ERGONOMIC INTERVENTION FOR THE SOFT DRINK BEVERAGE DELIVERY INDUSTRY

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

July 1996

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DHHS (NIOSH) Publication No. 96-109

ABSTRACT

The National Institute for Occupational Safety and Health (NIOSH) conducted an ergonomic study to investigate, identify, and reduce risk factors that may cause musculoskeletal disease and injury in the soft drink beverage delivery industry.

Nine soft drink beverage driver-salesworkers ages 34 to 58 were evaluated over a 4-month period, and ergonomic evaluations of their truck bays showed that the drivers exceeded the normal reach limit for workers. Extended reaches for heavy beverage cases can significantly increase the risk of musculoskeletal injuries. Most of the beverage lifting tasks also exceeded the recommended weight limit (RWL) when judged against the NIOSH lifting criteria. Heart rate measurements, an indirect measurement of metabolic demand, were high among the driver-salesworkers, especially during peak delivery periods. The physically demanding job of delivering beverages was shown to be associated with twice as many lost workdays as that of workers in general manufacturing jobs.

Ergonomic interventions to reduce and prevent musculoskeletal injuries which were implemented during the field survey included:

- ❒ Engineering controls for easier access to beverage products; such as,
  - a. pullout steps,
  - b. external handles, and
  - c. multilevel shelving units.
- ❒ 2-wheel hand trucks with counterbalancing devices.
- ❒ Substitution of plastic beverage containers instead of glass containers to reduce weight.
- ❒ Improved beverage carton design for better manual coupling during beverage product handling.

Changes in work risk factors were documented through:

- ❒ Videotaping.
- ❒ Biomechanical modeling of manual material handling.
- ❒ Continuous heart rate monitoring.
- ❒ Analysis of psychophysical discomfort assessment surveys.

Differences in work risk factors were compared before, during, and after ergonomic interventions were made to the beverage delivery trucks and in the delivery process.

Initially, discomfort reporting increased while new work routines and use of ergonomic interventions were developed for beverage delivery tasks. The lower back, knees, right elbow, and right shoulder were the most frequently reported locations of discomfort. However, as the beverage driver-salesworkers developed experience with the ergonomic interventions (approximately 3 weeks), both frequency and magnitude of body discomfort reporting decreased. Rest breaks during peak delivery periods also reduced fatigue and helped prevent injuries.

The benefits of the ergonomic interventions were in proportion to the amount of time such controls were used. Reductions in biomechanical stressors for the back and shoulders were observed when pullout steps, external handles, and multilevel shelving were used. Heart rate decreased for six of nine driver-salesworkers from the beginning versus the end of the survey, despite a slight increase in the product volume handled. The ergonomic interventions, in combination with improved work practices, reduced reports of worker fatigue, reduced multiple handling of beverage cases, and decreased awkward postures during beverage handling. In general, the beverage delivery industry should benefit from the lessons learned in this study and the resulting recommendations.

ACKNOWLEDGMENTS

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INTRODUCTION

The **National Institute for Occupational Safety and Health** (NIOSH) is the primary Federal agency engaged in occupational safety and health research. Located in the Department of Health and Human Services (DHHS), Centers for Disease Control and Prevention (CDC), NIOSH was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct research and educational programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) located in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering (DPSE) has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial processes, or specific control techniques. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

The goal of this study is to apply ergonomic controls and measure the effectiveness in reducing musculoskeletal injuries through psychophysical, physiological, and biomechanical methods in the soft drink beverage delivery industry. It should be noted that this study evaluated musculoskeletal hazards collectively; it did not study risk factors. Since the driver-salesworkers were self-selected volunteers, the demographic risk factors could not be studied. Nine driver-salesworkers with an average of 20 years of experience participated in this study.

Since the invention of artificially carbonated water nearly two hundred years ago, soft drink manufacturing has become one of the nation's most important food industries.[1] On average, Americans consume the equivalent of 12 ounces (oz) per day which averages to 32 gal per year. The industry has its roots in Philadelphia, Pennsylvania where a company started producing the bottled soda in the early 1830s.[2] The idea quickly caught on, and today approximately 1,300 soft drink manufacturers employ more than 100,000 workers and compete in a 25-billion dollar market for non-alcoholic beverages.[3] Added to this are the changing consumer tastes and needs which create an ever-increasing selection of products in various shapes and sizes. Many small bottlers have quit the soft drink industry because of the difficulty in adapting to changing products and packaging strategies.[4] This is evident when comparing the 1,300 plants in 1990 versus the over 3,400 plants in 1960. Because of this decrease, the average number of employees per facility has increased from 35 in 1967 to 80 in 1990.[1,4]

However, the popularity of the soft drink has not come without a price. Soft drink manufacturers experience a high incidence of workplace accidents and injuries. In 1992, the injury and illness rate for this industry was 18.5 cases per 100 full-time employees. This was above the 12.5 rate in manufacturing as a whole, and more than double the private industry rate of 8.9 cases per 100 full-time employees.[1,4,5] Moreover, nearly three-fifths of the injury and illness cases in the soft drink manufacturing industry were serious enough to require time off from work.

At 12.2 cases per 100 full-time employees, the industry's 1990 injury and illness rate for lost workday cases ranked sixth highest among corresponding rates reported for some 370 individual manufacturing industries. Ten years earlier it ranked thirteenth highest (11.9 cases per 100 full-time employees).[1,4] Soft drink workers had a comparatively high risk for sustaining a serious (lost worktime) injury or illness, but they returned to work more quickly than workers in other industries with an average of 18 workdays per lost workday case in 1990; this represents 3 days fewer lost workdays for injury and illness per year when compared to private industry as a whole or to all manufacturing. Figure 1 shows injury and illness incidence rates for all private industry, all manufacturing, and the soft drink manufacturing industry from 1980 to 1992.[5]

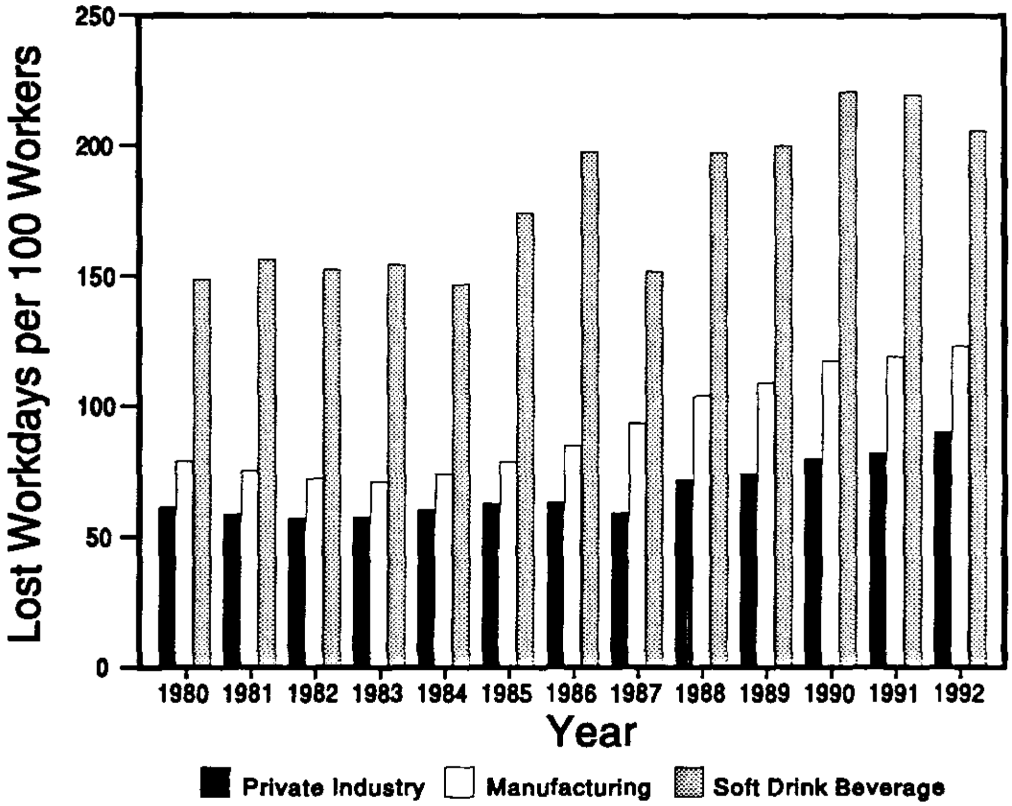

Figure 1. Bureau of Labor Statistics (BLS) Injury and Illness Incidence Report for Private Industry, Manufacturing, and the Soft Drink Beverage Industry from 1980 to 1992. **[Note: The BLS no longer publishes total lost workdays by industry beginning in 1992. The 1992 lost workdays data was acquired from BLS by telephone request.]**

The Supplementary Data System (SDS), which contains injury and illness information from 14 states for 1988, identifies four basic injury and illness case characteristics:

- Physical condition (nature) of injury or illness
- Part of body affected
- Event or exposure (type) of injury or illness
- Source of injury or illness[1,4]

For the soft drink industry, strain or sprain was the principle condition of injury for three-fifths of the cases reported compared to two-fifths of all manufacturing cases. The back and other portions of the trunk (such as abdomen and shoulders) accounted for 50% of the injury and illness cases reported; another two-fifths were evenly divided between the lower extremities (legs and knees) and upper extremities (fingers). Overexertion for lifting, pulling, or pushing heavy or unwieldy objects was the major event or exposure leading to disabling injuries and illnesses. This accounted for 50% of all soft drink cases compared to 33% for all manufacturing. Other notable events relating to disabling injuries in the soft drink industry include falls, striking against objects, and being struck by objects. These events accounted for one-third of the industry total. The sources of injury and illness were handling boxes, barrels, and containers including cartons and crates of soft drinks and other products. These sources were cited in more than one-third of the soft drink cases and in one-eighth of all manufacturing cases.

Beverage driver-salesworker was the leading occupation of the injured or ill workers in soft drink manufacturing. Of the 100,000 workers in the soft drink industry, one-seventh deliver beverages (14,200). However, more than one-third of the industry's cases reported by the SDS were from the beverage driver-salesworkers. Four other occupations in this industry; freight and stock handlers, industrial laborers, mechanics, and packaging and filling machine operators constituted three-tenths of the soft drink case total.[1,4] Injuries to driver-salesworkers were related to manual material handling, such as unloading trucks filled with soda cans and bottles, and carting and stacking the containers on customers' premises. Repeated maneuvering of heavy loads is likely to lead to sustained, serious sprains due to overexertion.[1,4]

In summary, the soft drink beverage industry has a high incidence of injuries and illnesses compared to other manufacturing and private industries. Incidence rates in this industry have been somewhat stable over the past several years, but severity rates continue to rise. Beverage delivery persons, also known as beverage driver-salesworkers, are those at greatest risk for injury and illness.

Because of the potential for more injuries and illnesses to the beverage driver-salesworkers, the goal of this study was to apply engineering controls and ergonomic improvements to existing conditions, and to determine the effectiveness of these measures in reducing musculoskeletal injury risk factors, using psychophysical, metabolic (heart rate), and biomechanical indices. Information gained from this study can be transferred to other industries that deliver products to customers.

BACKGROUND

Plant Description

The soft drink beverage delivery plant studied by NIOSH personnel is located in the Midwestern United States. There are approximately 240 employees at this plant, including 8 express, 4 transit, and 57 route drivers. This facility delivers a broad line of soft drink products, from individual servings for vending machines to bulk delivery for grocery stores. Normally, deliveries are made Monday through Friday. Most beverage driver-salesworkers leave the plant between 5:30 a.m. to 9:30 a.m., depending on the delivery schedule, locations, and amount of product to be delivered. The amount of product delivered per delivery person can vary from 150 to over 500 cases of soft drink product per day. This variability occurs for many reasons, including ***route structure*** (the variability of beverage delivery volume on a day-to-day basis, e.g., gas stations to large independent grocery stores); ***beverage sales and promotions;*** and ***delivery time*** (time of week, time of month, e.g., paydays and holidays, and time of year, e.g., seasonal [significantly more in summer than winter]). The delivery drivers have some flexibility in deciding how much they want to deliver on a daily basis, providing they meet a weekly average, as determined by their route and seasonal demand. For example, delivery on Monday can be 150 cases and on Tuesday can be over 300 cases. Peak delivery occurs before holidays, especially in the summer when demand for soft drink products is high. During these peak delivery periods, it is not unusual for some driver-salesworkers to sell over 500 to 700 cases of soft drink per day.

Driving and delivery are done by one person. The amount of driving by driver-salesworkers can range from 25 to over 200 miles per day, depending on the location of the route and the distance between service accounts.

The delivery truck fleet is composed of 43 route trucks and 12 "Low Boy" trailers. The most common vehicle is the 10-bay route truck (Figure 2). However, the company plans to acquire more "Low Boy" trailers which have 14 bays (Figure 3). Contrary to their title "Low Boy," these trailers have beverage bays approximately the same height as the 10-bay route trucks. The trucks vary in age (from new to 10 years) and vary in configuration and personal comfort. They may have fully automatic transmissions or up to 10-speed manual transmissions. The trucks are maintained at the plant by the maintenance department; mechanical problems are usually fixed within 24 hours. Most drivers use the same truck every day.

Job Description

The beverage delivery person is responsible for the following tasks:

Figure 2. Profile of 10-bay delivery truck (with retrofit controls installed).

Figure 3. Profile of 14-bay delivery truck (with retrofit controls installed).

1. Driving a prestocked route truck from the plant to designated customers.

2. Unloading the various cases of soft drink beverages from the truck and delivering them to the place of business.

3. Stocking shelves and displays within the establishment and retrieving empty, returnable bottles.

The employee typically works eight to ten hours per day. Customers include grocery and convenience stores, hospitals, schools, etc. During a typical delivery, a beverage delivery person:

1. Manually lifts approximately 160–550 boxes, beverage cases, and/or tanks piece-by-piece from the truck and places them on a hand truck.

2. Wheels the hand truck to the point of delivery specified by the customer.

3. Manually unloads the hand truck and places products on display shelves or in storage areas.

In the process, each item is manually handled a minimum of two times, but three to four times when sorting, pricing, rotating, or rearranging the display are required. Products delivered range from cases of cans and bottles to 2-L bottles, premixed tanks, bag-in-the-box, and 16-oz returnable bottles, with weights of 22 to 58 lb. Table 1 lists the principal soft drink products and respective weights. When hand trucks are fully loaded, the weight of the truck and load can exceed 350 lb.

Job Risk Factors

The beverage delivery person is exposed to a variety of musculoskeletal and safety risk factors when removing beverages from the truck:

1. Whole body vibration from driving a truck.

Table 1

Principal Soft Drink Products and Respective Weights Delivered by Driver-Salesworkers

Product	Weight (lb)
Lids (1,000)	7
Pre- and post-mix tanks (aluminum)—empty	10
Lids (2,500)	11
12-oz cans metal alloy (case of 24)	22
10-oz nonreturnable glass (case of 24)	23
Carbon dioxide cylinder (case iron)—empty	26
16-oz returnable tall glass bottle (case of 24)—empty	29
16-oz sport drink plastic (case of 24)	30
32-oz sport drink plastic (case of 12)	30
Cups (1,000 carton)	34
20-oz soft drink plastic (case of 24)	37
16-oz tea drink glass (case of 24)	39
2-L soft drink plastic (case of 8)	39
1-L soft drink glass (case of 15)	45
Carbon dioxide cylinder (cast iron)	45
20-oz soft drink glass (case of 24)	49.5
Bag-in-the-box (BIB)	53
Pre-mix tanks (aluminum)—soft drink	53.5
Wood pallets	55
Post-mix tanks (aluminum)—soft drink	57
16-oz returnable tall glass bottle (case of 24)	57.5

2. Pushing and pulling loads, which can exceed 350 lb, up and down stairs, ramps, confined areas, and rough terrain.

3. Repetitive lifting, lowering, stacking, and unstacking beverages in various size crates.

4. Slip and fall injuries occurring from climbing in and out of trucks (approximately 38 in. from the ground to the cab floor).

5. Other risk factors include slips, trips, and falls on wet or icy surfaces while drivers transport product.

6. Sharp glass from broken glass bottles.

7. Robberies.

8. Removing product from truck bays. For example, the bays are approximately 7 ft high × 40 in. wide and 40 in. deep.

Getting beverages out of the bay involves bracing the body with one hand and using the other to retrieve the beverages. Such maneuvers involve extended reaches with the arms and twisted body postures to pull the product forward and remove product from the truck. Beverage product can fall on drivers as they open bay doors. Slip and fall injuries can occur from climbing in and out of the bay (24 in. for regular bays, 50 in. for bays over wheels).

