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Big Bear Grocery Warehouse
Columbus, Ohio

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I. SUMMARY

On January 21, 1992, representatives from the National Institute for Occupational Safety and Health (NIOSH) undertook the first of four trips to the Big Bear Warehouse in Columbus, Ohio in response to a confidential request for a health hazard evaluation (HHE). The request was prompted by employee concerns about the potential hazards of repetitive lifting, excessive work pace, and heat stress associated with the job of "order selector." There were three objectives of this investigation:

1) Determine the prevalence and incidence of work-related musculoskeletal disorders (WMDs), particularly low back pain, associated with manual lifting activities of the order selectors in the grocery warehouse.

2) Document the presence of potential occupational hazards in the warehouse including repetitive lifting and heat stress.

3) Develop recommendations for preventing or reducing the physical stresses associated with repetitive lifting and heat stress.

During three separate visits over a six month interval, the NIOSH team collected information at the Big Bear work site to assess the extent and magnitude of the reported health hazards. During this and subsequent visits, we administered a questionnaires to the workers that included items designed to assess the workers' perceptions of physical workload and symptoms of musculoskeletal disorders. Occupational Safety and Health Administration (OSHA) logs and medical records were reviewed to determine the extent of the recorded injuries and lost time. Ergonomic analyses were conducted on the following dates:

1) On May 14, 1992, 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 July 14, 1992, 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. Measurements for assessing heat stress were also conducted on July 14.

3) On November 5, 1992, we examined the effects of lifting frequency and work duration as they affected oxygen use and heart rate.

The results of our medical evaluation confirmed that back injuries among selectors was the most important cause of lost workdays in the warehouse. Workers' compensation data provided by Big Bear for 1991 showed 22 cases of back sprain/strain among all the workers in the grocery warehouse (about 16 cases per 100 workers). On average, during the five years, back injuries among the selectors accounted for about 60% of all lost workdays in the grocerywarehouse.

A questionnaire was completed by more than 80% of current grocery selectors and showed that the work force was all male, who on average were younger, taller, and heavier than the majority of workers in the U.S. work force. More than 70% of the full time selectors reported significant physical discomfort in the region of the low back and 18% 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 selector at this work site will place even a highly selected work force at substantial risk of developing low back injuries based on the following findings from our work site analysis, which showed that 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.

Heat stress evaluation of this work location included measurement of the wet bulb globe temperature (WBGT) index, an assessment of the air velocity, and an estimation of the metabolic heat load of the task. Basic physiologic monitoring of the workers which included heart rate, and oxygen consumption was also used to comparatively establish the metabolic demand. Environmental monitoring revealed WBGT values that ranged from 76.5 - 79°F, with the peak dry bulb temperatures of 89°F. The metabolic heat load of the grocery selector job was determined to be moderate to high. Although the environmental heat conditions were not extreme, the metabolic demands of the job tasks caused the order selectors exposure to approach the heat stress (WBGT) criteria established by NIOSH and ACGIH. It is likely that on extremely hot and humid days, the heat stress criteria would be exceeded for the grocery selectors.

The objective of the present investigation was to determine if the job of order selector 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 selectors despite the highly selected nature of this workforce.

Biomechanical and metabolic job analyses were performed to identify and quantify stressful work postures, heavy loads, and high frequency lifting motions. The order selectors 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 selector at this worksite poses a significant health hazard.

The ergonomic job analyses using a variety of criteria for identifying hazardous job tasks were in general agreement that order selecting is a hazardous activity with a substantial risk of low back injury. These hazards are not only the result of unique characteristics of the work methods or workplace layout, but also 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. Although the environmental heat conditions were not extreme, the metabolic demands of the job tasks caused the order selectors exposure to approach the heat stress criteria. Recommendations 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, biomechanical, physiologic, production standards, muscle fatigue, heat stress, wet bulb globe temperature index, metabolic heat load, convective heat exchange.

II. INTRODUCTION

On January 21, 1992, representatives from the National Institute for Occupational Safety and Health (NIOSH) visited the Big Bear Grocery Warehouse in Columbus, Ohio, 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, excessive work pace, and heat stress associated with the job of "order selection." 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 selector."

2) Documenting the presence of potential hazards in the warehouse, including heat stress and ergonomic issues related to repetitive lifting.

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

An interim report was sent to the company and to the requestors in March, 1992, which discussed preliminary findings and proposed future assessments.

III. BACKGROUND

A. Plant and Job Description

Big Bear is a retail grocery food supplier with warehouses located in Columbus, Ohio. Although the warehousing operation includes several buildings, this investigation was limited to warehouse 1, which contained all of the nonperishable grocery items. This area was chosen because the majority of selectors worked in that facility and it had a higher rate of reported injuries.

1. Workforce

The company employs, on average, about 145 both full- and part-time workers in Warehouse 1, 67 (46%) of whom select groceries each day. These workers are referred to as "order selectors." Both full-time and part-time workers average about 40 hours per week of work, although the contract allows for up to 10 hours of mandatory overtime. Part-time workers are employed on a temporary basis and are not covered by the union contract. Part-time workers make up 15-20% of the order selectors. The work schedule consists of two shifts that overlap during the mid afternoon. The company reported a very low turnover rate of full-time workers[1], but the average absence rate is 15-20%. Each new (part-time) employee is given one week of training and has a 30-day trial period. The company provides no "light duty" jobs for injured workers; they are allowed to return only when they are fully fit.

1 The low turnover rate is in part a function of using a temporary work pool, which serves to screen employees.

2. Job Activity

The job of an order selector 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 located in supply pallets or slots on either side of the aisle. The grocery items are stored on wooden pallets located in either single or double deep slots, and may include a one or two item pick (two grocery items stored in the same slot at different levels). The total weight of the order and the total number of items per order may vary considerably.

According to data provided by the company from a recent 26 week period, on average, order selectors spend approximately 75% of their work time performing these tasks (range 44%-90%). The remainder of the time is spent on breaks, lunch, and doing a variety of other assigned tasks, including driving forklifts and doing maintenance work.

3. Job Cycle

A job sequence for the order selector, 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 selector drives to the loading dock area and places the loaded pallets there. The order selector 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. Incentive System

A few years ago, the company had installed a "standard incentive program," developed by an industrial engineering consulting firm. Standards were set based on a time measurement system, amount of weight, movement time between items, and lift height. The goal of the standard incentive system was to establish a "fair amount of time" to do a work cycle. A work cycle was defined by the consulting firm as "the selection and filling of a 2-pallet cube." Each motorized jack could carry two pallets. Achieving 100% of the standard was defined as a "day's work," and was averaged over a week of work. An employee was disciplined for performance below 95% of the standard. To allow for conditioning, there was a four-week build-up period. The incentive consisted of increased money or time off and occurred when the worker exceeded the standard. Before the standards, they had used historical in-house data as standards, based on the number of cases handled per hour. The company representatives stated the old production-based standards were not cost-effective.

B. Incidence and Costs

The job of order selector has been previously identified as physically demanding, primarily because of the frequent and heavy manual lifting demands associated with these jobs (Garg 1986). 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. 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.

IV. Evaluation Design and Methods

A. Medical Evaluation Methods

1. OSHA 200 Logs and Workers' Compensation

The OSHA 200 logs were obtained from the company for the period 1987-1991. 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. Data from workers' compensation claims for 1991 were also provided by the company.

2. Questionnaire

On July 14, a questionnaire was distributed to all Warehouse 1 grocery selectors who were at work that day on either the first or second shift. The questionnaire was completed by the workers 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:

Assessment of Perceived Physical Workload

The Borg scale was used to illicit an overall assessment of the perceived physical workload of the selectors' job. This scale consists of a 15-point numerical list, anchored by adjectives describing increasing levels of physical effort (Question 12, 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 13, 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)

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 selectors' perception of their job demands and control (Pages 3-5, 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 18, 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, first 4 items, 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 Warehouse 1 order selectors, 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

Two sets of criteria are commonly used to evaluate the potential risk associated with the manual lifting tasks: biomechanical and metabolic (NIOSH 1981). Biomechanical risks refer to the mechanical stress on the musculoskeletal system resulting from lifting, while metabolic risks refer to the physiological stress imposed by the workload of the lifting job. Researchers have developed hazard assessment models which utilize these risk factors to estimate the likelihood that a particular lifting job poses a significant risk of a work-related injury and for low back pain (Waters et al., 1993, Marras 1993).

