selected.

Although heat stress was not evaluated in this field study, a previous field study of grocery assemblers [NIOSH, 1993] revealed that high summer temperatures and humidity in the grocery warehouse significantly increased the metabolic heat load on workers and that the heat stress criteria for safe work was exceeded. Therefore, we also recommend that temperature and humidity samples be taken on a regular basis during warm work days to avoid potential heat stress hazards, and that a source of water be provided on the pallet jack.

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Copies of this report have been sent to:

1. Kroger Company, Nashville, Tennessee
2. Truck Drivers, Chauffeurs and Helpers Local Union No. 327
3. Confidential Requestors

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1
OSHA 200 Log Entries for Grocery Assemblers
Kroger Grocery Warehouse

Year	# Total Injuries per 100 Workers	# Lost-Time Injuries per 100 Workers	# Lost Workdays per 100 Workers	# Back Injuries per 100 Workers
1989	62	50	90	21
1990	62	33	160	31
1991	83	43	174	29
1992	86	55	234[1]	17

[1] Includes one neck injury causing 150 lost workdays

Table 2
Demographics of Study Participants
Kroger Grocery Warehouse

	Long-Term Assemblers (N=19)	Short-Term Assemblers (N=13)
Average Age (range)	30 yrs (23-42)	25 yrs (20-33)
% Male	100%	100%
Average Yrs at Kroger (Range)	5 yrs (2-22)	less than 1 yr
Average Yrs at Other Warehouse (range)	3 yrs (1-6))	4 yrs (0-13)
Average Height (range)	71 inches (67-76)	71 inches (67-75)
Average Weight (Range)	183 lbs (150-245)	177 lbs (135-205)

Table 3
Injuries and Missed Workdays Reported by Questionnaire
Occurring During the Previous 12 Months
Among 19 Assemblers Working At Least 1 Year

Body Part	**Injuries**		**Average # Missed Workdays**	**Range of Missed Workdays**
	Number	**Percent**		
Back	9	47%	7	0-21
Neck/Shoulder	1	5%	15	15
Lower Extremity	2	11%	2	0-3

Table 4
Rate of Reported Discomfort[1]
Kroger Grocery Warehouse Order Assemblers

Body Part	**Long-Term Assemblers (N=19)**	**Short-Term Assemblers (N=13)**
Back	47%	8%
Neck/Shoulder	11%	8%
Lower Extremity	11%	0%
Hand/Arm	5%	8%

[1] Reported discomfort of "very" or "extremely" uncomfortable.

Table 5
Summary results of NIOSH Lifting Equation Evaluation
Kroger Grocery Warehouse Order Assemblers

TASK #	LOAD (lbs)	LIFTING EQUATION COMPONENTS							RESULTS	
		LC	HM	VM	DM	CM	AM	FM	RWL (lbs)	LI
1	39	51	0.46	0.82	0.90	0.95	0.81	0.39	5.2	7.8
2	40	51	0.40*	0.87	0.88	0.95	0.87	0.39	5.0	7.7
3	27	51	0.42	0.96	0.86	0.95	0.86	0.39	5.6	4.8
4	60	51	0.47	0.89	1.00	0.95	0.85	0.38	6.6	9.1
5	29	51	0.40*	0.94	0.89	0.95	0.73	0.38	4.5	6.4
6	22	51	0.46	0.88	0.87	0.95	0.73	0.38	4.7	4.7
7	44	51	0.41	0.90	1.00	0.95	0.88	0.44	6.9	6.4
8	28	51	0.49	0.94	1.00	1.00	1.00	0.44	10.4	2.7
9	27	51	0.43	0.92	0.86	0.95	0.86	0.44	6.3	4.3
10	35	51	0.65	0.87	0.97	1.00	0.82	0.27	6.2	5.7

* Actual horizontal distances exceeded 25 inches, which according to the NIOSH equation would set HM equal to 0.0, resulting in RWL of 0 and the requirement to redesign the job. For this analysis, the HM was set to the maximum of 25 inches for comparison purposes.