EXPOSURE EVALUATION CRITERIA

Health Effects of Manual Materials Handling

Cumulative Trauma Disorders

Reports of chronic musculoskeletal disorders have been documented for centuries.[6] However, only recently have epidemiologic studies attempted to examine the association between job risk factors, such as repetitive motion, awkward postures, and forceful movements, with excess musculoskeletal morbidity.[7,8,9,10] Several cross-sectional and case-control retrospective studies of occupational cumulative trauma disorders (CTDs) have been done.[11,12,13,14,15,16] The conclusions from these studies have strengthened the association between job risk factors with disease outcome. Work-related CTDs of the arms have been associated with job tasks that include:

1. Repetitive movements of the upper limbs.

2. Forceful grasping or pinching of tools or other objects by the hands.

3. Awkward positions of the hand, wrist, forearm, elbow, upper arm, shoulder, neck, and head.

4. Direct pressure over the skin and muscle tissue.

5. Use of vibrating hand-held tools.

Occupational groups at risk for developing cumulative trauma disorders continue to be identified because of the repetitive nature of tasks required in many service and industrial occupations, including the beverage delivery industry.

Carpal tunnel syndrome (CTS) is one of the most commonly reported disorders of the hand/wrist. CTS is a neurological disorder of the wrist that can be caused, precipitated, or aggravated by repetitive motion, awkward postures, and forceful motions.[15] CTS symptoms may include pain, numbness, and weakness of the hand, as a result of compression or irritation of the median nerve as it passes through the carpal tunnel in the wrist. Without early intervention, CTS may lead to severe discomfort, impaired hand function, and disability. Workers who perform repetitive tasks are at risk of CTS; tasks include automobile manufacturers and assemblers, electrical assemblers, metal fabricators, garment makers, food processors, grocery checkers, typists, musicians, housekeepers, and carpenters.[17,18,19]

The diagnosis is confirmed by physical examination and/or electrodiagnostic studies.[18] CTS can be managed with conservative measures, such as wrist immobilization and nonsteroidal anti-inflammatory medications.[17] However, these methods are not recommended as the main course of action because symptoms are likely to recur when the patient resumes the precipitating tasks.[17] Work-related risk factors that may cause CTS should be recognized and evaluated in order to implement controls for reducing them. Engineering controls are the preferred method, with administrative controls, such as work enlargement, rotation, etc., as an interim measure. Redesign of tools, workstations, and job tasks may prevent the occurrence of CTS among workers.[17] Surveillance of work-related CTS, including first reports of incidents, can aid in identifying high-risk workplaces, occupations, and industries, and can aid in directing appropriate preventive measures.[20]

There are no evaluation criteria for predicting the risk of injury to the arms at this time even though theoretical models have been developed that show the relationship between repetitive motion, forceful movements, awkward posture, and recovery time.[21,22]

Back Injuries

A significant portion of the U.S. work force currently is engaged in manual materials handling tasks despite the trend toward automation. Injuries associated with these manual materials handling jobs account for the largest number of medically related work absences, the greatest number of lost workdays per year, and the largest amount of compensation paid.[23] Occupational risk factors for low back injuries include manual handling tasks,[24] lifting,[25] twisting,[25] bending,[25] falling,[24] reaching,[26] excessive weight,[25,27,28] prolonged sitting,[29] and vibration.[30,31] Some nonoccupational risk factors for low back injury include obesity,[32] genetic factors,[33] and job satisfaction[34,35] Approximately one-half of all compensable low back pain is associated with manual materials handling tasks.[36] Lifting has been implicated in 37% to 49% of the cases, pushing in 9% to 16%, pulling in 6% to 9%, and carrying in 5% to 8%. Twisting the trunk has been reported in 9% to 18% of low back pain, bending in 12% to 14%, and falling in 7% to 13%.[25]

Beverage delivery, construction, mining, transportation, and manufacturing are the industries that show high rates of low back injuries.[37] The risk for back injuries in the soft drink beverage industry may be related to the high volume of beverage product handled (*repetition*—thousands-of-pounds handled per day), the variety of beverage package weights (*force*—22 to 57.5 lb), and the stressful positions (*posture*) needed to retrieve the product from the truck. The combination of these factors increases the risk for back injury.

Returning to work following a back injury is dependent on the amount of time away from the job. The longer the worker is away from the job, the less likely the worker is to return to work.[38,39] In addition, a worker who has already suffered a back injury is three to five times more likely to be reinjured.[40] Some deterrents to returning to work include psychological disability, no follow-up or encouragement, rigid work rules, extensive medical treatment,[41] and litigation.[42]

Traditionally, employers have used three general approaches to attempt to reduce the problem of low back pain:

1. Training and education

2. Design

3. Job placement

Control and prevention of low back pain can be accomplished through job evaluation and identification of job risk factors. Studies have shown that good job design can reduce up to one-third of compensable low-back pain.[36] Redesigned jobs can lead to the reduction of risk factors, and good job design initially will prevent back injuries. To reduce bending, and reaching by the worker, the work should be performed at waist to elbow height. The workplace should be laid out to reduce twisting. Sit/stand workstations should be allowed, where possible, with good seat design to reduce uncomfortable, prolonged sitting or standing. Smaller packages should be designed with handholes for better coupling (grip) and weight limits that do not exceed human capabilities. Administrative changes to reduce back injuries include job placement;[44] strength and fitness testing;[45,46,47] strength and fitness training (work hardening);[48,49] and work enrichment, enlargement, or rotation to reduce cumulative exposure. In addition to educating and training workers, unions, and management about risk factors, multiple approaches, such as job redesign, worker placement, and training, may be the best methods for controlling back injuries and pain.[50]

Evaluation Criteria for Risk of Back Injury

The revised NIOSH lifting equation provides methods for evaluating asymmetrical lifting tasks and optimal couplings between the object and workers' hands. The Recommended Weight Limit (RWL) is the principal product of the NIOSH lifting equation and is defined for a specific set of task conditions as the weight of the load that nearly all (90%) healthy workers can perform over an 8-hour day without risk of developing lifting-related low back pain. The NIOSH lifting equation has a recommended weight limit that is considered safe for an "ideal" lift. This weight is 51 lb and is reduced according to various task-related factors, such as the horizontal distance of the load from the worker; the amount of twisting involved (asymmetry); vertical height (lift location); distance moved; frequency of lift; and coupling characteristics, such as handles on the container being lifted. Additional information on the revised NIOSH lifting equation may be found in Waters et al.[51]

In addition to the NIOSH RWL, there is a lifting index (LI) that can be computed to determine the magnitude of risk. The LI is computed by dividing the NIOSH RWL into the weight of the load. The higher the LI, the greater the risk for back injury. An LI of three or more is considered to place workers at excessive risk of injury. If the original NIOSH formula (1981) is used, a LI of 3 would be representative of the maximum permissible limit (MPL). When the LI is greater than 3.0, or above the original NIOSH formula, engineering controls are strongly recommended to reduce potential for injuries.

The 1981 NIOSH *Work Practices Guide for Manual Lifting,*[43] and the 1991 *Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks*[51] were developed using medical, scientific, and engineering resources to develop guidelines for manual materials handling. Both guides use quantitative recommendations regarding the safe load weight, size, location, and frequency of a lifting task. The 1991 version includes asymmetric lifting and hand/load coupling guidelines. Because of the additional parameters for evaluating manual materials handling and slight adjustments in the equation, the 1991 equation was used for evaluation of selected beverage material handling tasks. Appendix A shows details of the revised lifting equation.

The lifting index (LI) was also used to determine risk for the materials handling tasks evaluated. The LI is the ratio between the beverage product being lifted and the RWL. The higher the ratio, the greater the risk for back injury. For example, if the beverage product lifted is 50 lb, and the RWL is 25 lb, then the LI is 2.0. The LI is useful in prioritizing high, medium, and low hazard lifting tasks.

Additional information relevant to the design of ergonomic controls in the beverage industry, including container packaging, container handles, push versus pull, and whole body vibration, can be found in Appendix B.

EVALUATION DESIGN AND METHODS

Site Selection

The location of the study was chosen on the basis of the size of the work force size (i.e., > 30 employees), the willingness of management and workers to participate in the evaluation process to implement controls, and the proximity to NIOSH research facilities (because of the study duration and the need for repeat visits to the site).

Conduct of Survey

Worker Selection and Study Orientation

Ten driver-salesworkers were selected from company volunteers. The request for volunteers was made in cooperation with the company and union. NIOSH representatives met with all potential volunteers before and at the beginning (pre-intervention) of the study to present an overview of the project. NIOSH representatives also showed the potential volunteers the equipment to be used and asked for advice on how the instrumentation could best be used without interference of their jobs. None of the volunteers said that the equipment would cause problems. The selected study participants were experienced in urban beverage delivery, had good job performance records, and were in good physical condition (based on company records). One worker who participated in the initial survey suffered a back injury unrelated to the NIOSH study and could not be used in the follow-up study after ergonomic interventions were implemented.

At the beginning of the study, each beverage delivery person was instructed on:

1. The initial objectives of this study.
2. The use of the self-administered computerized Discomfort Assessment Survey (DAS).
3. The wearing of a portable noninvasive heart monitor (Polar Vantage XL)™ to indirectly determine metabolic demands of the job.

Questionnaire: Past Work Experience and Medical History

A questionnaire (Appendix C) was administered and completed at the beginning of the study. Descriptive information that measured height, forward reach (arm reach), and weight was requested. The volunteers disclosed information on age and work history as well as information on beverage delivery experience. Injury histories disclosed job-related musculoskeletal disorders and amount of time off resulting from such injuries.

Discomfort Assessment Survey

The Discomfort Assessment Survey (DAS), developed by researchers at the University of Michigan, Center for Ergonomics, was used to collect musculoskeletal discomfort data from workers selected for this study. The objective of the DAS was to survey changes in workers' discomfort and fatigue resulting from ergonomic controls installed in their jobs. The DAS collected three categories of information:

1. Descriptive, including the worker's name, social security number, and job title
2. Location of discomfort by the use of a body template
3. A discomfort score from 0 (nothing at all) to 10 (worst imaginable)

The discomfort score is based on work performed by Borg,[53] Seymour et al.,[53] and Corlett and Bishop.[54]

The DAS was implemented using a computer to facilitate the process of reporting musculoskeletal discomfort. The workstation consisted of a computer with a color monitor. A light pen was used as an input device. Software to run the program was developed by the University of Michigan's Center for Ergonomics.[55] The study participants, referred to from this point on as *Driver-Salesworkers,* entered their musculoskeletal discomfort data into the computer at the beginning (pre-intervention), middle, and end (post-intervention) of the beverage delivery workday.

Driver-Salesworkers received individual training, consisting of a demonstration on using the DAS, which they practiced on their own. Throughout the study one NIOSH researcher accompanied the driver as a passenger, while the other NIOSH researcher followed the driver-salesworker's truck in a minivan. This made it possible for the NIOSH researchers to always be available when the driver-salesworkers entered data in the DAS. None of the driver-salesworkers reported difficulty in using the system to generate their DAS reports. The average time to complete each DAS report ranged from 5 to 10 minutes. Appendix D illustrates the different DAS screens shown on the computer.

Discomfort data were systematically collected from the delivery person a total of nine times, once in the morning, afternoon, and evening, over three survey periods: (1) at the beginning of the study before interventions, (2) shortly after the ergonomic interventions were first introduced (approximately 3 weeks after the study began), and (3) at the end of the study (approximately 6 weeks after the study began), when the delivery person had adjusted to the controls. Data were collected from three driver-salesworkers per week, usually in the middle of the week (Tuesday, Wednesday, or Thursday).

DAS information was collected in two settings: (1) at the beginning and at the end of the workday, the delivery person entered the DAS data at the plant conference and office area and (2) approximately halfway through the delivery schedule, the delivery person took the DAS inside a minivan automobile. The portable computerized workstation was easy to set up and administer in the field.

Metabolic Measures

It was calculated that at least 9 volunteers were needed for this study to see statistical significance in changes in heart rate (i.e., direction sensitive one-tailed test to avoid false negative or false positive conclusions; $\alpha < .05$, $\beta = .80$, respectively). The metabolic demands of the delivery job were determined indirectly by monitoring heart rate. A Polar™ portable heart rate monitor (Polar USA Inc.) was used on each worker during delivery. Heart rate data were collected every five seconds from a combination electrode-transmitter band that was worn on the worker's chest and from a receiver attached next to the transmitter. The receiver stored up to two hours and forty minutes of heart rate data when programmed to collect data every five seconds. When it was convenient for the worker, the receiver was changed, approximately every two and a half hours. Up to five receivers were used per worker, per day. In the evening the data were downloaded through a transmitter-receiver coupling device connected to a portable computer. The heart rate data files were transported to a computer spreadsheet package (Lotus 123). A clock in the portable video camera was synchronized with the time of day on the heart rate receivers. Extraneous signals, caused by electronic noise (250 beats per minute) or by poor contact with the skin (0), were deleted from the spreadsheet.

Work Analysis

Ergonomic Evaluation

The ergonomic evaluation consisted of:

1. Collecting beverage delivery inventory reports that indicated the amount and type of product loaded and sold.

2. Videotaping the beverage delivery process, from activities performed at the plant to activities performed at the delivery sites.

3. Biomechanically evaluating (46 reports) musculoskeletal stress during manual handling of beverage containers.

4. Recording delivery truck dimensions.

5. Discussing musculoskeletal hazards associated with each job with the driver-salesworkers.

Biomechanical Evaluation

Biomechanical evaluations of the back were performed using the revised NIOSH lifting equation.[51] The purpose of this evaluation was to determine if certain tasks exceeded a worker's biomechanical and static strength capabilities, and to determine if such tasks placed workers at risk for developing musculoskeletal disorders. Posture and body angles were determined from stop action analysis of the videotapes filmed during beverage delivery. The tasks evaluated were selected from representative driver-salesworkers performing beverage handling tasks. The six tasks analyzed, selected on the basis of weight range, volume sold, and container size, were:

- Lifting 12-oz, 24-can cases of beverage from truck.

- Lifting 2-L, 8-pack case from truck.

- Lifting 20-oz case of beverage (glass containers) from truck.

- Lifting 16-oz case of beverage (glass returnable) from truck.

- Lifting 53.5-lb aluminum tanks containing pre-mix beverage.

- Lifting 53-lb, 5-gal bag-in-the-box (BIB) packages containing pre-mix beverage.

In addition to the NIOSH RWL, the LI was used as a relative measure of risk for back injury. An LI of less than 1 indicates low risk; 1 to 3, medium risk; greater than 3, high risk.[51] To determine biomechanical forces on the shoulders during beverage material handling, a University of Michigan, Center for Ergonomics, software program (2D Static Strength Prediction Program™) was used.[56]

Ergonomic Interventions

Beverage Delivery Trucks

Four beverage delivery trucks were retrofitted for this study: three 10-bay trucks (Figure 2), and one 14-bay tractor-trailer (Figure 3). The smaller 10-bay delivery trucks are the standard for city delivery, although the use of larger trucks is increasing because the number of soft drink packages is growing by 20 to 25 per year (over 200 different packages at the time of this study). Therefore, the 14-bay tractor-trailer was retrofitted with controls similar to those in the smaller trucks. Table 2 shows the retrofits to four beverage delivery trucks.

2-wheel Hand Trucks

The majority of driver-salesworkers preferred to use the trucks they had rather than the ergonomically designed 2-wheel hand truck called the "Equalizer" (Magliner Inc). However, some data were gathered with one delivery person using the "Equalizer." Most drivers had one 2-wheel hand truck, while others had a 2-wheel and a 4-wheel (for bulk delivery). NIOSH researchers performed

Table 2

Safety/Ergonomic Retrofits of Beverage Delivery Trucks

Safety Retrofits	Ergonomic Retrofits
5-in. spot mirror on right and left door (Figure 2, middle, right side)	Air-cushioned drive seat (Not shown)
5-in. spot mirrors mounted on right side of hood (Not shown)	Exterior grab handles all bays (Figure 2, middle of photograph)
Heated mirror installed on driver side (Not shown)	3-position drop shelf holes/all deep bays (Figure 27, middle of photograph)
Heated/motorized mirror passenger side (Figure 10, middle, top side)	Installed hand grips in single sheet divider (Not shown)
3-point seat belt (Not shown)	Wider step platform on wheel housing step bar (Figure 8, lower, right side)
Motion back-up alarms with guards (Figure 3, lower, left, on bumper)	Extra wide recessed steps, front and rear (Figure E1, lower, left side)
Raise stop/tail lights and back-up lights to hood level (Figure 3, middle, and top side)	Bay liners/all bays (Not shown)
Recess license plate brackets (Figure 24, lower, right side)	Anti-slip covering/coating installed on bottom rail and step holes (Not shown)
New caution "wide right turn" sign (Figure 3, middle, left side)	Pullout step/rear bays (Figure 2, lower, left side)
	Large hand truck holder and high back rest for 2 hand trucks (Figure 3, lower, left side)
	New rollers in all bay door slats, and lubricated doors (Not shown)
	New door straps (Figure 2, lower, middle of photograph)

maintenance on the hand trucks at the beginning of the intervention phase of the study, including measuring air pressure in the tires and inflating the tires where needed, balancing the tire air pressure, and cleaning and lubricating all moving parts of the hand trucks.