<u>Biomechanical Evaluation of Load and Posture.</u>

For this initial analysis, we conducted two separate evaluations. Information on load weights and body postures was systematically recorded for **five representative lifting tasks that were judged by both the workers and investigators as having a high potential for injury**. Each of the five lifting tasks are shown in Figure 1. Each example illustrates a different sample of stressful lifting postures observed by the investigators. (The pictures were taken directly from the video-tapes of the sampled lifting tasks.)

1) Lifting Task 1: 30 lb load, trunk flexion, no twist.
2) Lifting Task 2: 38 lb load, long reach, small twist.
3) Lifting Task 3: 42 lb load, trunk flexion, high twist.
4) Lifting Task 4: 38 lb load, long reach, high twist.
5) Lifting Task 5: 58 lb load, shoulder high reach, twist.

By examining a sample of the potentially most hazardous jobs first, the overall severity of the hazards can be estimated. This information is useful in planning the sampling scheme and measurement precision required for subsequent in-depth analyses.

Procedure: Two experienced male grocery selectors were randomly chosen to participate in this phase of the investigation. Both of the workers, referred subsequently to as participants, were healthy and conditioned for work. Both participants were informed of the investigative procedures before data collection began. Participant 1 performed Tasks 1-4, and Participant 2 performed Task 5 (See Figure 1). Each participant was instructed to perform the lifts using the same technique he would use when actually selecting a grocery order.

For those lifts which were selected for analysis, each participant was asked to momentarily hold his position at the lift-off point and set-down point. During the approximate 10-15-second interval, the investigator was able to record 15 angular values with the aid of an electro-goniometer (Lafayette Instruments, Inc., Model # 35). These data values serve as the input for the Michigan 3D Static Strength Prediction Program (SSPP). The Michigan 3D SSPP model provides estimates of lumbo-sacral (L5/S1) disc compressive forces as well as information on the muscle strength requirements which a person needs to perform the designated lift (Chaffin and Andersson, 1991). The model was used to estimate the percentage of the working male population which would have sufficient strength at the hip joint and at the torso to lift each of the objects. These two body parts were chosen because they are most closely associated with the development of low back pain.

Videotape and still photographs also were made for each lift to assist the analyst in interpreting the measured joint angles for the analysis. In addition, the measurements were recorded using the electro-goniometer and a standard retractable tape measure. These measurements were needed to apply the NIOSH lifting equation (Appendix B).

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 selector. 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: Three experienced male grocery selectors from the same warehouse 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 three participants was fitted with the LMM and monitored for one complete job cycle. (A job cycle was defined as a complete order selection.) For each lift and lowering motion, the participant was asked to identify the specific item to be selected and where it was to be placed on the pallet. Thus, each item was categorized into one of nine possible types of lift and lowering motions at three vertical heights for both the origin and destination of the lift. Vertical height was defined as 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 he performed order selections. The video tape was used as an independent audit trail to verify 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, approximately 200 lifting tasks were evaluated.

Metabolic Measures

To characterize the metabolic risk factors during the third and final assessment visit, the NIOSH team used three procedures to assess the energy demands of order selection: (1) oxygen measurement, (2) heart rate monitoring, and (3) energy expenditure modelling. Oxygen measurement provides a relatively objective assessment of the energy demands posed by the work load of the job, whereas heart rate monitoring and metabolic modeling are indirect procedures for assessing metabolic load, inherently less accurate, but somewhat easier to use.

Procedure: Three male grocery selectors were randomly chosen for this phase of the investigation. (For each 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 selector-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 displayed on the unit's display and manually recorded by the investigator every 5 minutes during the selection cycle. 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 equivalent to 100% of the existing performance standard.

To assist in the metabolic analysis, a printout of the order (i.e., items to be selected) was provided by management. This showed the total number of items selected, the weight, volume (size) of each item and location of each item. We also videotaped the order selections to allow us to conduct an independent task-based metabolic assessment using a model developed by Garg and others (Garg et al., 1978).

C. Heat Stress Evaluation

Environmental heat assessment of this work location included measurement of the wet bulb globe temperature (WBGT), an assessment of the air velocity, and an estimation of the metabolic heat load of the work task(s). Basic physiologic monitoring of the workers, which included the previously discussed heart rate and oxygen consumption measurements, was also utilized to determine the metabolic heat demand.

On May 14, 1992, a "baseline" heat stress evaluation was conducted to evaluate the conditions associated with a typical moderate weather day (of spring and autumn). On July 14, 1992, the heat stress measurements were repeated on a warm summer day to determine the exposure conditions more typical of this season. During each of these surveys, environmental heat measurements were obtained at twelve locations spatially spread throughout the warehouse. These measurements were obtained near the beginning of the first shift (early afternoon), as well as mid-way through the work shift (late afternoon/early evening). A stationary site (aisle 56, slot #3810), located in the center of the warehouse, was also selected for collecting measurements at five-minute intervals during the majority of the first shift (approximately 12 noon to 6 PM). In addition, a heat stress meter was mounted on a pallet jack, and data were logged at short intervals during order selecting to evaluate the cooling effect, if any, due to the wind induce by riding the pallet jack.

Environmental measurements were obtained using a Reuter Stokes RSS 211D Wibget® heat stress meter manufactured by Reuter Stokes, Canada. This direct reading instrument is capable of monitoring dry bulb, natural (unaspirated) wet bulb, and black globe temperatures in the range between 32° and 200°F, with an accuracy of ± 0.5-1.0°F. This meter also computes the indoor and outdoor WBGT indices in the range between 32° and 200°F. Measurements were collected about four feet from the floor after the meter was allowed to stabilize. A Veloci-Calc™ thermo-anemeometer, manufactured by TSI, was used to collect air velocity measurements with a read-out accuracy of ± 2.5%.

The heart rate and oxygen consumption measurements obtained during the ergonomic and physiologic assessment allow for an accurate determination of the metabolic rate required to perform the measured job tasks. However, the difficulty level of selecting a given grocery order can vary significantly, and only a limited number of heart rate and oxygen consumption measurements were collected. Therefore an estimation of the metabolic rates of this work was also performed using energy expenditure tables and the guidelines provided in <u>Occupational Exposure to Hot Environments, Revised Criteria 1986,</u> and <u>Threshold Limit Values for Chemical Substances and Physical Agents</u> (NIOSH, 1986; ACGIH, 1992). Using this method, the average energy expenditure for a "standard" male worker (body weight 70 kilograms; body surface 1.8 square meters) can be calculated utilizing basal metabolism, and specific task analysis information regarding body position, movement and type of work. Table 12 lists the average energy requirements for the task analysis components. Assessment of the metabolic heat demand of the job task(s) is essential to allow one to apply the appropriate WBGT evaluation criteria to the observed environmental conditions. It is important to note that errors in estimating metabolic heat from energy expenditure tables are reported to be as high as 30% (NIOSH, 1986). Because of the error associated with estimating metabolic heat, NIOSH recommends using the upper value of the energy expenditure range reported in Table 12 to allow a margin of safety. The metabolic rates obtained from each of these methods were compared and the most protective estimate was used to establish the appropriate heat stress exposure criteria.