Table 6
Comparison of LI Values for 2-Hour and 8-Hour Exposure
Kroger Grocery Warehouse Order Assemblers

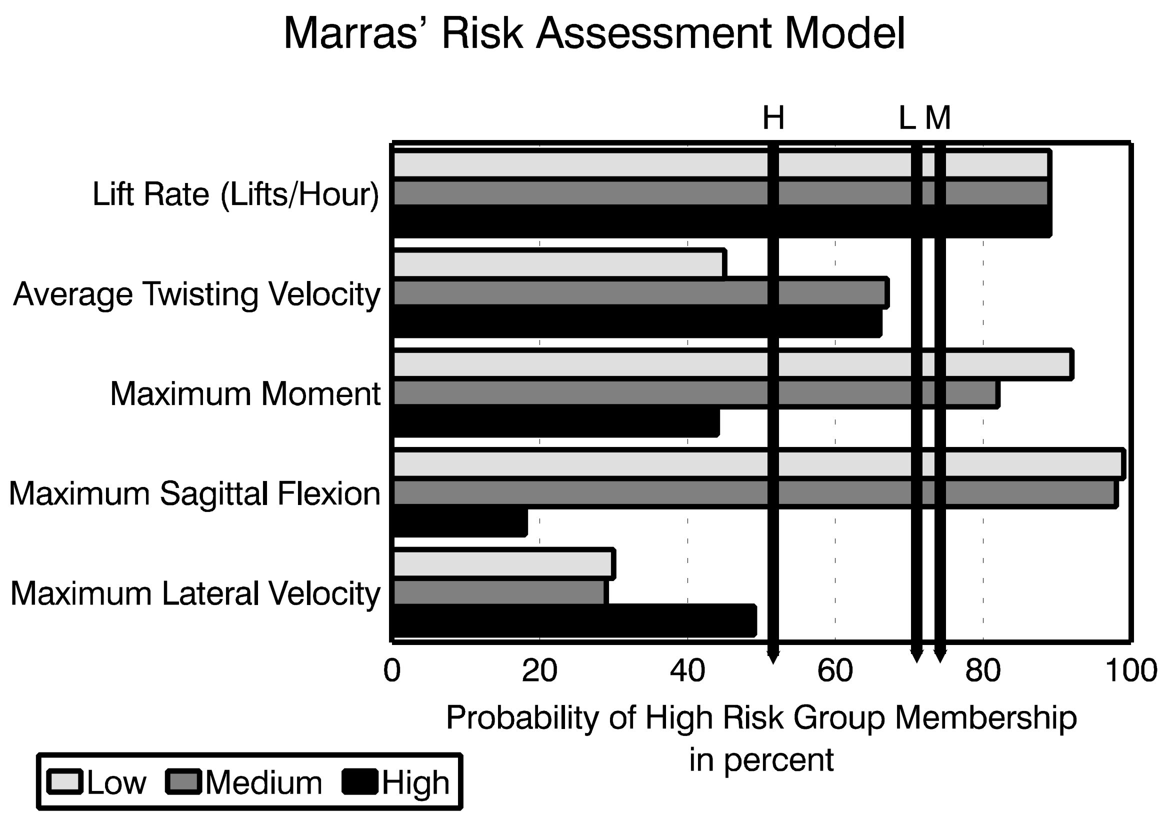
TASK #	LI (8-hour Exposure)*	LI (2-hour exposure)	Reduction in LI
1	7.8	4.7	39.7%
2	7.7	4.6	40.3%
3	4.8	2.9	39.6%
4	9.1	5.5	39.6%
5	6.4	3.8	40.6%
6	4.7	2.8	40.4%
7	6.4	3.9	39.1%
8	2.7	1.7	37.0%
9	4.3	2.7	37.2%
10	5.7	3.0	47.4%

***** Observed exposure at Kroger Warehouse.

Table 7
Dynamic Lifting Task Analysis
Kroger Grocery Warehouse Assemblers

Height Category	Lift Rate (Lifts/ HR)	Max. Moment (N·m)	Max. Sagittal Flexion (Degrees)	Avg. Transverse Velocity (Deg/Sec)	Max. Lateral Velocity (Deg/Sec)
Low N=101	294	84	65	8	32
Medium N=46	294	72	30	10	31
High N=26	294	48	9	9	32