Data Analysis

The null hypothesis (H_0) is defined as the following: no change in stress (DAS, heart rate, biomechanical) during the delivery process with ergonomic controls. The alternate hypothesis (H_a) is defined as the following: stresses were less with ergonomic controls implemented.

Ergonomic control factors (e.g., ergonomic retrofit and hand trucks) were evaluated for associations with measured outcomes, including changes in comfort level in the Discomfort Assessment Survey, heart rate, and biomechanical stress. Lotus 123 and the Statistical Graphics Package were used for analyses.[57,58] Student t-tests and McNemar's test were used to evaluate statistically the effects of controls.

RESULTS

Description of Beverage Driver-Salesworkers

Nine beverage driver-salesworkers (all male) participated in the ergonomic intervention study. Eight performed conventional delivery of soft drink cans and bottles in the city to small and mid-size grocery stores; one performed bag-in-the-box and tank delivery to restaurants.

Questionnaire: Demographics, Past Work Experience, and Medical History

Driver-salesworkers' weight, height, functional reach (measure of outstretched arm from the back of the shoulder to the end of the fingers in a pinch grip), for seniority with the company and delivery seniority are summarized in Table 3. Age ranged from 34 to 58 years, with an average of 42. Weight ranged from 164 to 256 lb, with an average of 210. Height ranged from 67 to 76 in., with an average of 72. Functional reach ranged from 28 to 33 in., with an average of 31.

Worker seniority with the company ranged from 15 to 34 years, with an average of 20. With the exception of one worker, who had a management position for a short time, all reported that they started with the company as beverage driver-salesworkers and had been performing the same job while with the company. This company does not have a career track that advances employees from beverage delivery to another job that pays as well or better.

During their career as beverage driver-salesworkers with this company:

- All nine driver-salesworkers reported that they had suffered a work-related musculoskeletal injury.
- Eight reported having back injuries.
- Five reported arm injuries.
- Four reported leg injuries.
- All had taken time off as a result of their injuries.
- The average time off was 2.8 months.

Table 3

Descriptive Characteristics of Driver-Salesworkers at the Beginning of Study

Subject*	Age (yrs)	Weight (lb)	Height (in.)	Functional Reach (in.)	Company Seniority (yrs)	Delivery Seniority (yrs)
1	43	218	73	30	25	25
2	37	216	76.5	32	17	17
3	36	153	71.5	30	13	13
4	58	190	70	31	34	34
5	39	215	67.5	28.5	16	16
6	38	243	76	32	15	15
7	34	256	73	33	17	15
9	43	239	69	31	19	19
10	51	164	67	28	20	20
Avg.	42.4	210.4	71.5	30.6	19.6	19.3
S.D.	7.5	35.2	3.4	1.7	6.4	6.5

*Subject 8 was dropped from study due to back injury before ergonomic interventions began.

Discomfort Assessment Survey (DAS)

Location of Discomfort

Three (two morning and one midday) DAS reports for one of the driver-salesworkers had been inadvertently destroyed. Because the incomplete reporting would bias the overall results for the group, data analysis was conducted on only the eight driver-salesworkers who had all reports available.

As shown in Table 4, six of the eight driver-salesworkers reported back discomfort. Shoulder, elbow, and leg (knees) discomfort were reported by four driver-salesworkers; neck and hands discomfort were reported by two driver-salesworkers.

The legs (44 reports) were affected by discomfort more than any other body part (Table 4). Then the back (21), shoulders (20), elbows (17), hands (8), and neck (3), respectively. As shown in Table 4, the specific areas most frequently cited with discomfort for each body part were the right and left knees (25), the lower back (18), back right shoulder (13), back left elbow (10), back left and right hands (8), and back of neck (3). These areas, highlighted in Figures 4, 5, 6, and 7, show the number of driver-salesworkers indicating discomfort in the shaded areas. The data indicate that the number of workers reporting discomfort in specific body locations decreased from the first to third survey. This decrease coincided with installation of ergonomic controls on the truck and improved maintenance of the hand truck, such as proper inflation of the tires and lubrication of moving parts.

Combined results from all three surveys, showed there was no significant difference in discomfort reports between the beginning (45 reports), middle (41), and end (44) of the workshift.

There was an increase in discomfort reporting from the first survey (46 reports) to the second survey (53 reports), and a decrease in discomfort reports from the first to the third survey (31 reports). The increase in discomfort reporting between the first and second survey was significant (t statistic, $p < .05$), as was the decrease in reporting between the first and third survey for body part discomfort reports (t statistic, $p < .05$). Decreased shoulder and elbow discomfort accounted for most of the change between the first and third survey. There was no significant decrease in back discomfort reporting between the first and third survey (McNemar's Test, one sided, $p > .05$).

Table 4

Reports by Driver-Salesworkers of Body Area Commonly Affected During Beverage Delivery

	Neck	Shoulders	Elbows	Hands (Including Wrists)	Back	Legs
Number of reports of discomfort	3	20	17	8	21	44
Area most commonly affected	back neck	back right shoulder	back left elbow	right and left back of hands	lower back	right and left knees, front
Percent of reports of areas most commonly affected	100	65	59	100	86	57
Percent of number of driver-salesworkers reporting discomfort	25	50	50	25	75	50

(N = 8)

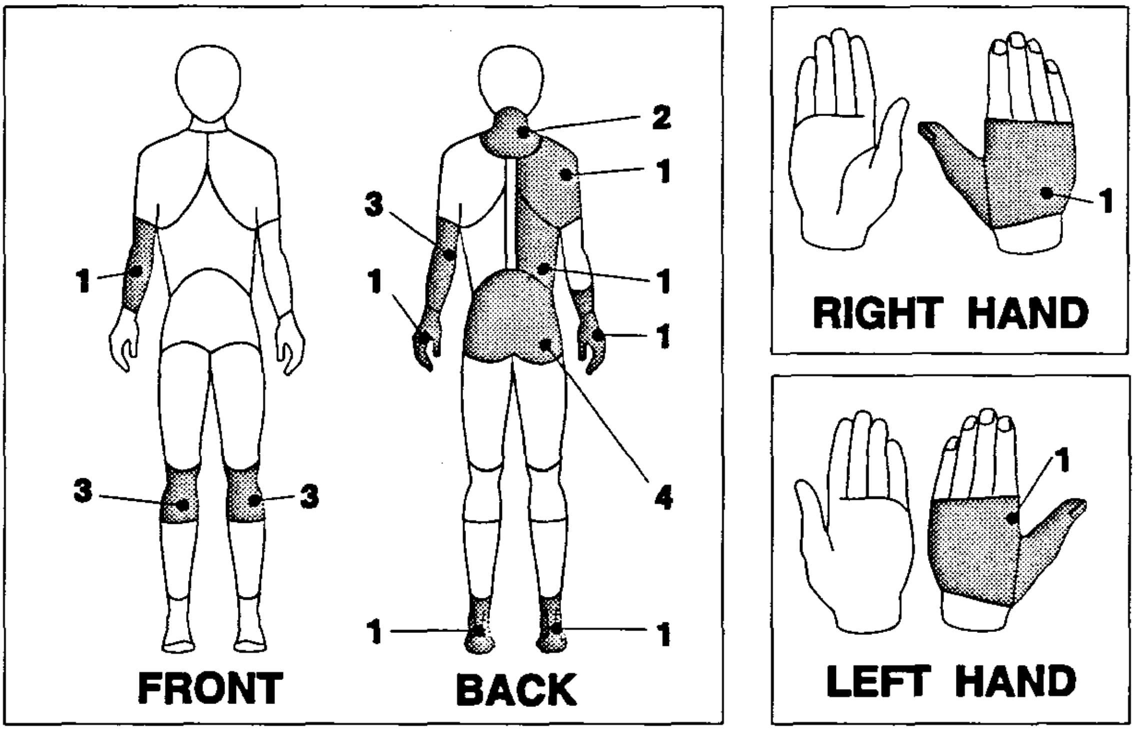

Figure 4. First survey results from Discomfort Assessment Survey (DAS).

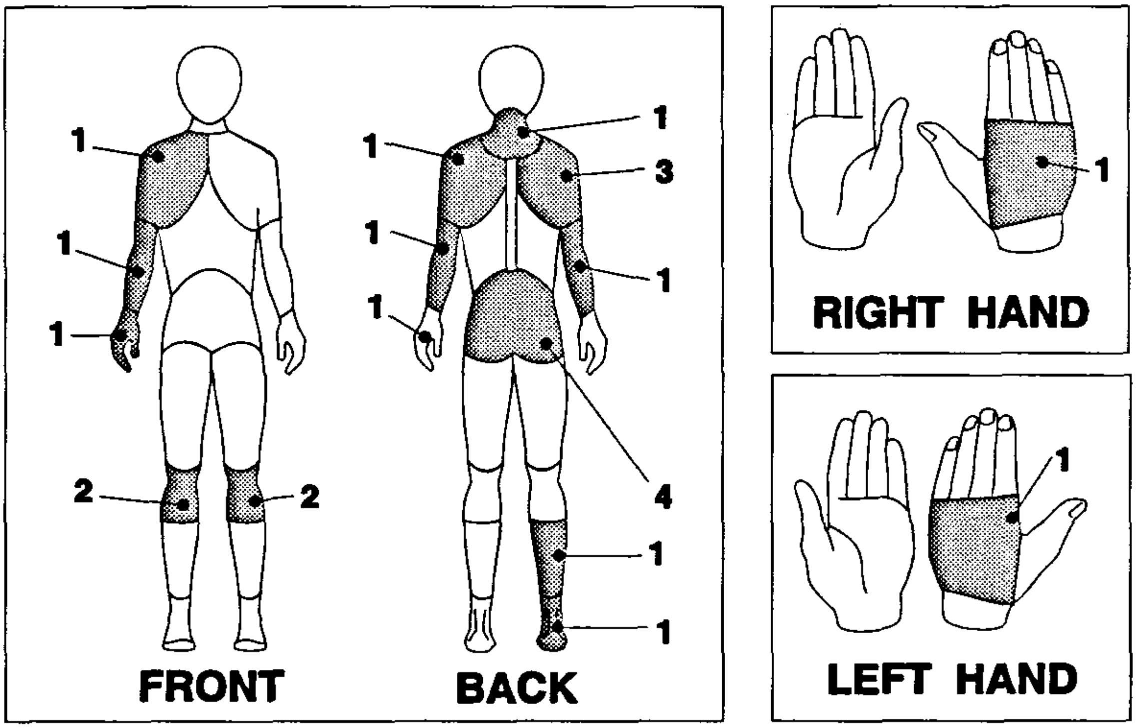

Figure 5. Second survey DAS results—approximately 3 weeks after first DAS.

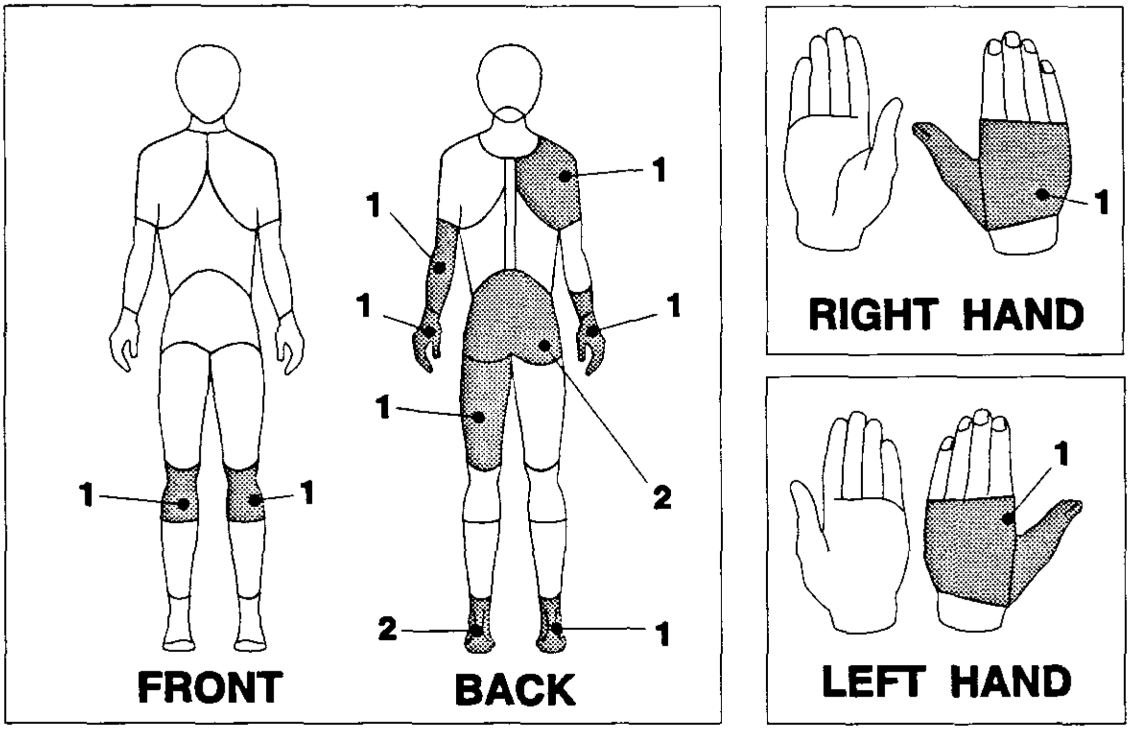

Figure 6. Third survey DAS results—approximately 6 weeks after first DAS.

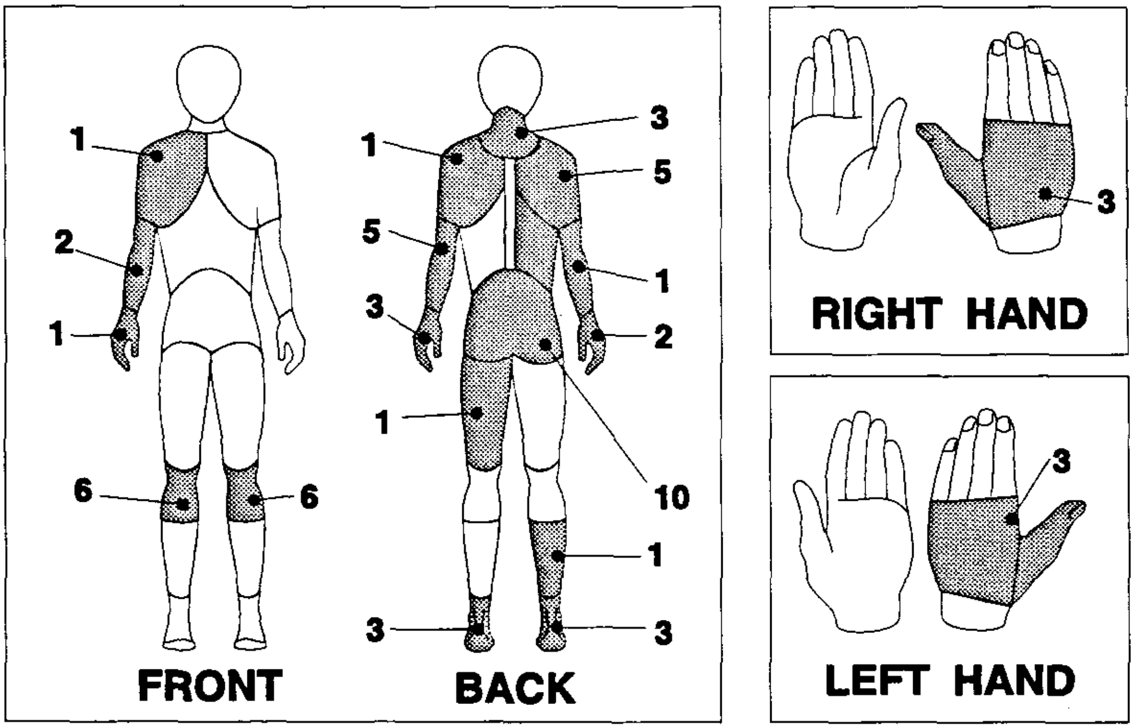

Figure 7. Composite survey DAS results (all three surveys).