Heat stress is defined as the total net heat load on the body with contributions from environmental sources and from metabolic heat production (Dukes-Dobos, 1981). Four factors influence the exchange of heat between the human body and the environment. These are: (1) air temperature, (2) air velocity, (3) moisture content of the air, and (4) radiant temperature. The fundamental thermodynamic processes involved in heat exchange between the body and its environment may be described by the basic equation of heat balance:

$$\mathbf{S = M - E \pm R \pm C}$$

where:

S = the change in body heat content (heat gain or loss);
M = metabolic heat gain associated with activity and physical work;
E = heat lost through evaporation of perspiration;
R = heat loss or gain by radiation (infrared radiation emanating from warmer surfaces to cooler surfaces);
C = heat loss or gain through convection, the passage of a fluid (air) over a surface with the resulting gain or loss of heat.

Under conditions of thermal equilibrium (essentially no heat stress), heat generated within the body by metabolism is completely dissipated to the environment, and deep body or core temperature remains constant at about 98.6°F (37°C). When heat loss fails to keep pace with heat gain, the body's core temperature begins to rise. Certain physiologic mechanisms begin to function in an attempt to increase heat loss from the body. First, the body attempts to radiate more heat away by dilating the blood vessels of the skin and subcutaneous tissues and diverting a large portion of the blood supply to the body's surface and extremities. An increase in circulating blood volume also occurs through the withdrawal of fluids from body tissues. The circulatory adjustments enhance heat transport from the body core to the surface. If the circulatory adjustments are insufficient to adequately dissipate excessive heat, sweat glands become active, spreading perspiration over the skin to remove heat from the skin surface through evaporation.

There are a number of heat stress guidelines that are available which are intended to protect against heat related illnesses such as heat stroke, heat exhaustion, heat syncope, and heat cramps. These include but are not limited to the wet bulb globe temperature (WBGT), Belding-Hatch heat stress index (HSI), and effective temperature (ET) (Yaglou et al, 1957; Belding et al, 1955; Houghton et al, 1923). The underlying objective of these guidelines is to prevent workers' core body temperature from rising excessively. The World Health Organization has concluded that "it is inadvisable for deep body temperature to exceed 38ºC (100.4ºF) in prolonged daily exposure to heavy work" (WHO, 1969). Many of the available heat stress guidelines, including those proposed by NIOSH and the American Conference of Governmental Industrial Hygienists (ACGIH), also use a maximum core body temperature of 38ºC as the basis for the environmental criteria (NIOSH, 1986; ACGIH, 1992).

Both NIOSH and ACGIH recommend the use of the WBGT index to measure environmental factors because of its simplicity and suitability in regards to heat stress. The International Organization for Standardization (ISO), the American Industrial Hygiene Association (AIHA), and the Armed Services have published heat stress guidelines which also utilize the WBGT index (ISO, 1982; AIHA, 1975; U.S. Dept of Defense, 1980). Overall, there is general conformity of the various guidelines; hence, the WBGT index has become the conventional technique for assessment of environmental conditions in regards to occupational heat stress.

The WBGT index takes into account environmental conditions such as air velocity, vapor pressure due to atmospheric water vapor (humidity), radiant heat, and air temperature, and is expressed in terms of degrees Fahrenheit (or degrees Celsius). Measurement of WBGT is accomplished with an ordinary dry bulb temperature (DB), a natural (unaspirated) wet bulb temperature (WB), and a black globe temperature (GT) as follows:

$$WBGT_{in} = 0.7\ (WB) + 0.3\ (GT)$$

for inside or outside without solar load,

Or

$$WBGT_{out} = 0.7\ (WB) + 0.2\ (GT) + 0.1\ (DB)$$

for outside with solar load.

Originally, NIOSH defined excessively hot environmental conditions as any combination of air temperature, humidity, radiation, and air velocity that produces an average WBGT of 79ºF (26ºC) for unprotected workers (NIOSH, 1972). However, in the revised criterion for occupational exposure to hot environments, NIOSH provides Recommended Exposure Limits (RELs) of WBGT environmental conditions in accordance with specific work-rest cycles and metabolic heat production (NIOSH, 1986). NIOSH has developed two sets of recommended limits; one for acclimatized workers [recommended exposure limit (REL)], and one for unacclimatized workers [recommended action limit (RAL)]. Refer to Figure 3 for the diagrams describing the RELs.

Similarly, ACGIH recommends a Threshold Limit Values® (TLV) for environmental heat exposure permissible for different work rest regimens and work loads (metabolic heat) (ACGIH, 1992). The NIOSH REL and ACGIH TLV criteria assume that the workers are heat acclimatized, are fully clothed in summer weight clothing, are physically fit, have good nutrition, and have adequate salt and water intake. Additionally, they should not have a preexisting medical condition that may impair the body's thermoregulatory mechanisms. Modifications of the NIOSH and ACGIH evaluation criterion should be made if the worker or conditions do not meet the previously defined assumptions.

It is important to distinguish the difference between the qualifying terms "high, moderate, & low," in regards to metabolic rate when applying it to a heat stress evaluation or a physiologic (ergonomic) assessment. The use of metabolic rate in a heat stress evaluation is necessary to provide an approximation of the bodily heat production as a result of the manual work performed, whereas the metabolic rate of a physiologic assessment is used as an indicator of muscle fatigue potential.

V. RESULTS

A. Medical

1. OSHA 200 Logs and Workers Compensation Data

Table 1 summarizes the rates of all injuries and back injuries alone among the selectors in Warehouse 1 between 1987 and 1991. These rates were based upon a population of 67 selectors (54 full-time and 13 part-time) as indicated by the company. The data provided in Table 1 also shows the total number of lost workdays each year due to back injuries and the average number of lost workdays for a back injury case. On average, during the five years, back injuries among the selectors accounted for about 60% of all lost workdays in Warehouse 1, including all jobs and all types of injuries.

According to the Big Bear risk management loss-prevention department, the rate of total OSHA 200 incidents for Warehouse 1 for 1990 was 32.2 lost-time and 12.9 no-lost-time per 200,000 manhours (100 40-hour per week workers). The Bureau of Labor Statistics (BLS) reports that for the Standard Industrial Classification (SIC) code for warehousing (422), which includes grocery warehouses, the average rate for 1990 was 8.2 lost-time and 7.2 no-lost-time incidents per 200,000 manhours. This shows that the rates are higher than the warehousing industry in general and that most of the excess is in lost-time injuries.

Workers compensation data provided by Big Bear for 1991 showed 22 cases of back sprain/strain among all workers in Warehouse 1 (about 16 cases per 100 workers). One investigation found that warehousemen averaged nearly 10 claims per 100 workers in 1984 (Klein et. al., 1984), whereas the annual incidence rate for lifting injuries for the total industrial population is about 2%.

2. Questionnaire

Eighty-one percent of all selectors were present the day the questionnaire was administered, 20 first-shift selectors and 34 second-shift selectors. Of those present, 48 (89%) completed the questionnaire. Of the 48 selectors, 10 were "part-time" temporary workers who had been hired within 6 months of the questionnaire. All questionnaire results are presented with the full-time and part-time workers separated.

Demographics

Table 2 shows the demographics of these groups. The workforce was 100% male, relatively young by national standards, with an average age of 29 years 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 6 years. In terms of physical size, the workers were above average in both height (181.1 cm) and weight (86.7 kg), in the 90th, and 60th percentile, respectively for American male workers.

Reported Injuries and Missed Workdays

Among the 10 part-time selectors, 3 (30%) reported missing work during the past year due to an injury at work. One injury involved the leg, one the elbow, and a third was unspecified. The average number of missed workdays was four. Among the 38 full-time selectors, 19 (50%) reported one or more injuries in the past year. Table 3 shows a detailed description of those full-time workers' reported injuries. Back injuries were the most common injury, with 18% of full-time selectors reporting a back injury during the previous year.

Although still substantial, the rate of back injuries from Table 3 was lower than that found on the OSHA 200 logs, which includes both full-time and part-time workers. This discrepancy can be explained in several ways: 1) workers may forget about minor injuries, 2) the full-time workforce is the most experienced workforce and may have adopted work techniques which protect against injuries, or 3) the full-time workforce represents a select group of workers who may be less likely to develop an injury than all workers. Nonetheless, these findings provide additional evidence that back injuries are a substantial cause of morbidity among grocery selectors.