Figure 1
Probability of High Risk Group Membership
Kroger Grocery Warehouse Assemblers



Arrows indicate the average probability for the three height categories (L, M, H)

Table 8
Metabolic Analysis
Kroger Grocery Warehouse Assemblers

Participant	Variables	Value
1	Total Cases/order	168
	Total Weight/order	4750 lbs
	Allowed Time/order	51 min
	Weight/min (work load)	114 lbs/min
	Performance Index[2]	122%
	Working Metabolic Rate	6.3 kcal/min
	Working Heart Rate	140 beats/min
2	Total Cases/order	120
	Total Weight/order	2522 lbs
	Allowed Time/order	38 min
	Weight/min (work load)	75 lbs/min
	Performance Index	113%
	Working Metabolic Rate	4.0 kcal/min
	Working Heart Rate	146 beats/min
3	Total Cases/order	116
	Total Weight/order	1894 lbs
	Allowed Time/order	43 min
	Weight/min (work load)	48 lbs/min
	Performance Index	106%
	Working Metabolic Rate	2.6 kcal/min
	Working Heart Rate	138 beats/min

[2] Performance Index = (allowed time per order/actual time per order) * 100.

Table 9
Psychophysical Weight Limits in Pounds for Males
(From Snook and Ciriello, 1991).

Vertical Location	Lifts/min	Weight Acceptable to 75% of Males (lbs)	Weight Acceptable to 50% of Males (lbs)	Weight Acceptable to 10% of Males (lbs)
Floor to Knuckle	6.7	12.1	15.8	23.3
	4.3	14.1	18.7	27.1
Knuckle to Shoulder	6.7	14.1	17.8	24.4
	4.3	15.8	19.6	28.2
Shoulder to Reach	6.7	11.2	16.9	20.7
	4.3	13.2	21.6	23.3

Appendix A
Questionnaire
Kroger Grocery Warehouse

National Institute for Occupational Safety and Health
Kroger Warehouse, Nashville, TN
HETA 93-0920, October 14, 1993

1. What is your name: __________________________ __________________________________
   Last First

2. What is your: age __________ yrs,
   height ________ ft ________ in,
   weight ________ lbs

3. When did you start working at this Kroger Warehouse?

   _______ month, 19____ yr

4. Total years worked at this Kroger Warehouse is: ______ yr (s)

5. Did you work at another warehouse previously? ______ yes, ______ no

6. If yes, how many years did you work at that other warehouse?

   _______ yrs, ______ months

7. On average, how many hours do you work each week?

   _______ hours

8. On average, how many hours do spend assembling pallets each week?

   ________ hours

9. During the past year (October 1, 1992--October 10, 1993), have you ever had an injury at work?

   __________ yes, ___________ no

10. If yes, what part of your body did you injure ? _____________________

11. During the past year, have you ever missed any workdays due to an injury at work ?
    ________ yes, _________ no

12. If yes, how many days did you miss? ______________ days

13. Using the rating scale shown below please rate the OVERALL physical effort level demanded by your

job today. Please circle the most appropriate number on the following scale.