Type of Discomfort

Up to twelve descriptive terms (symptoms) could be used to describe the discomfort for each affected body part (pain, cramping, aching, stiffness, swelling, weakness, stabbing pain, numbness, burning, tingling, loss of color, and other). During this survey, 186 symptoms were reported for the 130 body part discomfort reports. The most frequent symptom reported was aching (88 reports), followed by stiffness (46 reports), then pain (26); these data accounted for 86% of all reports. Remaining symptoms accounted for 14% of the reports.

There was no significant difference in symptom reporting by time of day ($p > .05$). However, symptom reporting increased between the first and second survey from 65 to 74 and decreased in the third survey to 47. Aching and pain increased, and stiffness decreased, from the first to second survey. Stiffness decreased significantly ($p < .05$) from the first to third survey, aching returned to the first survey level; and pain stayed at the second survey level. The decrease in stiffness between the first and third survey was accounted for by several workers; however, the increase in pain reports was dominated by one worker.

Pain Level

Only one pain score on a 1–10 scale (1 = least, 10 = worst) could be selected per affected body part. Therefore, there were 130 responses. The distribution of pain scores were: 1 (19 reports), 2 (25), 3 (51), 4 (23), 5 (7), 6 (4), 7 (0), and 8 (1).

Pain scores did not differ by time of day. Between the first and third survey, there was a decrease in pain reporting for pain levels 1, 3, 4, 8; an increase in levels 2 and 5; and no change for level 6. None of these changes in pain level reporting by time were significant.

There was an increase in pain reports between the first (46) and second (53) survey, then a decrease in pain responses in the third (31) survey. When pain scores were compared by category for the first and third survey, there was a decrease in pain reporting for pain levels 1, 2, 3, and 5; an increase in levels 4 and 6; and no changes for level 8. None of the changes in pain level reporting by survey were significant.

Table 5 summarizes the results of the Discomfort Assessment Survey.

Metabolic Measures

Heart Rate

Table 6 shows the heart rate data collected on the driver-salesworkers at the beginning and end of the study. Individual average heart rate at the beginning of the study ranged from 94 to 114 beats per minute (bpm). The average heart rate at the end of the study, when ergonomic controls were in place, ranged from 93 to 115 bpm. The average heart rate for the nine workers at the beginning of the study was 104 (± 8.4) and at the end was 100 (± 8.9). The minimum heart rate range at the beginning of the study was 58 to 79 for the workers with an overall average of 67 (± 7.7) bpm. At the end the minimum range was 49 to 78 with an overall average of 66 (± 9.9) bpm. The maximum (peak) heart rate ranged from 137 to 167 with an average of 154 (± 9.5) bpm at the beginning of the study. At the end of the study, the maximum heart rate ranged from 123 to 163, with an average of 144 (±12.7) bpm.

Comparisons for the average, minimum, and maximum heart rate values showed a trend in decreased cardiovascular demands by the end of the survey when compared to the beginning. One-sided, paired Student t-tests for before and after differences for average (decrease of 4 bpm), and peak (decrease of 10 bpm) heart rate were significant ($p < .05$). The difference in cardiovascular demands may be attributable to a number of factors, including ergonomic interventions.

Heart Rate Values Before and After Ergonomic Interventions

Table 7 shows the workers' ages, maximum heart rates based on age, resting heart rates, heart rate ranges, and 50% of the maximum potential heart rates. The maximum potential heart rate (220 - age) range was 162 to 186, with an average maximum value of 178 bpm. The resting heart rate ranged from 63 to 92, average 77 bpm at the

Table 5

Summary of Discomfort Assessment System Survey

Examined by Time of Day and Survey	Symptom Reporting	Pain Level Reports
• No significant difference in reporting for discomfort between morning, afternoon, or end of workshift. • When examined by survey, an increase in reporting between 1st (46 reports) and 2nd (53 reports), and a decrease in reporting for 3rd (31 reports). The increase in discomfort between the 1st and 2nd survey was significant, and the decrease in discomfort between 1st and 3rd was significant. • There was not a significant decrease in discomfort reporting for the back between the 1st and 3rd survey. • There was a notable (but not significant) decrease in discomfort for the shoulder and elbow between the 1st and 3rd survey.	• Most frequent symptom reported was aching (88 reports), followed by stiffness (46 reports), followed by pain (26 reports). • There was a slight increase in symptom reporting between the first and second survey (65 to 74), and a decrease in symptom reporting for the third survey (47 reports). • Aching and pain reporting increased from the 1st and 2nd survey; however, most pain reporting was by one worker. • Stiffness reporting decreased from the 1st to 3rd survey, this was reported by several workers.	• No pain level was reported above 8 (pain scale was from 1 to 10). • Distribution of pain reporting was: 1(19), 2(25), 3(51), 4(23), 5(7), 6(4), 7(0), 8(1). • Time of day; there was no significant change in pain reporting. • An increase in pain responses between 1st (46) and 2nd (53) survey, and a decrease in pain responses for 3rd survey (31). Survey; decrease in pain scores from 1st and 3rd survey at levels 1, 3, 4, 8; increase in pain levels 2, 5; and no change in pain level 6. The changes in pain level reporting were not significant.

Table 6

Heart Rate Results for Beverage Driver-Salesworkers at the Beginning and End of the Field Study[1]

	Average Heart Rate		Minimum Heart Rate		Peak Heart Rate		Standard Deviation	
Subject[2]	B[3]	E[4]	B	E	B	E	B	E
1	94	94	62	61	152	157	15	17
2	100	99	66	75	147	133	12	11
3	109	101	71	65	152	152	17	17
4	95	96	58	55	149	139	23	20
5	114	113	79	76	163	163	17	16
6	114	115	71	71	164	149	15	13
7	99	88	59	49	137	135	15	17
9	99	93	62	64	167	123	15	12
10	114	102	77	78	155	144	15	13
Average	104	100	67	66	154	144	16	15
S.D.[5]	8	9	8	10	10	13	3	3

[1] Heart rate average, minimum, maximum, and standard deviation, based on 5 second averages during the workday.
[2] Subject 8 was dropped from study due to back injury before ergonomic interventions began.
[3] B = Beginning of Study—before ergonomic interventions.
[4] E = End of Study—after ergonomic interventions.
[5] Standard deviation (based on values reported in this table).

Table 7

Maximum, Resting, Range, and 50 Percent Potential Maximum Heart Rate Results for Beverage Driver-Salesworkers at the Beginning and End of the Field Study

Subject[1]	Age	Maximum Heart Rate[2]	Resting Heart Rate[3] (B)[4]	Resting Heart Rate (E)[5]	Heart Rate Range[6] (B)	Heart Rate Range (E)	50% of Maximum Potential Heart Rate[7] (B)	50% of Maximum Potential Heart Rate (E)
1	43	177	63	60	114	117	120	118
2	37	183	64	64	119	119	124	124
3	36	184	69	69	115	115	126	126
4	58	162	72	69	90	93	117	115
5	39	181	75	74	107	107	128	128
6	38	182	80	78	102	104	131	130
7	34	186	85	82	101	104	135	134
9	43	177	91	82	86	95	134	129
10	51	169	92	87	78	82	130	128
Average	42	178	77	74	78–119	82–119	127	126
S.D.[8]	8						6	6

[1] Subject 8 was dropped from study due to back injury before ergonomic interventions began.
[2] Maximum heart rate determined from following equation (220–age).
[3] Resting heart rate determined from 5 minute average of 5-second interval heart rate while sitting in a chair before beginning a route.
[4] B = Beginning of Study—before ergonomic interventions.
[5] E = End of study—after ergonomic interventions.
[6] Heart rate range determined from difference between resting and maximum potential heart rate.
[7] 50% of potential maximum heart rate determined from resting heart rate plus 50% of the heart rate range.
[8] S.D. = Standard Deviation.

beginning of the study and ranged from 60 to 87, average 74 at the end of the study.

The heart rate range for these driver-salesworkers was 78 to 119 at the beginning and 82 to 119 at the end of the study. Fifty percent of the maximum potential heart rate (resting heart rate + 50% of the maximum heart rate potential) was from 117 to 135 bpm before the interventions, and from 115 to 134 after the interventions. At the beginning of the survey, the average heart rate was approximately 32% of the maximum potential heart rate and at the end approximately 30% of the maximum potential heart rate. When the heart rate exceeds 50% of the maximum heart rate over an 8-hour day, rest periods should be implemented to reduce fatigue.[59] As these data show, there were metabolic demands during beverage delivery as noted from the peak heart rates. However, because the job allowed self-pacing, there was time for the heart rate to recover.

Average percentage of maximum heart rate (a measure of cardiovascular demand for work performed) decreased over the course of the study. This decrease is most evident when comparing the actual maximum heart rate values (Table 6) at the beginning (87%) versus the end (81%) of the study, and the percent of maximum potential heart rate values (Table 7). While the amount of beverage delivered varied from the beginning to the end of the study, the overall weight of beverage delivered increased slightly by the end of the study. The combination of ergonomic interventions and good work practices may have caused some of the decrease in maximum heart rate.

Work Analysis

Work Documentation and Analysis

All workers were videotaped during beverage delivery at the beginning, middle, and end of the study to determine work risk factors. In addition, discussions with the workers provided more information about the work risk factors and how risk could be reduced. Selected pictures of these activities and associated risk factors are shown in Appendix E.

Biomechanical

Stop-action analysis of videotapes of the workers delivering beverage products were used for biomechanical analysis. Selected work activities for each delivery person before and after ergonomic interventions were used for biomechanical evaluations, using the NIOSH revised lifting model. This approach provides the broadest overview of the biomechanical risks and the changes in these risks as a result of the interventions.

Tables 8–13 and Figures 8–19 show the results from this analysis. All beverage packages handled exceeded the NIOSH RWL, especially when worker posture was taken into consideration. Because of the workers' postures and the weight of many beverage products being removed from the truck, the LI often exceeded 3 (Tables 8-13), indicating a substantially increased risk of back injury, according to the NIOSH model.

Table 8

Calculations Using 1991 NIOSH Formula for Lifting Two 22-lb Aluminum Can Cases of 12-oz Soft Drink Beverages

Job Analysis Worksheet

Job Description: Conventional Beverage Delivery
Risk Factor Evaluated: Lifting two 22-lb cases of 12-oz soft drink in aluminum cans
(See Figures 8 and 9)
Height of Worker: 73 in., functional reach 30 in.

STEP 1. Measure and record task variables

Object Weight (lb)		Hand Location (in.) Origin: See Figure 8		Hand Location (in.) Destination: See Figure 9		Vertical Distance (in.)	Asymmetric Angle (degrees) Origin	Asymmetric Angle (degrees) Destination	Frequency Rate lifts/min	Duration Hours	Object Coupling
L(Avg.)	L(Max.)	H	V	H	V	D	A	A	FM		CM
44	44	20	39	17	15	24	10	10	6	< 1	Poor

STEP 2. Determine the multipliers and compute the Recommended Weight Limits (RWLs)

RWL = LC x HM x VM x DM x AM x FM x CM

ORIGIN RWL = 51 x .50x .93x .89 x .97 x .75 x .90 = 13.8 lb

DESTINATION RWL = 51 x .59 x .89x .89 x .95 x .75 x .90 = 15.5 lb

STEP 3. Compute the Lifting Index

ORIGIN Lifting index $= \frac{\text{Object Weight}}{\text{RWL}} = \frac{44.0}{13.8} = 3.2$

DESTINATION Lifting index $= \frac{\text{Object Weight}}{\text{RWL}} = \frac{44.0}{15.5} = 2.8$

Using the University of Michigan 2-D Static Strength Prediction Model, biomechanical analysis of shoulder strength for a hypothetical driver-sales-worker lifting an 8-pack, 2-L beverage case showed that only 25% of the males and 0% of the females, at the 50 percentile in weight and height (70 in., 166 lb; 64 in., 137 lb, respectively), were capable of lifting and moving such cases in this posture.[56] When the 2-L case weight was reduced from approximately 40 lb to 30 lb (simulating a 2-liter 6-pack case), 65% of the males and 1% of the females, at the 50 percentile, had the shoulder strength to lift in this posture and move such cases.

When the delivery person used the pullout shelf, 63% of the males and 3% of the females had the shoulder strength to lift and move the 40-lb cases in this posture. When the case weight was reduced to 30 lb, simulating a 2-L, 6-pack, 84% of the males and 24% of the females had the shoulder strength to lift and move such cases. The instability of the 8-pack, 2-L bottles (due to the low height of the cases) and the combination of weight and poor case design, make material handling more difficult and increases the potential for injuries to the shoulders.

Table 9

Calculations Using 1991 NIOSH Formula for Lifting 39- lb, 8-pack of 2-Liter Soft Drink Beverages in Plastic Bottles

Job Analysis Worksheet

Job Description: Conventional Beverage Delivery
Risk Factor Evaluated: Lifting 39-lb, 8-pack, 2-L soft drink package of plastic bottles (See Figures 10 and 11)
Height of Worker: 71.5 in., functional reach 30 in.

STEP 1. Measure and record task variables

Object Weight (lb)		Hand Location (in.) Origin: See Figure 10		Destination: See Figure 11		Vertical Distance (in.)	Asymmetric Angle (degrees) Origin	Destination	Frequency Rate lifts/min	Duration Hours	Object Coupling
L(Avg.)	L(Max.)	H	V	H	V	D	A	A	FM		CM
39	39	10	51	20	4	47	0	15	6	< 1	Good

STEP 2. Determine the multipliers and compute the Recommended Weight Limits (RWLs)

RWL = LC × HM × VM × DM × AM × FM × CM

ORIGIN RWL = 51 × 1.0 × .85 × .86 × 1.0 × .75 × .95 = 28.0 lb

DESTINATION RWL = 51 × .50 × .80 × .86 × .95 × .75 × .95 = 12.0 lb

STEP 3. Compute the Lifting Index

ORIGIN Lifting index = $\frac{\text{Object Weight}}{\text{RWL}} = \frac{39.0}{28.0} = 1.4$

DESTINATION Lifting index = $\frac{\text{Object Weight}}{\text{RWL}} = \frac{39.0}{12.0} = 3.2$

Figure 8. Driver-salesworker lifting two 24-can cases of 12-oz soft drink beverages (44 lb) from truck.

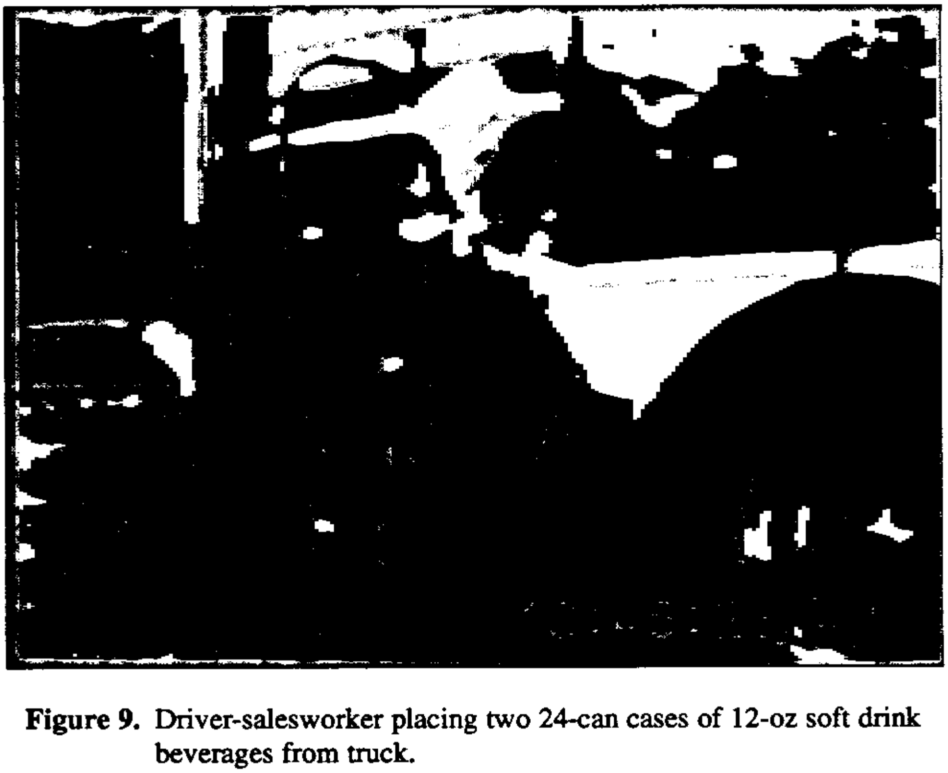

Figure 9. Driver-salesworker placing two 24-can cases of 12-oz soft drink beverages from truck.

Table 10

Calculations Using 1991 NIOSH Formula for Lifting 49.5-lb Case of 24 Glass 20-oz Soft Drink Beverages

Job Analysis Worksheet

Job Description: Conventional Beverage Delivery
Risk Factor Evaluated: Lifting 49.5-lb case of 24 20-oz soft drink in glass bottles
(See Figures 12 and 13)
Height of Worker: 70 in., functional reach 31 in.