Reported Symptoms

The body discomfort map shown in Appendix A, Question 14 was simplified into four body part areas for purposes of analysis: neck/shoulder, back, hand/arm, and lower extremity. Figure 2 shows which area were included in each category. 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. Table 4 shows the rate of "very or extremely uncomfortable pain" in each of the four-body part areas. For the full-time workers, over 70% reported significant back pain in the past year, while the rates for the other body parts ranged between 24 and 37%. These finding suggest that in addition to the 20-30% of workers with recorded back injuries, there are a substantial proportion of selectors who continue to work with substantial back pain.

Borg Scale

The full-time workers reported an average Borg score (Appendix A, Question 12) of 17 (very hard physical effort), with a range of 13-20. The part-time workers reported an average of 15 (hard physical effort), with a range of 11-19. These findings correlate well with those found using heart rate and oxygen consumption monitoring, described below.

Job Demand and Control

All of the items included in each of the two scales were combined and overall average demand and control scores were computed. Only the 38 full-time workers were included in this analysis. These results were then compared to the results from a previous NIOSH investigation of 2300 Maine public employees working in a wide range of occupations. The average demand score for the warehouse workers was 3.9 (fairly often demanding), while the average for the Maine public employees was 3.4 (sometimes-fairly often demanding). The biggest difference between these two groups was in their reports of how frequently their job requires them to work very fast or very hard. The average score for these two indicators alone for the warehouse and Maine public employees were 4.2 and 3.2, respectively. The average control score for the warehouse workers was 2.0 (little control), while the average for the public employees was 3.7 (moderate-much control). All of these differences were statistically significant at at least the p=.001 level.

These finding suggest that order selecting is a high-demand low-control job, as compared to a large diverse group of public employees. In particular, the selectors reported a much lower level of control over their job activities. During informal interview with selectors, 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. Biomechanical Data

a. NIOSH Lifting Equation

Table 5 displays the results of the evaluation of five sample lifting tasks that are shown in Figure 1. Information on the use of the NIOSH revised equation and the complete analyses for the five tasks is found in Appendix B. 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 the majority of workers (Waters et al, 1993).

Three of the five lifting tasks (Tasks 2-4) shown in Table 5 required horizontal reach distances that exceed the maximum allowable distance of 25 inches. In order to make the calculation comparable for all 5 tasks, the maximum distance (25 inches) was used in the calculation. For all five of the tasks, the weight lifted (L) far exceeded the RWL, which resulted in LI values ranging between 4.2 and 8.0, respectively.

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 horizontal distance between the load and the body and 2) the frequency of lifts. Therefore, the LI can be brought closer to 1 by either moving the loads closer to the body during a lift and/or decreasing the required lifting rate.

b. Michigan 3-D Model

Table 6 displays the results of the evaluation of the five tasks shown in Figure 1 using the University of Michigan's 3D SSPP model. Four of the five tasks evaluated had a disc compression force at the lumbo-sacral disc greater than 770 pounds (3.4 kN). Compressive force values of 3.4 kN and larger have been identified with increasing rates of reported low back pain and lost time (Herrin et al. 1986). This value also serves as the maximum compressive force level reported as the "biomechanical criterion" for the revised NIOSH lifting equation (Waters et al., 1993).

Those four lifting tasks that produced maximum compressive force levels greater than 770 lbs, based on the available evidence, would pose a significant risk to the majority of workers for the development of low back pain or overexertion injury. The only lifting task with a disc compression value below 770 pounds was Task 4.

Only a fraction of the U.S. male workforce would have the strength capacity at both the hip and torso necessary to perform the five lifting tasks with the attendant postures. In fact, according to the model, only 16 percent of the male working population would have the hip strength capability to perform Task 3, and only about 50% of the workforce would have the hip strength capability to perform Tasks 4 or 5 (52% and 55%, respectively).

Table 6 also provides data on shear force and torsion. Shear force is defined as the transverse force applied perpendicular to the vertical axis of the spinal segment. Resultant shear force is defined as the sum of the sagittal and frontal plane shear force components. Although there are no published criteria on spinal shear forces, the results displayed in Table 6 indicate that substantial shear forces exist for all five lifts evaluated.

Spinal torsion is defined as the magnitude of the twisting moment about the vertical axis of the spinal segment. When someone twists to pick up a load, the musculoskeletal system must develop greater force on one side of the spine than on the other. These asymmetric muscular contractions between the right and left side of the body usually result in torsional moments.

Research evidence suggests that increases in both shear force and spinal torsion, which accompany asymmetric loading, significantly increase the risk of low back disorders, especially when lifting heavy loads (Andersson, 1981; Majora, 1973). For the present, there are limited data to predict the exact relationship between combinations of shear force and torsional levels and the risk of musculoskeletal injury. However, the results displayed in Table 6 seem to indicate that asymmetric loading is present in these five tasks, especially for Task 2. In general, asymmetric loading is associated with lower levels of acceptable lifting capacities and an increased risk of low back injury (Garg and Badger, 1986; Bean et al., 1988).

c. Dynamic Trunk Motion Analysis

<u>Lift Distribution</u>

Table 7 provides a tabulation of the origin and destination of the lifts that were evaluated using the LMM. Of the 306 lifts that were performed by the participants during the measurement period, the LMM successfully recorded data on 216 (70%). From Table 7, it is evident that the 216 lifts were fairly evenly distributed with regard to origin and destination height, with 37, 28, and 35 percent originating in the low (below 30 inches), medium (30-50 inches), and high (above 50 inches) range, respectively, and 23, 37, and 40 percent ending in the low, medium, and high range, respectively. Lifts that both originate and end in the medium height range are considered desirable from a biomechanical perspective. However, only 7.4% of 216 lifts observed during our visit were in this category. This finding indicates that the majority of the tasks required lifting motions that began or ended either high or low.

To simplify the data, all lifts were classified in one of three categories: 1) low, if either the origin or destination was below 30 inches (53% of all lifts); 2) medium, if both the origin and destination were between 30 and 50 inches (7% of all lifts); and 3) high, for all other lifts (40% of all lifts). The lumbar motion monitor was then used to calculate the average trunk motion for all of the lifts in each of the three categories.

Marras et al. (1993) have developed a model using the LMM which, based on an analysis of over 400 industrial jobs, found that five variables were most effective in predicting which job titles were associated with a high rate of back injuries reported on the OSHA 200 logs. These five variables include three trunk motions which were obtained from the LMM: (1) the peak lateral velocity of the trunk, (2) the average twisting velocity of the trunk, and (3) the peak sagittal flexion angle of the trunk (forward bending angle). We computed the remaining two workplace variables needed for the model: (1) the average lifting rate, and (2) maximum L5/S1 moment, which is the product of the average horizontal distance between the worker and the load and the weight of the load.

Table 8 shows the results of these five variables for each of the three lifting categories. Using the Marras model, all three types of lifts would have a high probability of being included in a high risk category for low back injury.

Lifting Rate/Maximum Moment

The average lifting rate for the 216 tasks was 4.1 lifts/minute (246 lifts/hour). Load weights were obtained for 155 of the 216 lifts that were analyzed with the LMM. The average weight of the load for those lifts was 30.4 pounds [135 Newtons (N)]. The horizontal distance of the load from the spine was obtained for 141 of the 216 lifts analyzed with the LMM. The average horizontal distance at the origin of the lift for those lifts was 27.0 inches [0.69 meters (M)]. Thus, for an average lift, the estimated peak static spinal moment was 821 in·lbs (93 N•M).

The values shown in Column 3, Table 8 are based on the same data set, but were combined and averaged by lift height. For the low height range, below 30 inches, the maximum moment averaged 92 N·M; for the medium height, 30 - 50 inches, the maximum moment averaged 126 N·M; and, for heights above 50 inches, the maximum moment averaged 87 N·M. Maximum moments of this magnitude are likely to generate lumbo-sacral disc compressive forces well above the value of 3400 N, chosen as the upper limit of the biomechanical criterion for the revised NIOSH lifting equation (Waters et al, 1993).