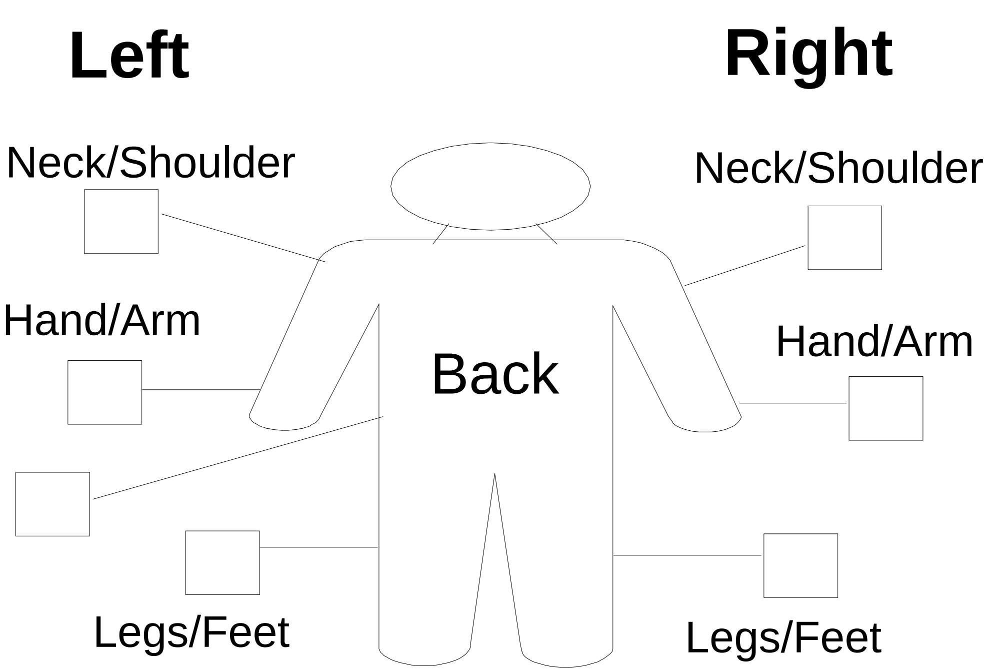
20
19 - Very, very hard
18
17 - Very hard
16
15 - Hard
14
13 - Somewhat hard
12
11- Fairly light
10
9 - Very light
8
7 - very, very light
6

14. Have you had any pain or discomfort during the last year? __________ yes, __________ no

If No, skip to question 15.
If YES, continue with question 14.

If YES, put a number in each box to indicate your level of discomfort, using the following scale:

0 = No discomfort
1 = Uncomfortable
2 = Very uncomfortable
3 = Extremely uncomfortable



15. Please circle the relevant number next to the question.

How often:	Rarely	Occasionally	Sometimes	Fairly Often	Very Often
Does your job require you to work very fast?	1	2	3	4	5
Does your job require you to work very hard?	1	2	3	4	5
Does your job leave you with little time to get things done?	1	2	3	4	5
Is there a great deal to be done?	1	2	3	4	5

16. The next series of questions ask how much influence or control you have at work. Please circle the appropriate number corresponding to the question.

How much influence do you have over the:	Very Little	Little	Moderate	Much	Very Much
Variety of tasks you perform?	1	2	3	4	5
Amount of work you do?	1	2	3	4	5
Order in which you perform tasks at work?	1	2	3	4	5
Pace of your work, that is how fast or slow do you work?	1	2	3	4	5
Quality of the work that you do?	1	2	3	4	5
To what extent can you do your work ahead & take a short rest break during work hours?	1	2	3	4	5
In general, how much influence do you have over work & work-related factors?	1	2	3	4	5

Appendix B
NIOSH Lifting Equation Calculations
Kroger Grocery Warehouse

A. Calculation for Recommended Weight Limit

RWL = LC * HM * VM * DM * AM * FM * CM
(* indicates multiplication.)

Recommended Weight Limit

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

Where:

H = Horizontal location of hands from midpoint between the ankles. Measure at the origin and the destination of the lift (cm or in).

V = Vertical location of the hands from the floor. Measure at the origin and destination of the lift (cm or in).

D = Vertical travel distance between the origin and the destination of the lift (cm or in).

A = Angle of asymmetry - angular displacement of the load from the sagittal plane. Measure at the origin and destination of the lift (degrees).

F = Average frequency rate of lifting measured in lifts/min.
Duration is defined to be: ≤ 1 hour; ≤ 2 hours; or ≤ 8 hours assuming appropriate recovery allowances.

Appendix B
Table 1
Frequency Multiplier (FM)
NIOSH Lifting Equation

Frequency Lifts/min	Work Duration					
	≤ 1 Hour		≤ 2 Hours		≤ 8 Hours	
	V < 75	V ≥ 75	V < 75	V ≥ 75	V < 75	V ≥ 75
0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

† Values of V are in cm; 75 cm = 30 in.

Appendix B
Table 2
Coupling Multiplier
NIOSH Lifting Equation

Couplings	V< 75 cm (30 in)	V ≥ 75 cm (30 in)
	Coupling Multipliers	
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90