STEP 1. Measure and record task variables

Object Weight (lb)		Hand Location (in.) Origin: See Figure 12		Hand Location (in.) Destination: See Figure 13		Vertical Distance (in.)	Asymmetric Angle (degrees) Origin	Asymmetric Angle (degrees) Destination	Frequency Rate lifts/min	Duration Hours	Object Coupling
L(Avg.)	L(Max.)	H	V	H	V	D	A	A	FM		CM
49.5	49.5	15	50	20	5	45	0	0	6	< 1	Fair

STEP 2. Determine the multipliers and compute the Recommended Weight Limits (RWLs)

RWL = LC × HM × VM × DM × AM × FM × CM

ORIGIN RWL = 51 × .67 × .85 × .86 × 1.0 × .75 × 1.0 = 18.7 lb

DESTINATION RWL = 51 × .50 × .81 × .86 × 1.0 × .75 × .95 = 12.7 lb

STEP 3. Compute the Lifting Index

ORIGIN Lifting index = $\frac{\text{Object Weight}}{\text{RWL}} = \frac{49.5}{18.7} = 2.6$

DESTINATION Lifting index = $\frac{\text{Object Weight}}{\text{RWL}} = \frac{49.5}{12.7} = 3.9$

Figure 10. Driver-salesworker lifting 8-pack of 2-L soft drink beverages (39 lb) from truck.

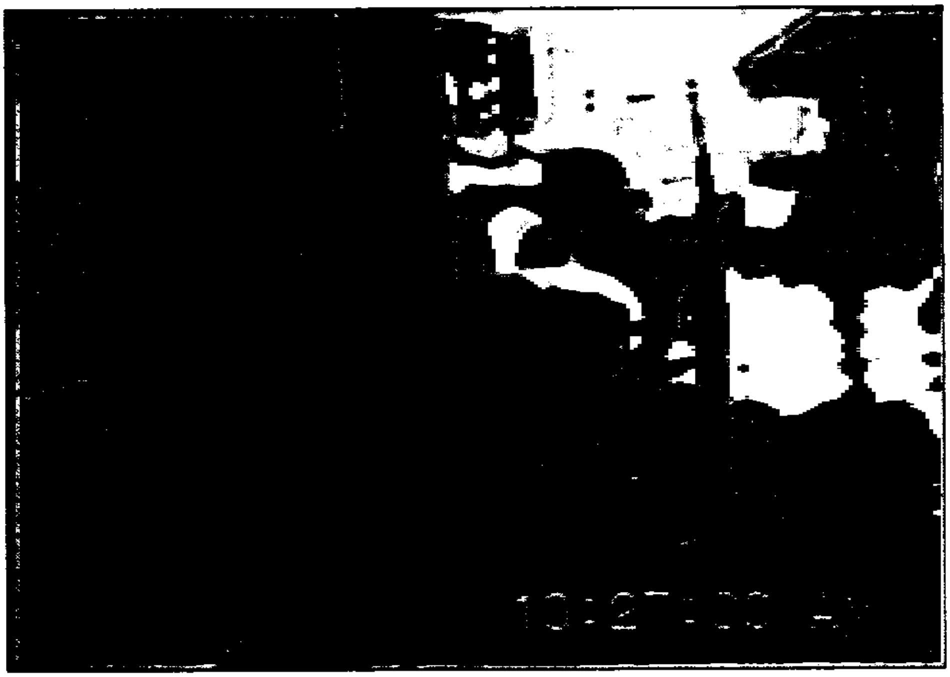

Figure 11. Driver-salesworker placing 8-pack of 2-L soft drink beverages on hand truck.

Figure 12. Driver-salesworker lifting 24-pack of 20-oz glass bottled soft drink (49.5 lb) beverages from truck.

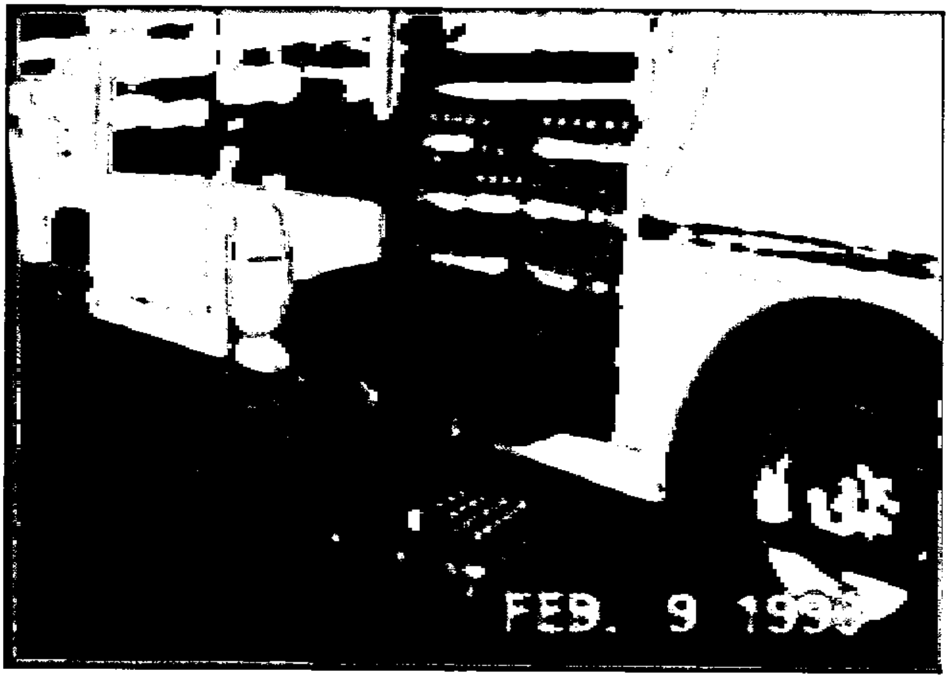

Figure 13. Driver-salesworker placing 24-pack of 20-oz glass bottled soft drink beverages on ground.

Figure 14. Driver-salesworker lifting 24-pack of 16-oz glass bottled soft drink (57.5 lb) beverages from truck.

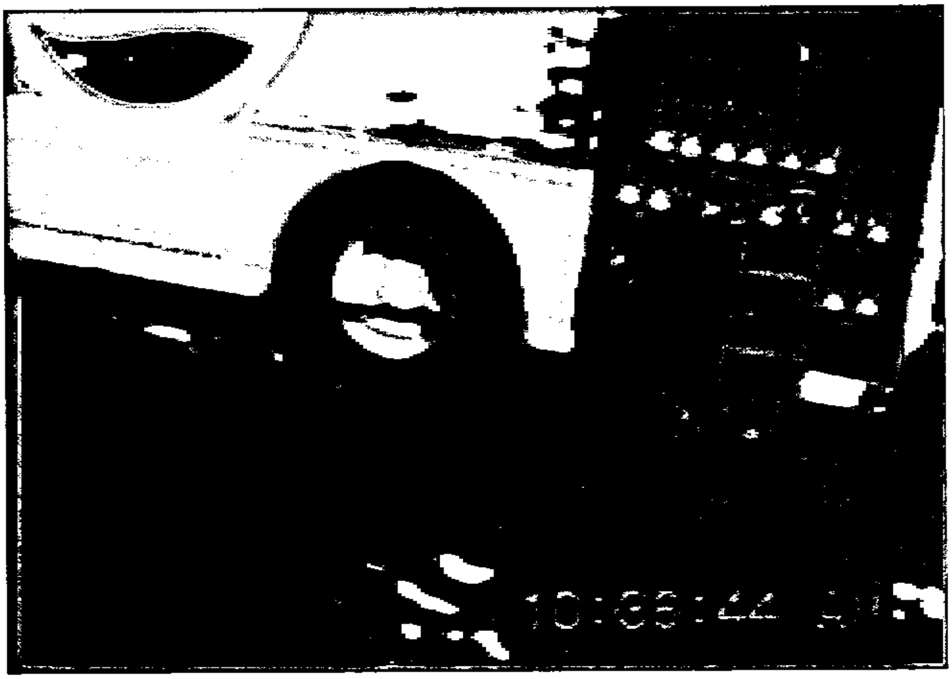

Figure 15. Driver-salesworker placing 24-pack of 16-oz glass bottled soft drink beverages on hand truck.

Table 11

Calculations Using 1991 NIOSH Formula for Lifting Case of 24 Glass 16-oz Soft Drink Beverages

Job Analysis Worksheet

Job Description: Conventional Beverage Delivery
Risk Factor Evaluated: Lifting case of 24 16-oz soft drink in glass bottles
(See Figures 14 and 15)
Height of Worker: 70 in., functional reach 31 in.

STEP 1. Measure and record task variables

Object Weight (lb)		Hand Location (in.) Origin: See Figure 14		Destination: See Figure 15		Vertical Distance (in.)	Asymmetric Angle (degrees) Origin	Destination	Frequency Rate lifts/min	Duration Hours	Object Coupling
L(Avg.)	L(Max.)	H	V	H	V	D	A	A	FM		CM
57.5	57.5	13	50	15	5	45	15	30	6	< 1	Fair

STEP 2. Determine the multipliers and compute the Recommended Weight Limits (RWLs)

RWL = LC × HM × VM × DM × AM × FM × CM

ORIGIN RWL = 51 × .77 × .85 × .86 × .95 × .75 × 1.0 = 20.4 lb

DESTINATION RWL = 51 × .50 × .81 × .86 × 1.0 × .75 × .95 = 16.1 lb

STEP 3. Compute the Lifting Index

ORIGIN $\text{Lifting index} = \frac{\text{Object Weight}}{\text{RWL}} = \frac{57.5}{20.4} = 2.8$

DESTINATION $\text{Lifting index} = \frac{\text{Object Weight}}{\text{RWL}} = \frac{57.5}{16.1} = 3.6$

Hand Grip

Table 14 shows right and left hand grip strength at the beginning and end of the workday over the survey period. The purpose of collecting hand grip data was to determine if there was any musculoskeletal fatigue in the forearms and hands at the end of the day. On average, grip strength increased at the end of the day, compared to the beginning although this increase was not statistically significant. Similar patterns of grip strength were seen at the beginning and end of the study. The difference in grip strength may have been related to driver-salesworkers' reporting of general stiffness in the morning, whereas in the evening they were "warmed up" from the day's activities and could exert more force. The average grip strength at the beginning of the day for the left hand was 103 (± 23) lb and for the right hand 106 (± 29) lb. At the end of the day, the grip strength for the left hand was 107 (± 29) lb and for the right hand 112 (± 29) lb. The range of grip strength was 65 lb for the right hand at the beginning of the day to 174 lb for the left hand at the end of the day.

Table 12

Calculations Using 1991 NIOSH Formula for Lifting 5-Gallon Bag-in-the-Box Containing Soft Drink Beverages from the Delivery Truck

Job Analysis Worksheet

Job Description: Tank and Bag-in-the-Box Beverage Delivery
Risk Factor Evaluated: Lifting 53-lb bag-in-the-box post-mix soft drink beverage drink
[Note: Container weight exceeds NIOSH RWL of 51 lb]
(See Figures 16 and 17)
Height of Worker: 76.5 in., functional reach 32 in.

STEP 1. Measure and record task variables

Object Weight (lb)		Hand Location (in.) Origin: See Figure 16		Destination: See Figure 17		Vertical Distance (in.)	Asymmetric Angle (degrees) Origin	Destination	Frequency Rate lifts/min	Duration Hours	Object Coupling
L(Avg.)	L(Max.)	H	V	H	V	D	A	A	FM		CM
53	53	20	45	15	10	35	30	0	6	< 1	Good

STEP 2. Determine the multipliers and compute the Recommended Weight Limits (RWLs)

RWL = LC × HM × VM × DM × AM × FM × CM

ORIGIN RWL = 51 × .50 × .89 × .87 × .90 × .75 × .90 = 12.0 lb

DESTINATION RWL = 51 × .67 × .85 × .87 × 1.0 × .75 × .90 = 17.0 lb

STEP 3. Compute the Lifting Index

ORIGIN Lifting index $= \frac{\text{Object Weight}}{\text{RWL}} = \frac{53.0}{12.0} = 4.4$

DESTINATION Lifting index $= \frac{\text{Object Weight}}{\text{RWL}} = \frac{53.0}{17.0} = 3.1$

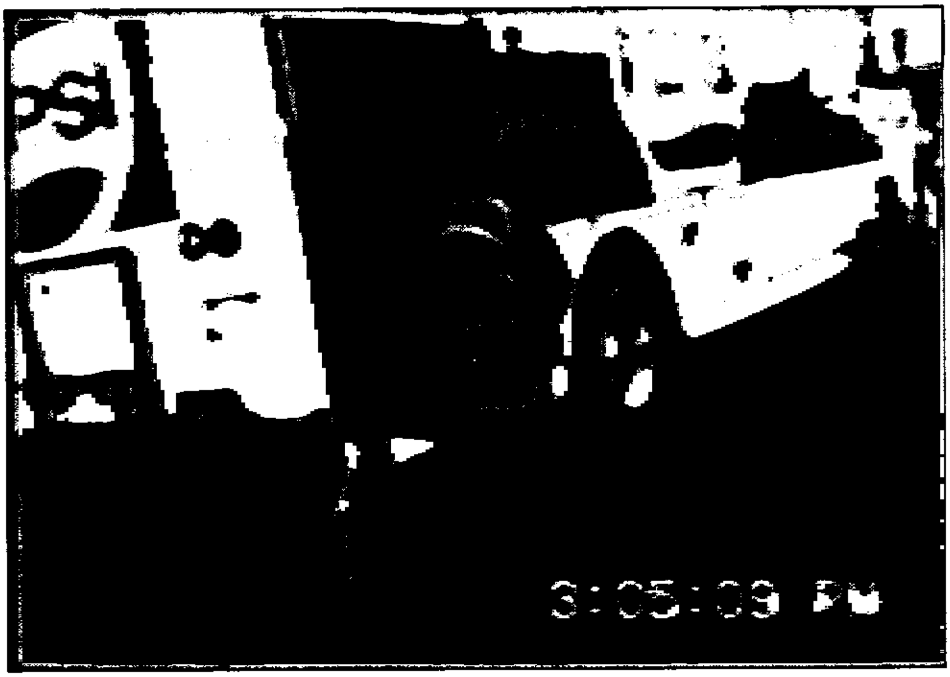

Figure 16. Driver-salesworker lifting bag-in-the-box (BIB) beverage syrup (53 lb) from truck.

Figure 17. Driver-salesworker placing bag-in-the-box (BIB) beverage syrup on hand truck.

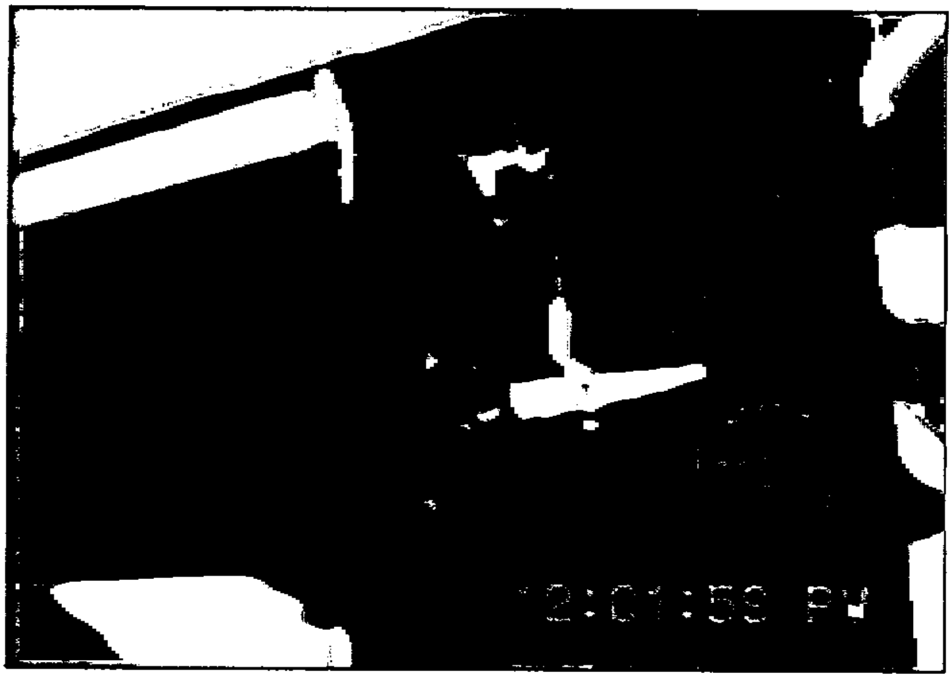

Figure 18. Driver-salesworker lifting aluminum cylinder containing pre-mix soft drink beverage (54.5 lb) from truck.