Rotation Angle.

As the height of the lifts increased, there was a significant decrease in the average peak sagittal lumbar flexion angle ($p = 0.047$). The average peak (maximum) sagittal flexion recorded for the low, medium, and high categories was 56, 38, and 28 degrees, respectively (Column 4, Table 8). There were no significant differences between frontal and transverse ranges of motion.

The average peak transverse velocity for the low, medium, and high height categories was 42.6, 46.2, and 43.2 degrees/second, respectively. In a recent paper by Marras et al. (1993), the average twisting (transverse) velocity during a dynamic activity was found to be a better predictor of injury risk than the peak twisting velocity. Therefore, 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 5.9, 5.8, and 6.5 degrees/second for the low, medium, and high height categories, respectively (Column 5, Table 8).

As with the range of motion variable, there was no significant difference in the average peak frontal or transverse velocity between the three height categories. The average peak lateral velocity was 31.0, 33.3, and 26.0 degrees/second, for the low, medium, and high category, respectively (Column 6, Table 8).

2. Metabolic Data

Table 9 displays a summary table of results for evaluating the metabolic 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, measured average heart rate, and predicted metabolic rate. The length of time required to complete the order varied from 18 to 31.5 minutes, depending on the size of the order and the worker's pace.

During the monitored work cycles, all three participants exceeded the criterion for energy expenditure (5.0 kcal/min, as measured by oxygen consumption, and predicted using Garg's metabolic model). The aerobic work load, which ranged from 5.4 kcal/min to 8.0 kcal/min in our sample, is typically defined as "heavy" to "very heavy" work for individuals of average capacity (Eastman Kodak, 1986, Table 26-24). Average heart rates over the duration of the selection cycle for two of the three workers also exceeded the criterion of 110 beats per minute, recognized as acceptable for workers (Astrand and Rodahl, 1986). Average heart rates for younger, highly conditioned workers can be lower than what is found among the general working population.

Based on the metabolic assessments of three workers and the assessment of energy demands required to perform the job of order selector, these jobs pose a significant risk for overexertion injury from excessive physical fatigue for the majority of healthy workers who would perform this type of job. This conclusion is based on the energy demands of the jobs, which exceeded 5 Kcal/min.

3. Workplace Layout Analyses:

Two different types of racks or slots for storing the grocery items are used in Warehouse 1: (1) a one-level pick or single tier (walk-in slot, double deep) that was approximately 75" high by 101" wide and 105" deep, and comprised about 80% of the slots, and (2) a double tier (2-level pick) that also was 101" wide by 51" deep, but had an opening height of 98." The lower tier opening provided a 46" high clearance, and the upper tier clearance height was also 46." The two tiers were separated by a 5" shelf. The pallets on which the groceries were stored added another 3 - 4," which resulted in reduced head clearance.

Most workers under 6' were able to stand up in the walk in-slots, whereas with the double-tier slots workers typically had to squat or bend at the waist to reach the items in the lower slot. Workers were observed kneeling and crawling to reach some objects in the lower racks. Selecting grocery items from the top tier, located at a height of 51" could also pose a stress for shorter workers, since 51" is only 7" below the shoulder height of an average male. This effort is increased when the workers have to reach for objects which are located further back in the slot. Again, 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 selection order. Workers were observed climbing on their jacks to build their load to accommodate the size of the order. This poses a risk of falling and produces high levels of shoulder stress to maneuver heavy items above one's head. Workers were also observed having to hold objects in place on the pallet as they organized the fitting of boxes on the pallet.

C. Heat Stress

The heat stress potential that the grocery selectors were exposed to was evaluated in both the Spring and Summer seasons. During this evaluation, WBGT measurements were collected at a stationary location (in the center of the warehouse) as well as throughout the building. Environmental heat (WBGT) measurements were also obtained on a pallet jack when it was used for selecting orders.

The WBGT data collected during the Spring and Summer surveys are presented in Table 10 and Table 11, respectively. A total of 12 locations were selected, spatially spread throughout the warehouse to include sample locations in the front near the loading dock, in the back close to the axial fans as well as in central zones of the building. A meter, which logged heat stress data at 5-minute intervals (through most of the first shift), was also positioned in Aisle 56, slot 3810, in the center of the warehouse.

The purpose of the Spring survey was to establish the baseline conditions that the warehouse workers experienced during mild weather of spring and fall. During this evaluation, the ambient temperature (dry bulb) ranged from 70º F around noon to 62ºF shortly after 6:00 PM. The interior heat conditions on May 14, 1992, were also quite mild and reasonably consistent throughout the building. The DB measurements ranged from 73 - 77ºF, with WBGT measurements that ranged from 62 - 65ºF. Relative humidities inside and outside the warehouse were consistently in the mid 30%. The air velocity within the warehouse was typically below 50 feet per minute, unless a pallet jack or fork lift passed, producing a moderate wind.

The Summer heat stress evaluation was performed on a warm day that was partly cloudy with a peak ambient air (dry bulb) temperature of 93ºF. Although this is not the most extreme hot weather one would expect in Columbus, Ohio, it does represent typical conditions of the summer months for this geographic location. The WBGT heat stress measurements recorded spatially throughout the warehouse were reasonably close to one another. Temperatures in the front of the warehouse near the loading dock and numerous bay doors were slightly higher than those in the rest of the building. (The large axial fans in the back of the building exhausted air, which was replaced by outside air infiltrating through the bay doors where trucks were staged.) The early afternoon WBGT measurements ranged from 77.1 - 79.2ºF, with a mean of 77.7ºF, and the late afternoon average WBGT was 77.0ºF. The data obtained from the fixed monitoring location were consistent with these values. The dry bulb and globe temperatures were very similar (demonstrating the lack of a significant radiant source), and the DB increased as the day progressed (from 83.5 to 85.5ºF). As the day proceeded into the late afternoon and early evening, the WBGT measurement slowly decreased, largely due to the wet bulb temperature reductions. The data collected on the pallet jacks suggested that any cooling effect obtained from riding the jacks was insignificant, since the workers typically walk the jack to each grocery slot and only ride between aisles and back to the dispatch office.

In order to apply the WBGT measurement to the evaluation criteria, an estimate of the metabolic rate necessary to perform the work and a characterization of the work-rest regimen are required. The heart rate monitoring and oxygen consumption measurements allowed the investigators to identify the specific metabolic rates during the measured order selection. In addition to this estimation, Table 13 presents the metabolic rate estimation based on the job cycle tasks utilizing the metabolic rate approximations provided in Table 12. Both of these methods provided estimates of metabolic rates which were reasonably close to each other, ranging from 5.0 to 7.1 kcal per minute. The metabolic rate of the grocery selector job was determined to be moderate to high, in regards to a heat stress evaluation. The production standards and work shift schedule during the order selecting resulted in a 100% work-0% rest regimen.

The **NIOSH Recommended Exposure Limit** (REL) to environmental heat for heat acclimatized workers functioning at a metabolic rate of 400 kcal/hr and a 100% work-0% rest cycle is a WBGT of 79°F (NIOSH, 1986). The ACGIH Threshold Limit Value (TLV) WBGT for a moderate to high work rate (approximately 400 kcal/hr) and a 100 work-0% rest cycle is also 79°F. The WBGT heat exposure observed in the warehouse during a typical summer day **approached these criteria**. During more extreme heat conditions of peak summer weather the heat stress exposure for the grocery selectors would probably exceed the evaluation criteria.

Prolonged exposure to excessive heat may cause increased irritability, lassitude, decrease in morale, increased anxiety, and inability to concentrate. The acute physical disabilities caused by excessive heat exposure are, in order of increasing severity: heat rash, heat cramps, heat exhaustion, and heat stroke. Refer to Appendix C for a description of these acute heat stress effects. There are other concerns besides health effects from excessive exposure to heat stress. Ramsey et al describe an increase in unsafe acts associated with exposure to environmental heat, as well as with increased level of physical work (Ramsey et al, 1983).