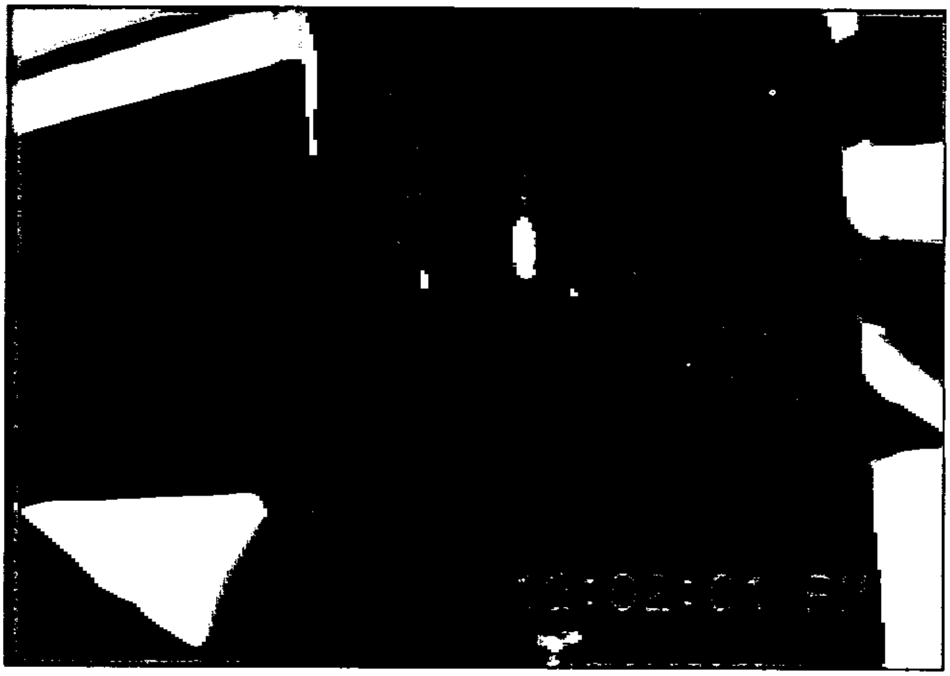

Figure 19. Driver-salesworker placing aluminum cylinder containing pre-mix soft drink beverage on ground.

Material Handling

Beverage Material Loaded and Delivered

Table 15 shows the average, maximum, and minimum number of cases loaded and sold during the NIOSH study. Sixty-four percent of the cases loaded were sold over the study period. The range was 47% to 74%. The tank and bag-in-the-box route data is also shown in Table 15. A similar pattern is seen for the tank and bag-in-the-box driver-salesworker, where more than 25% of the beverage loaded on the truck was brought back to the plant. The average number of tanks sold (pre- and post-mix, and CO_2) was 130, and the average number of bag-in-the-box units sold was 325, totaling 455.

Beverage Material Handled During Delivery Day

Table 16 shows the minimum (handled twice —remove beverage packages from truck and load on hand truck, transport to store and unload in store), probable (handled three times— same as above, but also counts for additional material handling, such as unloading from hand truck on loading dock, moving beverage packages around on truck, rotating back stock in stores, etc.), and maximum weight handled (handled four times, but more beverages handled due to multiple handling of packages, setting up island displays, etc.) at the beginning, middle, and end of the survey. The minimum weight handled was calculated by adding the total weight of products sold during that day and multiplying by two. This equation

Table 13

Calculations Using 1991 NIOSH Formula for Lifting 5-Gallon Bag-in-the-Box Containing Soft Drink Beverages and Placing on Hand Truck

Job Analysis Worksheet

Job Description: Tank and Bag-in-the-Box Beverage Delivery
Risk Factor Evaluated: Lifting 53.5-lb aluminum tanks containing pre-mix soft drink
[Note: Container weight exceeds NIOSH RWL of 51 lb]
(See Figures 18 and 19)
Height of Worker: 76.5 in., functional reach 32 in.

STEP 1. Measure and record task variables

Object Weight (lb)		Hand Location (in.) Origin: See Figure 18		Destination: See Figure 19		Vertical Distance (in.)	Asymmetric Angle (degrees) Origin	Destination	Frequency Rate lifts/min	Duration Hours	Object Coupling
L(Avg.)	L(Max.)	H	V	H	V	D	A	A	FM		CM
53.5	53.5	10	50	15	0	50	15	15	6	< 1	Good

STEP 2. Determine the multipliers and compute the Recommended Weight Limits (RWLs)

RWL = LC × HM × VM × DM × AM × FM × CM

ORIGIN RWL = 51 × 1.0 × .85 × .86 × .95 × .75 × 1.0 = 26.6 lb

DESTINATION RWL = 51 × .67 × .78 × .86 × .95 × .75 × 1.0 = 16.3 lb

STEP 3. Compute the Lifting Index

ORIGIN $\text{Lifting index} = \frac{\text{Object Weight}}{\text{RWL}} = \frac{53.5}{26.6} = 2.0$

DESTINATION $\text{Lifting index} = \frac{\text{Object Weight}}{\text{RWL}} = \frac{53.5}{16.3} = 3.3$

Table 14

Hand Grip Strength—Beginning and End of Workday

	Begin Left	Begin Right	End Left	End Right
Average (lb)	103	106	107	112
s.d.[1]	23	29	29	29
Maximum	150	151	174	166
Minimum	70	65	73	74

[1] s.d. = standard deviation

Not statistically significant comparing beginning with end grip strength.

Table 15

Truck Inventory—Beverages Loaded and Sold

Does not include bag-in-the-box/tank route	
Average number of cases loaded	517 (s.d.[1] 94)
Average number of cases sold	332 (s.d. 116)
Maximum number of cases loaded	681
Maximum number of cases sold	581
Minimum number of cases loaded	345
Minimum number of cases sold	162
Bag-in-the-box (BIB) and tank route	
Average number of 5-gal pre-mix tanks delivered	72
Average number of 5-gal post-mix tanks delivered	35
Average number of 5-gal Bag-in-the-box delivered	325
Average carbon dioxide tanks delivered	23
Maximum number of BIB/tanks loaded	1407
Maximum number of BIB/tanks sold	493
Minimum number of BIB/tanks loaded	1046
Minimum number of BIB/tanks sold	400

[1] s.d. = standard deviation

Table 16

Average Amount of Conventional Beverage Material Handled

n = 8	Minimum Weight[1] Handled & (s.d.)	Probable Weight[2] Handled & (s.d.)	Maximum Weight[3] Handled & (s.d.)
Begin Survey	23,815 ± (7,253)	35,722 ± (10,880)	47,629 ± (14,507)
Middle Survey	20,436 ± (5,926)	30,655 ± (8,888)	40,873 ± (11,851)
End Survey	24,005 ± (6,512)	36,008 ± (9,767)	48,010 ± (13,023)
Average Overall	22,752 ± (6,512)	34,128 ± (9,768)	45,504 ± (13,024)

[1] Each beverage package handled two times.

[2] Each beverage package handled three times.

[3] Each beverage package handled four times.

accounts for removing the beverage from the delivery truck, loading it on the hand truck, transporting it to the store, and unloading it from the hand truck. The probable weight handled is the total weight of beverage sold times 3, and the maximum weight handled is the total weight of beverage sold times 4. Based on observations by NIOSH researchers and on evaluations of selected videotapes showing beverage delivery, it was estimated that most beverage packages were handled three times. This equation takes into account moving cases around in the truck to get at needed beverage product for each stop, moving beverage stock already in the stores to the shelves (not counted because the beverage was not sold that day), and rotating beverage back stock to keep product fresh.

The decrease in the average amount of weight from the beginning of the study may have been from adjustments workers made in getting used to the retrofitted trucks. Every effort was made to make sure delivery days were kept consistent for each phase of the study. The increase in average weight at the end of the study may have resulted from the seasonal change from winter to spring, a higher demand for soft drinks due to sales and promotions, and the introduction of a new line of cold tea drink. Other factors may have resulted from the workers' growing comfort with the ergonomic controls and their ability to work more effectively.

Beverage and Type of Load

Table 17 shows the number of cases delivered per day for selected drivers, but these data may not be a good indicator of the delivery person's work load. For example, the first survey load comparisons between two driver-salesworkers (Subject 4 versus Subject 10) showed nearly equal total weights for beverages sold (26,202 lb versus 26,870 lb) during a routine delivery day. But the difference in cases sold was significant: 306 versus 451. Subject 10 sold many more cases of the 24-can cases of the12-oz can beverages (which average 22 lb each), compared to Subject 4 who sold less canned soft drinks, but substantially more 20-oz nonreturnable (49.9 lb) and 16-oz returnable (57.5 lb) packages of 24 glass bottles. Another example is shown in the second survey when Subject 3 sold 400 cases (23,330 lb) versus Subject 4, who sold 218 cases (21,023 lb). Subject 4 sold more 16-oz returnable and 20-oz nonreturnable glass bottles and 2-L plastic bottles, compared with Subject 3, who sold 312 cases of 12-oz cans out of 400 total cases sold. Finally, during the last survey, Subjects 4 and 7 sold approximately the same number of cases (308 and 312, respectively); however, the weights are significantly different (41,415 versus 29,429 lb, respectively), a difference of nearly 12,000 lb. When the weights, metabolic demand, biomechanical stress, and posture are figured in, the worker's day can vary significantly with regard to stress and strain. Therefore, while the number of cases sold can be a benchmark in determining worker stress, it is more important to determine weight delivered.

Ergonomic Interventions

Beverage Delivery Trucks

Table 18 summarizes the evaluation of safety and ergonomic interventions for the four beverage delivery trucks. Each truck had 21 modifications; some of these modifications were designed to make beverage delivery safer while others were aimed at reducing musculoskeletal injuries. As mentioned earlier, a check list similar to this table was used to evaluate each delivery truck for the completeness of the retrofit. At the beginning of the workday a walk around of the delivery truck was performed and deficiencies were noted on the check list. This procedure was repeated for each truck at the beginning and end of the intervention phase of this study. Problems with any of the modifications were relayed to the maintenance department supervisor to be fixed. Usually, the problems were fixed by the next day.

At the beginning of the intervention phase of the study, if the modification was done properly, then a **1** *(yes)* was marked in the column for that modification; if it was not done properly, then a **2** *(no)* was marked in that column. If the average score was close to 1, the modification was successful. If the score was closer to 2, then there were problems. Comments about the problem were written in the column next to the modifications noted in the checklist. The data in Table 18 show that 12 of 21 modifications were done to each truck without any problems. Safety retrofits that were not done or safety retrofits in need of repair were the spot mirrors on the right and left door and the heated/motorized mirror on the passenger side.

The ergonomic retrofit problems were:

- No installation of three-position drop shelf holes in some of the deep bays.
- No extra wide recessed steps on front and rear areas of wheels to access high bays.
- Missing anti-slip strips installed on bottom rail and step holes.
- Absence of pullout rear bay on one of the trucks.
- Worn rollers or absence of lubrication on some bay doors.
- Missing door straps to open and close bay doors.

Less than 10% of the total percentage of controls for the 4 trucks (three 10 bay, one 14 bay) had retrofit problems. As these deficiencies were pointed out by NIOSH researchers to management many of these problems were fixed before the end of the study.

For safety retrofit, most of the spot mirrors on the right and left doors as well as most motorized mirrors were in place at the beginning of the intervention phase of the study. Ergonomic retrofits included bays being fitted with 3-position drop shelves; installing anti-slip surfacing in bays and on step holes; installing more pullout steps on rear bays; lubricating doors and fixed rollers and installing bay door straps. Between the beginning and end of the intervention phase of this study, only two retrofits deteriorated during the study period: a missing external grab handle on one of the trucks (caused by a fork lift truck hitting it), and the backup alarm system. Video pictures in Appendix E show the various ergonomic retrofit controls used by the driver-salesworkers in this study.

Table 17

Beverage Cases and Loads Handled Comparing Driver-Salesworkers

		First Survey		Second Survey		Third Survey	
Beverage Package	**Weight (lb)**	**Subject 4**	**Subject 10**	**Subject 3**	**Subject 4**	**Subject 4**	**Subject 7**
10-oz bottles	(23)	0	0	0	0	4	0
12-oz cans	(22)	77	299	342	15	40	175
1-L glass	(45)	4	0	0	2	0	0
16-oz returnable glass	(57.5)	67	11	0	55	59	0
16-oz sport drink plastic	(30)	0	0	0	0	0	6
16-oz iced tea glass	(39)	0	0	6	2	11	18
20-oz glass nonreturnable	(49.5)	73	47	22	70	95	25
2-L plastic	(39)	85	94	30	74	99	88
Total Cases		306	451	400	218	308	312
Total Weight - Product WT × 3		39,303	40,303	30,495	31,535	41,415	29,429

Table 18

Beverage Truck Safety and Ergonomic-Related Intervention Results

Middle Versus End	Scores[1]		Comments
Safety and Ergonomic Retrofits for Beverage Trucks	Begin	End	
5-in. spot mirror on right and left door	1.44	1.22	Missing right spot mirror
5-in. spot mirrors mounted on right side of hood	1.0	1.0	
Heated mirror installed on driver side	1.0	1.0	
Heated/motorized mirror passenger side	1.22	1.11	Motor mirror not working
Air-cushioned driver seat	1.0	1.0	Stiff
3-point seat belt	1.0	1.0	
Exterior grab handles all bays	1.0	1.11	Missing grab handle
3-position drop shelf holes/all deep bays	1.22	1.0	Some not in
Installed handgrips in single sheet divider	1.0	1.0	Only applied to one truck
Wider step platform on wheel housing step bar	1.0	1.11	
Extra wide recessed steps front and rear	1.11	1.11	Not on all trucks
Bay liners all bays	1.11	1.11	Not on all trucks
Anti-slip installed on bottom rail and step holes	1.44	1.33	Skid strips gone, replaced with grit
Pullout step rear bays	1.11	1.0	Pullout rear bay
Motion backup alarms with guards	1.0	1.22	Faulty backup alarm
Large hand truck holder and high back rest for 2 hand trucks	1.0	1.0	
Raised stop/tail lights and backup lights to hood level	1.0	1.0	
Recessed license plate brackets	1.0	1.0	
New rollers in all bay door slats and lubricated doors	1.22	1.0	All lubricated, but some stick
New door straps	1.33	1.11	Bay door straps replaced
New "caution wide right turn" sign	1.0	1.0	

Notes: Seven interventions improved from initial to final evaluation; 2 got worse, 12 stayed the same.
Perfect scores of 1.0 indicates changes were made to all trucks; a decrease in End score compared to Begin score shows improvement; an increase End score compared to Begin score shows deterioration of retrofit changes.
Bold print indicates improvements; *Italic* indicates deterioration.

[1] Scores calculated from number of yes=1, versus no=2 for safety and ergonomic retrofit changes for the four trucks from the beginning (i.e., retrofits first installed) versus end of the NIOSH study.

Bay Door Forces for Opening and Closing

The force to raise and lower bay doors was measured using a force gauge (Accuforce Cadet™ 0–100 lb, Metek, Mansfield and Green Division, Wagner Instruments, Greenwich, CT). Table 19 shows the differing forces needed to lift and lower the bay doors at the beginning, middle, and end of the study. Over the study period there was a significant reduction (mean: 7.8 ± 1.1 lb) in the amount of force needed to lift and lower the bay doors, but there was not a significant reduction ($p > .05$) during the intervention phase.

Hand Trucks

Six of the nine participants used at least one hand truck with pneumatic (balloon) tires. In general, at the beginning of the study the tires were underinflated and not always evenly pressurized (Table 20). Pre- and post-intervention tire measurements were made with a small tire pressure gauge, and then the tires were inflated from 28 to 32 lb with a tire pump. When properly pressurized, the tires usually maintained their pressure over the study period.

Table 19

Bay Door Force, Before, During, and After Ergonomic Interventions —Bay Door Force (lb and S.D.)

	Up Left Driver Side	Down Left Driver Side	Up Right Passenger Side	Down Right Passenger Side
Beginning	47.2 (13.8)	31.9 (13.3)	49.9 (20.7)	29.4 (8.7)
Middle	41.1 (11.5)	24.4 (5.0)	41.1 (11.1)	22.8 (6.3)
End	39.7 (9.4)	23.5 (4.6)	41.1 (8.7)	23.1 (5.5)

Notes: t-statistic:Significantly reduced up and down bay door forces for left and right sides between first and third surveys.

Non-significantly reduced up and down bay doors forces for left and right sides between second and third surveys.

Table 20

Tire Pressure from Hand trucks—Tire Pressure (lb)

	2-Wheel Pneumatic Tires		4-Wheel Pneumatic Tires[1]	
	Left	Right	Left	Right
Begin	21	20	26	20
End	28	28	31	32

[1] **Note:** 4-wheel hand trucks have 2 hard rubber and 2 pneumatic tires.

DISCUSSION

As stated in the Introduction, the goal of this study was to apply ergonomic controls and measure their effectiveness in reducing musculoskeletal injuries through psychophysical, physiological, and biomechanical methods in the soft drink beverage delivery industry. It should be noted that this study evaluated musculoskeletal hazards collectively; it did not study individual risk factors, as the driver-salesworkers were self-selected volunteers, the demographic risk factors could not be studied. Nine driver-salesworkers with an average of 20 years of experience participated in this study.

Discomfort Assessment System

As shown in Table 5, the prevalence of musculoskeletal discomfort increased between the first and second survey, then decreased on the third survey. This pattern is similar to other intervention studies, where an increase in awareness and adjustment to new controls result in increased reporting of injuries among workers. Then after workers adjust to the controls, discomfort reporting decreases.[19]

The body part most frequently affected was the low back, followed by the back right shoulder, left elbow, and knees. While discomfort reporting decreased by 50% between the first and third survey for the low back, due to the small sample size the decrease was not statistically significant. However, the reporting of shoulder and elbow discomfort did decrease significantly. This reduction in discomfort reports may be attributed to some of the ergonomic interventions, such as the external handles, pullout shelves, adjustable height shelves, and heavier load beverage cases placed on lower shelves for easier access with less lifting.

There was no significant change in the level of pain between the first and third surveys. Because the majority of responses for pain were 4 and below on a scale of 1 (very low discomfort) to 10 (worst imaginable discomfort), this lack of change is not surprising.

Metabolic Measures

The average decrease in heart rate of 4 bpm (104 to 100 beats per minute [bpm]), over the course of this study was significant ($t = 2.29$, $p = .026$, one-tailed test). The peak heart rate also decreased significantly ($t = 2.09$, $p = .035$, one-tailed test) by 10 bpm (54 to 144 bpm) over the course of this study. There was not a significant decrease in resting heart rate (67 bpm beginning to 66 bpm end). The decrease in average and peak heart rate may be attributable to several factors, including the ergonomic interventions on the truck and the use of well-maintained hand trucks. Figures 20–23 shows photographs of beverage driver-salesworkers' activities overlaid with real-time heart rate. Figure 20 shows the heart rate increased, suggesting pooling of blood from the upper extremities to the heart, when lifting beverages with arms outstretched and above the shoulders. Figure 21 shows the same work activity as in Figure 20 but provides a perspective of cardiovascular demands (note higher heart rate demand when work is done above the shoulders relative to lower demand for activities where arms perform work below shoulder height). Figure 22 shows cardiovascular demand when using pullout shelf on beverage delivery truck. Figure 23 shows higher cardiovascular demands when kneeling down to put beverages on shelves, suggesting pooling of blood from the lower extremities to the heart.

Fifty percent of the maximum predicted heart rate is cited in the literature as a bench mark for determining whether rest breaks should be taken during an 8-hour day. Data from this study show that the average heart rate was approximately 32 and

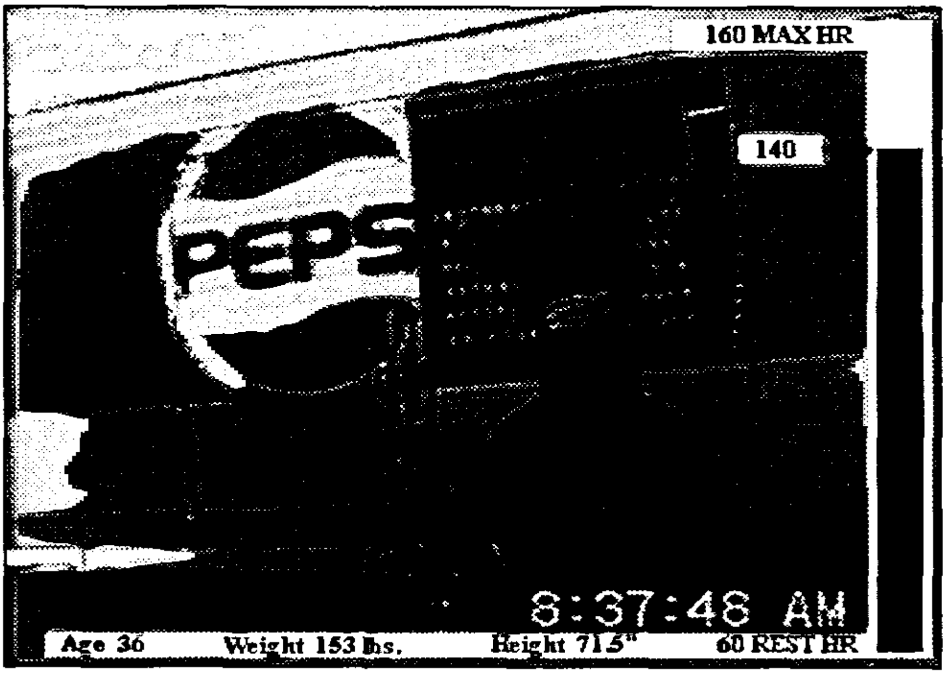

Figure 20. Heart rate overlay (bar graph) on videograph of worker getting soft drinks from top shelf in truck. **[Arrow points to driver-salesworker's current heart rate.]**

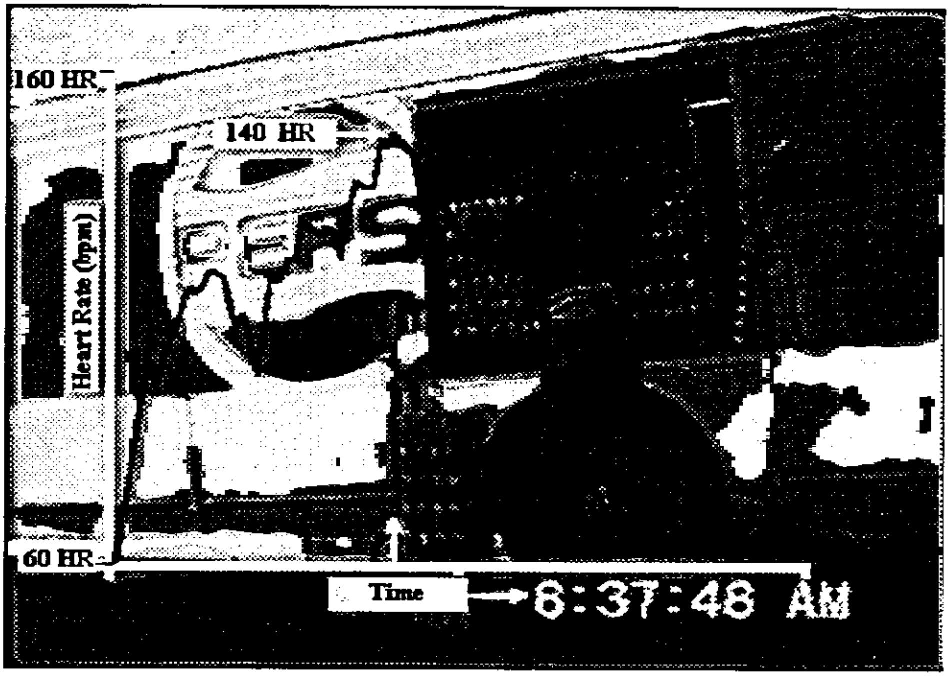

Figure 21. Heart rate overlay (chart) on videograph of worker getting soft drinks from top shelf in truck. **[Arrow points to driver-sales-worker's current heart rate.]**

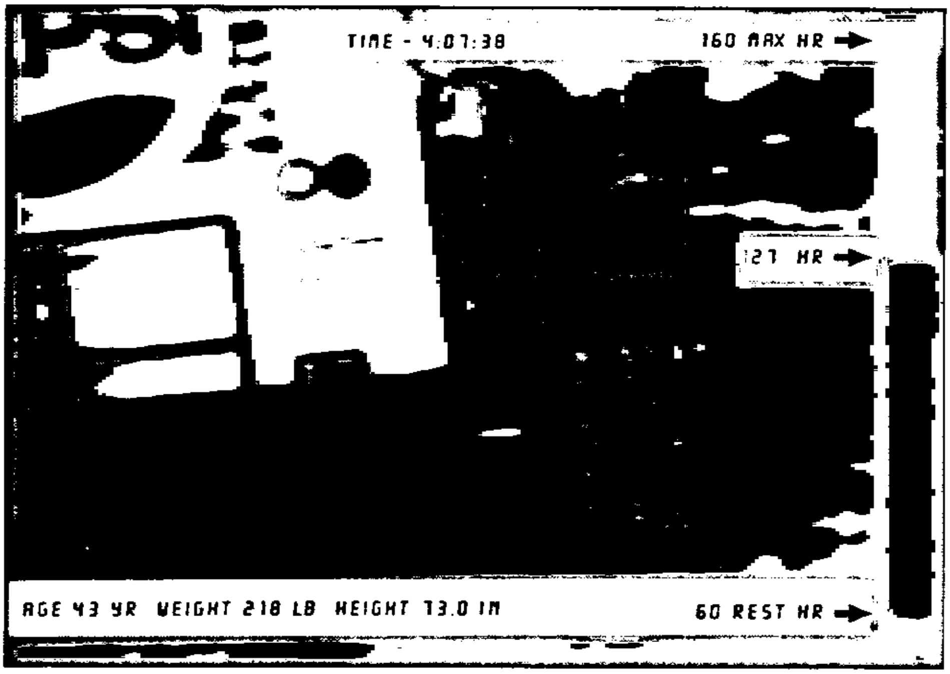

Figure 22. Heart rate overlay (bar graph) on videograph of worker pulling out shelf on beverage delivery truck.

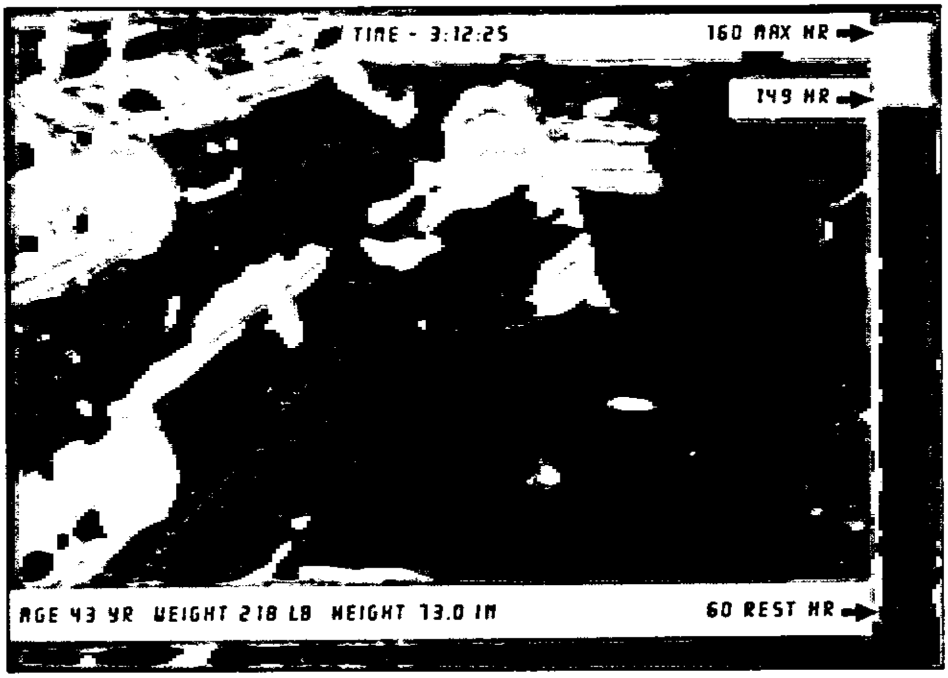

Figure 23. Heart rate overlay (bar graph) on videograph of worker in squatted position putting soft drinks on store shelf.

30% of the maximum predicted heart rate, at the beginning and end of the study, respectively. These data suggest the driver-salesworkers know how to pace themselves; if more time is needed to perform deliveries during a day, they have the option to take it. Also, the heart rate data were taken in the winter and early spring when the volume of beverage delivery is lower than in late spring, summer, and early fall. During the warm seasons, the increased temperature and load would tend to increase heart rate. This may not happen if there is sufficient time during the day for compensatory self-pacing. These driver-salesworkers are aware of this fact and reportedly drink plenty of water. Driver-salesworkers without as much experience, however, may not be aware of the need to replenish body fluids or have the experience to properly pace themselves. Inexperienced workers should therefore be trained about the need for rest breaks, proper self-pacing, and for adequate fluid replacement.

Biomechanical Analysis of Videotapes

Beverage package weights evaluated in this study were arbitrarily divided into three categories:

- Above the 51-lb NIOSH lifting equation limit (category 1)
- Less than 51 lb, but greater than 39 lb (category 2)
- Less than 39 lb (category 3).

Packages in category 1 were pre-mix tanks (53.5 lb), post-mix tanks (57 lb), bag-in-the-box (53 lb), 16-oz returnable (57.5 lb), and wood pallets (55 lb). Those packages exceeded the ideal load and, according to the NIOSH guidelines, should be handled using mechanical aids. As shown in Table 13 (Figures 18 and 19), when the task-related factors were computed, the ideal weight was adjusted to 26.6 lb at the beginning of the lift (i.e., removing the tank from the truck), and 16.3 lb at the end of the lift (i.e., placing the tank on the ground). The LI, a ratio of the product weight divided by the NIOSH RWL, showed a LI of 2.0 at the beginning of the lift, and 3.3 at the end. However, if the pullout steps were used, analysis of this same task showed that the ideal weight was 27.2 lb at the beginning and 31.6 lb at the end (Table 21, Figures 24 and 25). The LI did not change at the beginning, but decreased substantially to 1.7 at the end. This decrease occurred because the delivery person did not have to reach as far to set the tank down. This was also the case with the bag-in-the-box (BIB) material handling. The BIB weighed 53 lb, (Table 12, and Figures 16 and 17); the LI at the beginning of the lift was 4.4 and at the end was 3.1. In this case, the LI was higher at the beginning of the lift than at the end. The decreased LI resulted from the worker twisting and reaching for the BIB at the beginning and releasing the load approximately 8 in. above the hand truck at the end. Analysis of material handling for the other packages (wooden pallets) in category 1 showed similar results on risk for back injury. Even though wooden pallets were not handled often during beverage delivery, their weight (55 lb) and awkward size (approximately 40 in. × 40 in. × 5 in.) meant that they had to be handled with care. If the NIOSH RWL is exceeded, the recommendation is to use engineering controls, such as a hoist or the soft drink should be repackaged into smaller, lighter units. An example is to reduce the 5-gal BIB to a 3-gal BIB. The smaller and lighter BIB could reduce risk for the delivery person, as well as for the customer who may need to change the BIB when empty. The BIB

Table 21

Calculations Using 1991 NIOSH Lifting Formula for Manual Material Handling of Soft Drink Beverages

Job Analysis Worksheet

Job Description: Tank and Bag-in-the-Box Beverage Delivery
Risk Factor Evaluated: Lifting 53.5-lb aluminum tanks containing pre-mix soft drink
[Note: Container weight exceeds NIOSH RWL of 51 lb]
(See Figures 24 and 25)
Height of Worker: 76.5 in., functional reach 32 in.