The control of occupational heat exposure can be accomplished by addressing the heat balance components that significantly contribute to heat gain (stress). The four environmental heat exchange components which potentially contribute to heat stress and possible methods of control are described below (NIOSH, 1986; ACGIH, 1988; Belding, 1973):

Metabolic heat - Metabolic heat can be reduced by mechanization of some or all tasks, increasing rest time, reducing work pace, and sharing the work load with additional workers (particularly during peak heat periods).

Radiant heat gain - Reduction of radiant heat gain can be accomplished by shielding the worker line of sight to the radiant source, insulating radiant heat sources, using reflective screens, wearing radiant reflective clothing (especially if the worker directly faces the source), and covering exposed body parts. None of these apply to Big Bear Warehouse since radiant heat was not a significant contributor to the heat load.

Convective heat exchange - Heat can be gained or lost by convection depending on the air temperature. If the air temperature exceeds the mean skin temperature (considered to be 95°F), then increasing air movement across the skin will contribute to convective heat gain. Control of heat gain under these conditions will require reducing the air temperature, reducing air velocity, and wearing lose fitting (single layer) clothing. If the air temperature is below 95°F, increasing the convective heat loss can be accomplished by increasing air velocity across the skin, removing clothing (maximizing exposed skin surface), and decreasing the air temperature.

Evaporative heat loss - The maximum evaporative cooling capacity of the environment can be expanded by increasing the air velocity and by decreasing the water vapor pressure (humidity) of the work atmosphere. Consideration must be given to the potential of convective heat gain when increasing air velocity, since the benefit of evaporative cooling may be overcome by the convective heat gain due to high air temperatures (≥95°F).

In addition to modifying the work place environmental conditions, the risk of a serious incident due to excessive heat exposure can be reduced by the implementation of a heat stress management program. This is especially important when modification of the environmental conditions is not feasible. The elements of a comprehensive **heat stress management program** is provided in Appendix D.

VI. 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 and physiological 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 selectors in Warehouse 1.

In summary, the order selectors have an elevated risk for musculoskeletal disorders, including low back pain, because of the combination of adverse job factors all contributing to fatigue including heat stress in hot weather, 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 selector 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, all of the lifting tasks that were sampled 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 ergonomically stressful.

2) Estimated compressive force on the L5/S1 disc exceeded the recommended biomechanical limit of 770 lbs (3.4 KN), identified by NIOSH as an upper limit for protecting most workers from the risk of low back injury.

3) 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 (56 degrees) and highest velocities and accelerations.

4) Based on the fact that spinal forces increase as the flexion angle increases, the results here indicate that 53% of lifts (those included in the low category) would be associated with the greatest biomechanical spine loading, especially when the increased accelerations are considered.

5) Although Marras's model has not been fully validated, it indicates a high probability that warehouse grocery selector 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 selectors, a prediction borne out by the company's OSHA logs and workers' claims and the questionnaire survey.

6) Based on average energy demands, the job of order selector exceeded the established criterion of 5 kcal/min (4 METS) for an 8-hr day, which is recognized as moderate to heavy work for a majority of healthy workers.

7) The order selectors at the worksite frequently had an average heart rate of more than 110 beats per minute, which has been suggested as the minimum acceptable for the majority of healthy workers.

8) The order selectors' physiologic energy demands from continuous lifting at a rate of 4.1 lifts/minute (246 lifts/hour) would probably result in fatigued muscles, especially when extended shifts of 10 hours are considered.

9) Ergonomic evaluations showed that the racks were very deep, and the stacking arrangement resulted in most grocery items being located either too high or too low. In addition, the order selectors 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.

10) Data collected from OSHA 200 logs, workers' compensation logs, and employee questionnaires all found a high rate of back injuries amongst the order selectors.

11) The heat stress exposure during grocery selecting on a moderately hot summer day approached the NIOSH and ACGIH WBGT heat stress criterion. This was largely due to the work activities that resulted in moderate to high metabolic heat production.

12) The dry bulb temperature of the air within the warehouse was cool enough (<95ºF) to provide for convective heat loss if air velocity were increased.

13) A source of cool potable water was not easily accessible (on the pallet jacks) at the immediate vicinity of the order selecting.

14) The company lacked a comprehensive heat stress management program, including effective medical examinations and policies.

15) Self-regulation of work activity by selector employees, an important safeguard which reduces the potential for a serious heat related incident, is not compatible with maintaining the incentive standards.

16) 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.

VII. Limitations

This investigation performed a number of assessments of the ergonomic characteristics and potential for heat stress of specific job tasks performed by order selectors. 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 selector 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 worker compensation records, OSHA logs and the questionnaire survey.

VIII. Recommendations

A. Ergonomic

The selectors' 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 selectors, 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 selector's job are very high, even with the recommended changes, certain administrative will be necessary, such as worker rotation, to reduce the future risk of injury and illness among the order selectors.

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 eight-hour 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 a walk 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.

B. Heat Stress

A number of control options are available for addressing occupational heat exposure; these include engineering controls, administrative controls, and personal protective equipment. Typically, implementation of a single control will not adequately address the entire heat stress problem. It is prudent to identify the most significant conditions that contribute to the heat stress so that the initial focus of the corrective measures address the most hazardous heat balance component. During hot periods, when worker exposure exceeds or approaches the WBGT criterion, the following recommendations should be considered:

1) The grocery selectors' metabolic heat production should be reduced by relaxing the work pace and/or by increasing rest time in cool locations.

2) Provide space cooling fans in the aisles of the warehouse to maximize evaporative cooling due to the increased air velocity.

3) When exterior temperatures are significantly higher than those in the warehouse, uncooled outside air should not be brought into the building by operating the (existing) exhaust fans. (Implementation of this recommendation requires alternative equipment to create air movement and circulation within the warehouse; otherwise, failure to operate the exhaust fans would reduce the air movement and adversely impact evaporative heat loss.)

4) Install ceiling vents to assist in removing heat from within the building.

5) Provide large-capacity supply air fans on the dock side of the warehouse (on the opposite side of the warehouse from the existing exhaust fans already present). These fans should be operated in conjunction with the exhaust fans in the evenings and night hours to bring cool air into the warehouse and remove hot air.

6) Ensure that extra precautionary measures are implemented for protecting unacclimatized workers such as reduced work rate expectations, increased resting time, and gradually increased work loads to allow for safe heat acclimatization. This is especially important during sudden heat waves or when a worker returns to work after a prolonged absence.

7) Provide cool drinking water on each pallet jack so that order selectors have easy accessibility to water at their work locations.

8) Implement a comprehensive heat management program, which includes heat alert policies that are based on environmental conditions.

IX. References

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XI. DISTRIBUTION AND AVAILABILITY

Copies of this report may be freely reproduced and are not copyrighted.

Copies of this report have been sent to:

1. Big Bear Stores Company, Columbus, Ohio
2. United Industrial Workers Union
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 Selectors
Big Bear Grocery Warehouse 1

Year	**All Injuries**		**Back Injuries**		**Back-Related Lost Workdays**	
	# Cases	**Rate**	**# Cases**	**Rate**	**Total #**	**Average #[1]**
1991	35	52%	19	28%	642	34
1990	54	81%	21	31%	932	44
1989	58	87%	26	39%	468	18
1988	59	88%	21	31%	710	34
1987	53	79%	19	28%	288	15

[1] Average number of lost-workdays for each back injury case

Table 2
Demographics of Study Participants
Big Bear Grocery Warehouse 1

	Full-Time Selectors	**Part-Time Selectors**
Average Age (range)	30 yrs (19-47)	25 yrs (19-31)
% Male	100%	100%
Average Yrs at Big Bear (Range)	4 yrs (1-12)	less than 1 yr
Average Yrs at Other Warehouse (range)	3 yrs (0-18)	less than 1 yr (0-5)
Average Height (range)	71 inches (66-76)	71 inches (66-76)
Average Weight (Range)	189 lbs (150-290)	192 lbs (158-233)

Table 3
Injuries and Missed Workdays Reported by Questionnaire
Occurring During the Previous 12 Months
Big Bear Grocery Warehouse 1 Full-Time Selectors Only

Body Part	Injuries		Average # Missed Workdays	Range of Missed Workdays
	Number[1]	Rate		
Back	6	18%	91	0-510
Neck/Shoulder	5	13%	26	0-90
Lower Extremity	5	13%	2	0-5
Hand	3	8%	3	0-7

[1] This column adds up to 20 because one worker reported two injuries (Back and Hand)

Table 4
Rate of Reported Discomfort
Big Bear Grocery Warehouse 1 Selectors

Body Part	Full-Time Selectors (N=38)	Part-Time Selectors (N=10)
Neck/Shoulder	37%	60%
Back	71%	40%
Lower Extremity	37%	10%
Hand/Arm	24%	40%

Table 5
Summary results of NIOSH Lifting Equation Evaluation
Big Bear Grocery Warehouse 1 Selectors

TASK #	LOAD	LIFTING EQUATION COMPONENTS							RESULTS	
		LC	HM	VM	DM	CM	AM	FM	RWL	LI
1	30 lbs	51	0.46	0.81	0.89	0.95	1.00	0.45	7.2 lbs	4.2
2	38 lbs	51	0.40*	0.87	1.00	0.95	0.89	0.45	6.8 lbs	5.6
3	42 lbs	51	0.40*	0.92	0.89	0.95	0.73	0.45	5.2 lbs	8.1
4	38 lbs	51	0.40*	0.78	1.00	1.00	0.72	0.45	5.2 lbs	7.3
5	58 lbs	51	0.48	0.89	1.00	0.95	0.77	0.45	7.2 lbs	8.0

* 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 exercise, the HM was set to the maximum of 25 inches for comparison purposes.

TABLE 6
Summary Results of 3-D Biomechanical Analysis
Big Bear Grocery Warehouse 1 Selectors

Task	Load	Disc Comp.	% Capable*		Shear Force	Torsion
			Hip	Torso		
1	30 lbs	930 lbs	63	94	123 lbs	69 ft-lb
2	38 lbs	830 lbs	70	95	131 lbs	113 ft-lb
3	42 lbs	896 lbs	16	76	116 lbs	40 ft-lb
4	38 lbs	662 lbs	52	59	87 lbs	61 ft-lb
5	58 lbs	801 lbs	55	86	112 lbs	68 ft-lb

* The minimum percentage of the male working population who have sufficient strength for that lifting task

Table 7
Lifting Task Conditions by Origin and Destination
Big Bear Grocery Warehouse 1 Selectors

Origin	**Destination**			
	Low	**Medium**	**High**	**Total**
Low	15 (7%)	36 (17%)	29 (13%)	80 (37%)
Medium	10 (5%)	16 (7%)	34 (16%)	60 (28%)
High	24 (11%)	28 (13%)	24 (11%)	76 (35%)
Total	49 (23%)	80 (37%)	87 (40%)	216 (100%)

Table 8
Dynamic Lifting Task Analysis
Big Bear Grocery Warehouse 1 Selectors

Height Range	**Lift Rate (Lifts/HR)**	**Max. Moment (N·M)**	**Maximum Sagittal Flexion (Degrees)**	**Average Transverse Velocity (Deg/Sec)**	**Maximum Lateral Velocity (Deg/Sec)**
Low	246	92.0	55.7	5.9	31.0
Medium	246	126.0	37.5	5.8	33.3
High	246	87.0	28.0	6.5	26.0

Table 9
Summary Table For Metabolic Criteria
Big Bear Grocery Warehouse 1 Selectors

Participant	Variables	Value
1	Total Cases/order	167
	Total Weight/order	2198 lbs
	Allowed Time/order	34.9 min
	Weight/min	63 lbs/min
	Performance Index*	116%
	Working Metabolic Rate	5.4 kcal/min
	Working Heart Rate	122 beats/min
	Predicted Metabolic Rate	6.0 kcal/min
2	Total Cases/order	138
	Total Weight/order	4220 lbs
	Allowed Time/order	36.7 min
	Weight/min	115 lbs/min
	Performance Index	116%
	Working Metabolic Rate	5.9 kcal/min
	Working Heart Rate	104 beats/min
	Predicted Metabolic Rate	5.0 kcal/min
3	Total Cases/order	101
	Total Weight/order	3862 lbs
	Allowed Time/order	25.8 min
	Weight/min	150 lbs/min
	Performance Index	143%
	Working Metabolic Rate	8.0 kcal/min
	Working Heart Rate	131 beats/min
	Predicted Metabolic Rate	7.6 kcal/min

* Performance Index = (allowed time per order/actual time per order) * 100

Table 10
Heat and Humidity Measures on May 14, 1992
Big Bear Grocery Warehouse 1

GRID, EARLY PM, (13:05 - 14:40)					
	WB*	DB*	GT*	WBGT*	RH
Minimum	57.2	73.1	74.3	62.3	
Maximum	60.3	75.9	77.5	65.4	
Mean	58.4	74.4	75.5	63.5	37.5%
Outside (shade)	55.1	69.6	76.2	61.4	37.5%

GRID, LATE PM, (17:00 - 18:15)					
	WB	DB	GT	WBGT	RH
Minimum	56.7	73.6	75.0	62.3	
Maximum	59.3	77.4	77.5	64.7	
Mean	58.1	75.2	75.7	63.4	35%
Outside - shade, (18:50)	49.0	62.3	64.6	53.7	37.5%

STATIONARY, (12:25 - 18:30)					
	WB	DB	GT	WBGT	RH
Minimum	57.9	73.6	74.7	63.0	
Maximum	60.5	76.3	77.1	65.5	
Mean	59.1	75.2	76.2	64.2	37.5%

* Degrees Fahrenheit

Table 11
Heat and Humidity Measures on July 14, 1992
Big Bear Grocery Warehouse 1

GRID, EARLY PM, (11:35 - 13:05)					
	WB*	DB*	GT*	WBGT*	RH
Minimum	74.4	82.6	83.5	77.1	
Maximum	76.0	87.4	85.3	79.2	
Mean	74.9	84.1	84.5	77.7	65%
Outside (shade)	75.5	92.8	100.6	83.0	45%

GRID, LATE PM, (16:50 - 18:15)					
	WB	DB	GT	WBGT	RH
Minimum	72.9	84.2	84.9	76.5	
Maximum	73.9	88.7	88.8	77.9	
Mean	73.3	85.4	85.8	77.0	55%
Outside (shade)					
16:50	73.4	89.9	93.8	79.5	45%
18:15	73.0	88.6	90.2	78.1	47.5%

STATIONARY, (11:15 - 17:50)					
	WB	DB	GT	WBGT	RH
Minimum	73.1	83.5	83.2	76.7	
Maximum	75.1	85.5	85.6	77.8	
Mean	74.0	84.6	84.8	77.2	60%

* Degrees Fahrenheit

Table 12
Metabolic Heat Production Rates by Task Analysis
Big Bear Grocery Warehouse 1

A. Body Position and Movement		**kcal/min***
Sitting Standing Walking Walking uphill		0.03 0.6 2-0-3.0 add 0.8 per meter rise
B. Type of Work	**Average kcal/min**	**Range kcal/min**
Hand work light heavy	 0.4 0.9	 0.2-1.2
Work one arm light heavy	 1.0 1.8	 0.7-2.5
Work both arms light heavy	 1.5 2.5	 1.0-3.5
Work whole body light moderate heavy very heavy	 3.5 5.0 7.0 9.0	 2.5-9.0
C. Basal metabolism	1.0	
D. Sample calculation**		**Average kcal/min**
Assembling work with heavy hand tools 1. Standing 2. Two-arm work 3. Basal metabolism Total		 0.6 3.5 1.0 5.1 kcal/min

* For standard worker of 70 kg body weight (154 lbs.) and 1.8 m^2 body surface (19.4 ft^2).
** Example of measuring metabolic heat production of a worker when performing initial screening.

Table 13.
Estimated Metabolic Rate, Grocery Selectors
Big Bear Grocery Warehouse 1

	Range[1] (Kcal/min)	Estimate (Kcal/min)
Body Position 1. Always standing and walking	0.6 2.0-3.0	1.5
Type of Work[2] 1. LIFTING and CARRYING Whole body - moderate weights, repetitive lifts, high pace. 2. PALLET FORMING Both Arms - with bending and reaching	6.0 2.0	4.5[2]
Basal Metabolism	1.0	1.0
Summation		7.0
Hourly Estimation		420
Metabolic Rate Work Category		Moderate to high

NOTES:
[1] From Reference 1, Table 12.
[2] Worker spends most of the work cycle lifting and carrying (6.0 Kcal/min), with the remainder of time spent pallet forming (2.0 Kcal/min) and walking pallet jack to the next slot.
[3] kcal/min = kilocalories per minute.

Appendix B
NIOSH Lifting Equation Calculations
Big Bear 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)	
CM = Coupling Multiplier	(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: $\leq$ 1 hour; $\leq$ 2 hours; or $\leq$ 8 hours assuming appropriate recovery allowances (See Table X).

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 $\geq$ 75 cm (30 in)
	Coupling Multipliers	
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

Appendix C
Acute Physical Effects Caused by Excessive Heat Stress.
Big Bear Grocery Warehouse

Heat rash - Heat rash (prickly heat) may be caused by unrelieved exposure to hot and humid air. The openings of the sweat ducts become plugged due to the swelling of the moist keratin layer of the skin which leads to inflammation of the glands. There are tiny red vesicles (fluid filled bumps) visible in the affected area and, if the affected area is extensive, sweating can be substantially impaired. This may result not only in discomfort, but in a decreased capacity to tolerate heat.

Heat cramps - Heat cramps may occur after prolonged exposure to heat with profuse perspiration and inadequate replacement of salt. The signs and symptoms consist of spasm and pain in the muscles of the abdomen and extremities, especially in the muscles which are working the hardest. Albuminuria (protein in the urine) may be a transient finding.

Heat exhaustion - Heat exhaustion may result from physical exertion in a hot environment when vasomotor control (regulation of muscle tone in the blood vessel walls) and cardiac output are inadequate to meet the increased demand placed upon them by peripheral vasodilation or the reduction in plasma volume due to dehydration. Signs and symptoms of heat exhaustion may include pallor, lassitude, dizziness, syncope, profuse sweating, and cool moist skin. There may or may not be mild hyperthermia.

Heat stroke - Heat stroke is a medical emergency. An important predisposing factor is excessive physical exertion. Signs and symptoms may include dizziness, nausea, severe headache, hot dry skin due to cessation of sweating, very high body temperature [usually 106 °F (41 °C) or higher], confusion, delirium, collapse, and coma. Often circulation is compromised to the point of shock. If steps are not taken to begin cooling the body immediately, irreversible damage to the internal organs and death may ensue.

Appendix D
Elements of a Comprehensive Heat Stress Management Program.
Big Bear Grocery Warehouse

Written program - A detailed written document is necessary to specifically describe the company procedures and policies in regards to heat management. The input from management, technical experts, physician(s), labor union, and the affected employees should be considered when developing the heat management program. This program can only be effective with the full support of plant management.

Environmental monitoring - In order to determine which employees should be included in the heat management program, monitoring the environmental conditions is essential. Environmental monitoring also allows one to determine the severity of the heat stress potential during normal operations and during heat alert periods.

Medical examinations and policies - Preplacement and periodic medical examinations should be provided to all employees included in the heat management program where the work load is heavy or the environmental exposures are extreme. Periodic exams should be conducted at least annually, ideally immediately prior to the hot season (if applicable). The examination should include a comprehensive work and medical history with special emphasis on any suspected previous heat illness or intolerance. Organ systems of particular concern include the skin, liver, kidney, nervous, respiratory, and circulatory systems. Written medical policies should be established which clearly describe specific predisposing conditions that cause the employee to be at higher risk of a heat stress disorder, and the limitations and/or protective measures implemented in such cases.

Work schedule modifications - The work-rest regime can be altered to reduce the heat stress potential. Shortening the duration of work in the heat exposure area and utilizing more frequent rest periods reduces heat stress by decreasing the metabolic heat production and by providing additional recovery time for excessive body heat to dissipate. Naturally, rest periods should be spent in cool locations (preferably air conditioned spaces) with sufficient air movement for the most effective cooling. Allowing the worker to self-limit their exposure on the basis of signs and symptoms of heat strain is especially protective since the worker is usually capable of determining their individual tolerance to heat. However, there is a danger that under certain conditions, a worker may not exercise proper judgement and experience a heat-induced illness or accident.

Acclimatization - Acclimatization refers to a series of physiological and psychological adjustments that occur which allow one to have increased heat tolerance after continued and prolonged exposure to hot environmental conditions. Special attention must be given when administering work schedules during the beginning of the heat season, after long weekends or vacations, for new or temporary employees, or for those workers who may otherwise be unacclimatized because of their increased risk of a heat-induced accident or illness. These employees should have reduced work loads (and heat exposure durations) which are gradually increased until acclimatization has been achieved (usually within 4 or 5 days).

Clothing - Clothing can be used to control heat stress. Workers should wear clothing which permits maximum evaporation of perspiration, and a minimum of perspiration run-off which does not provide heat loss, (although it still depletes the body of salt and water). For extreme conditions, the use of personal protective clothing such as a radiant reflective clothing, and torso cooling vests should be considered.

Buddy system - No worker should be allowed to work in designated hot areas without another person present. A buddy system allows workers to observe fellow workers during their normal job duties for early signs and symptoms of heat intolerance such as weakness, unsteady gait, irritability, disorientation, skin color changes, or general malaise, and would provide a quicker response to a

Appendix D (cont.)
Elements of a Comprehensive Heat Stress Management Program.
Big Bear Grocery Warehouse

heat-induced incident.

Drinking water - An adequate amount of cool (50-60ºF) potable water should be supplied within the immediate vicinity of the heat exposure area as well as the resting location(s). Workers who are exposed to hot environments are encouraged to drink a cup (approximately 5-7 ounces) every 15-20 minutes even in the absence of thirst.

Posting - Dangerous heat stress areas (especially those requiring the use of personal protective clothing or equipment) should be posted in readily visible locations along the perimeter entrances. The information on the warning sign should include the hazardous effects of heat stress, the required protective gear for entry, and the emergency measures for addressing a heat disorder.

Heat alert policies - A heat alert policy should be implemented which may impose restrictions on exposure durations (or otherwise control heat exposure) when the National Weather Service forecasts that a heat wave is likely to occur. A heat wave is indicated when daily maximum temperature exceeds 95ºF or when the daily maximum temperature exceeds 90ºF and is at least 9ºF more than the maximum reached on the preceding days.

Emergency contingency procedures - Well planned contingency procedures should be established in writing and followed during times of a heat stress emergency. These procedures should address initial rescue efforts, first aid procedures, victim transport, medical facility/service arrangements, and emergency contacts. Specific individuals (and alternatives) should be assigned a function within the scope of the contingency plan. Everyone involved must memorize their role and responsibilities since response time is critical during a heat stress emergency.

Employee education and training - All employees included in the heat management program or emergency contingency procedures should receive periodic training regarding the hazards of heat stress, signs and symptoms of heat-induce illnesses, first aid procedures, precautionary measures, and other details of the heat management program.

Assessment of program performance and surveillance of heat-induced incidents - In order to identify deficiencies with the heat management program a periodic review is warranted. Input from the workers affected by the program is necessary for the evaluation of the program to be effective. Identification and analysis of the circumstances pertinent to any heat-induce accident or illness is also crucial for correcting program deficiencies.