STEP 1. Measure and record task variables

Object Weight (lb)		Hand Location (in.) Origin: See Figure 24		Destination: See Figure 25		Vertical Distance (in.)	Asymmetric Angle (degrees) Origin	Destination	Frequency Rate lifts/min	Duration Hours	Object Coupling
L(Avg.)	L(Max.)	H	V	H	V	D	A	A	FM		CM
53.5	53.5	10	50	10	20	30	15	0	6	< 1	Good

STEP 2. Determine the multipliers and compute the Recommended Weight Limits (RWLs)

RWL	= LC × HM × VM × DM × AM × FM × CM
ORIGIN RWL	= 51 × 1.0× .85× .88 × .95 × .75 × 1.0 = 27.2 lb
DESTINATION RWL	= 51 × .1.0× .94× .88 × .1.0× .75 × 1.0 = 31.6 lb

STEP 3. Compute the Lifting Index

ORIGIN Lifting index = $\frac{\text{Object Weight}}{\text{RWL}} = \frac{53.5}{26.6} = 2.0$

DESTINATION Lifting index = $\frac{\text{Object Weight}}{\text{RWL}} = \frac{53.5}{16.3} = 3.3$

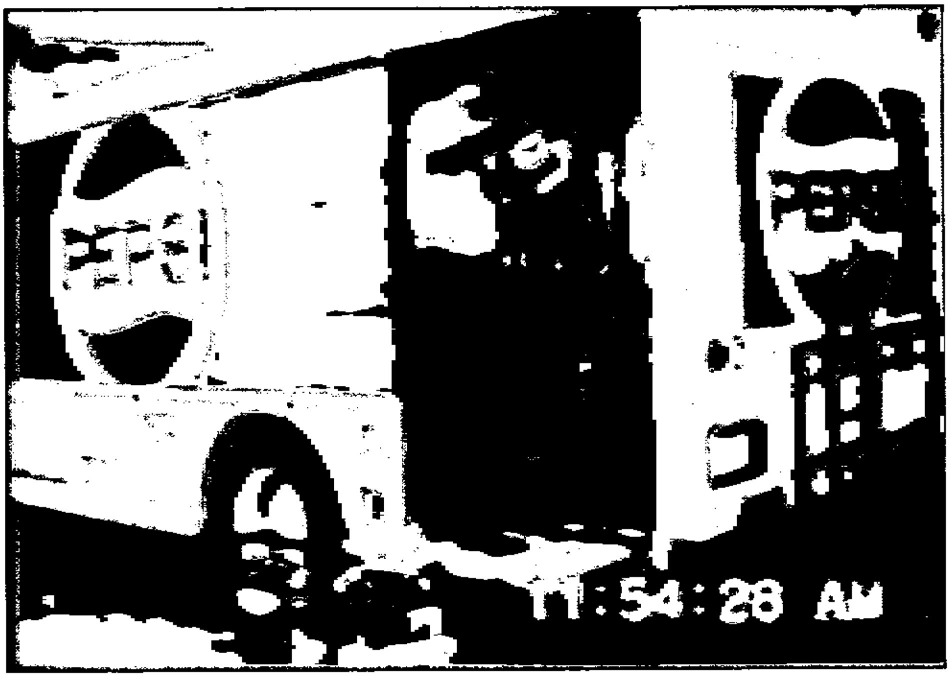

Figure 24. Driver-salesworker lifting aluminum cylinder containing pre-mix soft drink beverage (54.5 lb) from truck while standing on pullout platform.

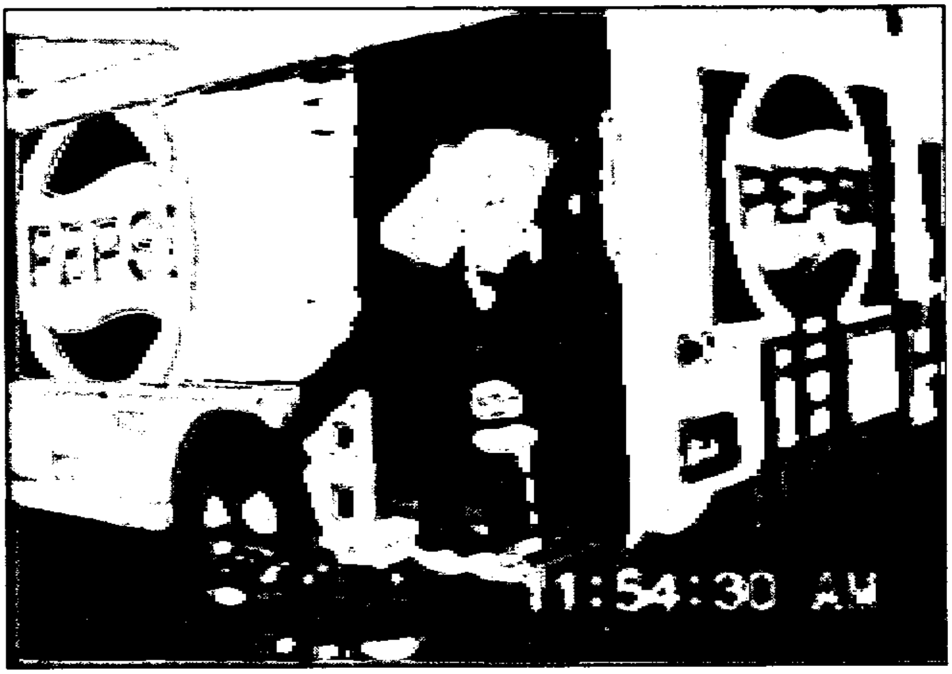

Figure 25. Driver-salesworker placing aluminum cylinder containing pre-mix soft drink beverage on pullout platform.

now comes in 3-gal package which weighs approximately 32 lb. Using the example given in Table 12 (Figures 16 and 17), the LI changes to 2.7 (from 4.4) at the beginning of the lift (i.e., lifting BIB from truck) and 1.9 (from 3.1) at the end (i.e., placing the BIB on the ground). If good work practices are used to bring the load closer to the body and to reduce twisting, the LI can be reduced to less than 1.0.

Category 2 containers (39 to 50 lb) included 20-oz glass bottles (package of 24 was 49.5 lb), 1-L glass (package of 15 was 45 lb), 2-L plastic 8-pack (39 lb), and 16-oz glass (package of 24 was 39 lb). While these beverage packages are less than the NIOSH specified ideal weight of 51 lb (as recommended by the revised NIOSH Lifting Equation), risk for back injury can be high depending on the worker's posture when handling these packages. For example, Table 10 (Figures 12 and 13) shows that the weight should be no more than 18.7 lb and 12.7 lb at the beginning and the end of the lift. The LI is 2.6 and 3.9, respectively. However, by substituting glass containers for plastic, the weight would be reduced from 49.5 lb to 37 lb and the LI would then be reduced to 1.9 at the beginning of the lift and 2.9 at the end of the lift. This would prove to be a substantial reduction considering the repetitive lifting of a popular package over time. For example, if the delivery person sold 200 cases of this product per day, the difference in weight handled per day between the plastic versus glass packages would be 7,400 lb versus 9,900 lb, and per week 37,000 lb versus 49,500 lb. A difference of 12,500 lb per week is substantial. Even if the number of cases sold were cut in half, to 6,300 lb per week, the reduction is still considerable. Putting beverage into plastic containers also benefits the warehouse worker who loads and unloads the beverage on the trucks.

The 2-L, 8-pack package used during this study was poorly designed. The package was heavy (39 lb) and awkward to handle. The instability of the 2-L containers in the plastic shell made handling awkward and more stressful to the driver-salesworkers. The plastic shell was long (18 in.) and narrow (8 in.) relative to its height (5 in.). At the base of each end of the shells were two openings (4 in. wide × 1 in. high × 1 in. deep) which served as handles. Approximately 25% (4 in.) of the bottom half of the 2-L containers fitted into the base of the plastic shell. The bottom of the shell had ribbed circular rings which are concave to fit over the tops of the 2-L bottles when stacked on top of each other. This design helped to hold the packages in place during delivery from the beverage plant to the customer. However, the design also made it hard for the driver-salesworkers to remove the packages from the truck because they had to lift and pull each package forward. The lifting and pulling caused repeated stress to the worker's shoulders, which could have resulted in injury. Figures 10 and 11 show a delivery person removing this package from a truck. Two options for reducing musculoskeletal stress to the shoulders and back were suggested for this package (see biomechanical analysis results presented earlier). The first was to reduce the weight by repackaging from 8-pack to 6-pack shells. This change would reduce the weight of the package by approximately 10 lb and also make the package more stable during manual handling. The other option is to redesign the plastic shell by making the two 1-L pods (i.e., openings for the bottle to be seated) deeper, smoothing ribs on the underside of the shell, and improving the handles by making them deeper and wider. This would stabilize the contents and make it easier for manual handling. Also, if the 8-pack shell is redesigned, then it should be loaded in a bay no higher than mid-chest height to reduce stress on the shoulders and back. Other packages in this category, such as the package of fifteen 1-L beverages, are generally not handled in enough volume to be of concern.

Category 3 beverage packages included the 10-oz nonreturnable (case of 24–23 lb), 12-oz cans (case of 24–22 lb), 16-oz glass (case of 24–30 lb), 20-oz soft drink plastic (case of 24–37 lb), 32-oz sport drink (case of 12–30 lb), 64-oz sport drink (case of 6–30 lb), pre- and post-mix tanks empty (10 lb), CO_2 tanks empty (26 lb), cups (34 lb), and lids (11 lb).

The beverage products handled in sufficient quantities include the 12-oz cans, 20-oz soft drink plastic containers, and pre- and post-mix tanks. As shown in Table 8 (Figures 8 and 9), the NIOSH RWL for the 12-oz can packages is 13.8 and 15.5 lbs, given the constraints of the delivery person's posture and the absence of handles. This worker was handling 2 cases at a time for this analysis, resulting in a LI of 3.2 at the beginning of the lift, and 2.8 at the end of the lift. However, if the packages were handled one at a time, the LI would be reduced to 1.6 and 1.4, respectively. This change would reduce the risk of back injury significantly. Therefore, driver-salesworkers should be encouraged to handle the 12-oz can packages one at a time.

The other beverage packages, such as the 10-oz glass nonreturnable (23 lb), 15-oz glass sport drinks, empty cylinders, cups and lids, were either light enough not to be a priority for controls or were not handled in sufficient quantity to cause concern. However, if there is an opportunity to make the packages lighter, for example substituting plastic for glass, then this should be done. Another reason for switching to plastic is that glass containers should not be stored above shoulder height (approximately 58 in. [147 cm]), as they can fall out of their cases and shatter.

Material Handling

On average only 75% of the beverages loaded on the trucks were sold during the NIOSH study. This figure means that 25% of the load that left the plant was carried around from one establishment to another, moved about by the driver-salesworkers to access other beverage packages, and brought back to the plant on a daily basis. Such an inefficient system can be very costly to the company in terms of loading and unloading at the plant, extra fuel for transportation, and multiple handling by the driver-salesworkers. The excess beverage packages cannot be left on the truck because the route and orders change daily. Also, it is easier to manually build the beverage order on a pallet outside the truck and load it using a forklift truck. The driver-salesworkers said management wanted the beverages available for customers and wanted to "push" new products that were brought on line, such as a new line of iced tea drinks introduced during this study. Management said that the driver-salesworkers took more than needed of a product because they wanted to have it available should an unexpected sales opportunity arise. A more efficient system needs to be put in place, such as a computerized data entry system that transmits the beverage information automatically to the plant at the completion of each sales transaction. Such a system would improve the bookkeeping at the plant, result in better planning, and reduce the amount of beverages transported and handled for the delivery person, as well as the warehouse worker.

Beverage Material Handled

As shown in Table 16, an average of 34,000 lb (assuming each case was handled 3 times) of beverage was handled on a daily basis by the driver-salesworkers for conventional delivery in the city in the winter when soft drink beverage sales were relatively slow. In the summer, especially before holidays, delivery of soft drink beverages may commonly exceed 500 cases per day per delivery person. Therefore, the estimates of load handled during this study may be conservative. For example, one delivery person said that he sells approximately 80,000 cases of soft drink beverage per year. This number averages to approximately 1,600 cases per week (assuming 50 work weeks). If seasonal trends are taken into consideration, then the number of cases sold per week may range from 1,200 in the winter to 2,000 in the summer. Following this reasoning, the estimate for the average daily beverage weight handled during the period of this study was approximately 60% of the peak summer work load, approximately 56,000 lb.

Beverage and Type of Load

As shown in Table 17, the number of cases delivered per day is not a good indicator of the driver-salesworkers' work load. The three examples shown in this table show that neither the number of cases sold nor total weight handled is a good indicator of musculoskeletal stress. When determining weight handled for driver-salesworkers, it is important to determine what beverage product was sold and how many.

With the variety of beverages and the types of packages rapidly expanding each year, it is important that package designers give some thought to package weight and size. The heavier packages, such as the 20-oz glass containers, the unwieldy 2-L, 8-pack, and the 16-oz glass returnable, add to the stress and strain on the driver-salesworkers. The cumulative trauma from repeated exposure to lifting beverage products can result in musculoskeletal injuries to the driver-salesworkers.

Ergonomic Interventions

The study participants liked all of the ergonomic features, especially the air-cushioned ride seats, the exterior grab handles, the 3-position drop shelves, the anti-slip strips, the extra wide recessed steps front and rear of wheels and wider step platform, the new rollers, and the lubrication of bay doors. The anti-slip strips were replaced by an anti-slip grit paint that lasted longer than the strips. The strips frequently pealed off as the fork lift trucks slid palletized loads on and off the trucks. The pullout step on the rear bay had mixed reviews by the driver-salesworkers. Generally, those who liked the pullout step were less than 6-ft tall. The platform allowed easier access to the beverage packages stored high in the bay for the shorter driver-salesworkers. This feature reduced the musculoskeletal stress to the shoulders and backs. Taller driver-salesworkers did not like the platform as much because it meant double handling of the product in moving it from the bay to the platform and from the platform to the hand truck. Another concern was that the driver-salesworkers would sometimes forget to slide the platform back in its pocket in the bay and other driver-sales workers would run into it, especially when turning around the corner of the truck. When the platform is pulled out, it extends about 2 ft from the truck bay and is approximately 24 in. off the ground (about knee level). Also, the taller workers noted that the platform raised beverage packages another 5 in. from the bottom of the bay, causing them to reach higher to get the packages when they choose not to use the platform. Most of the driver-salesworkers suggested that the platforms might be better used in the center of the trucks since the trucks tended to be higher here, and the position would be less problematic for people running into the platform. They also recommended that the openings for the platform be enlarged. This improvement would allow for foot clearance (approximately 4 in. high and 6 in. wide) to make it easier to stand on the bay floor should a worker not want to pull out the platform.

The safety features on the truck most liked by the driver-salesworkers included the 5-in. spot mirrors and the heated/motorized mirror on the passenger side. All driver-salesworkers said they did not like the back-up alarm system. As the drivers understood it, the audible alarm was to increase in frequency and change in pitch the closer the truck came to an object when it was backing up. When the driver-salesworkers backed the truck up, an audible sound was given, but the change in frequency and pitch were not easily distinguishable and caused confusion. They soon discounted the audible alarm and used the new spot mirrors on each side of the truck to back up.

One of the ergonomic controls was to replace rollers and lubricate the bay doors to make the doors on the truck easier to open and close thus reducing stress to the worker's back and shoulders. Other studies have shown that when bay doors are not lubricated or are in poor repair from fork lift trucks hitting them, they cause musculoskeletal problems.

Hand Trucks

Hand trucks are indispensable when delivering beverages from the truck to the customer. Beverage loads for a 2-wheel hand truck can range from 240 lb (11 cases of 24-can 12-oz beverage) to over 350 lb (6 cases of 16-oz returnable). Beverage loads for a portable 4-wheel hand truck can range from 585 lb (15 2-L 8-packs) to over 700 lb (12 cases 16-oz returnable). When loads are pushed up hill, up ramps, or pulled up steps the musculoskeletal stress can be significant. A poorly maintained hand truck will greatly increase the physical stress. When hand truck tires are unevenly pressurized the arms, back, and legs have to compensate in order to move the load in a straight line. Under-pressurized and unevenly pressurized tires may add significantly more compressive force to the back during beverage delivery. These conditions can also create a safety hazard in that the beverage load is less stable and may fall off the hand truck when the delivery person turns a corner or stops suddenly.

Hard rubber tires do not have the problems associated with balloon tires, and hand trucks are easier to maneuver in stores because of the smaller width at the base. However, hard rubber tires do not move very well over rough terrain. Gravel, sand, grass, snow, and ice cause problems for these hand trucks. Hand trucks with balloon tires are better suited for such terrain.

Based on this study, the driver-salesworkers should have a minimum of two hand trucks, a 2-wheel hand truck and a 4-wheel hand truck. The driver-salesworkers should have the option of hard wheels or balloon tires for the 2-wheel hand truck.

Installing dual hand truck holders on the back of the truck allows the two hand trucks to be transported more easily by the driver-salesworkers. Maintenance of the hand trucks is important since they are indispensable to the driver-salesworkers. Lubricating moving parts, replacing worn parts (such as the stair climbing support brackets), and making sure the tires are evenly and properly pressurized are critical to reducing the overall musculoskeletal stress during beverage delivery. Also, the slot openings of the hand truck holders should be wide enough to easily slip the foot of the hand truck in and out. During this study, one of the retrofitted trucks had a narrow opening in one of the holders and the delivery person had to force the hand truck in and out of the opening.

One-Year Follow-up

NIOSH researchers did a one-year follow-up from the end of the study to observe delivery truck engineering changes. Because of the ever-increasing line of products and packages (24 new products added to an existing line of over 200 products and packages), this plant was changing over to 14-bay tractor-trailer trucks. The 14-bay tractor-trailers can be used for both city and rural conventional beverage delivery. The additional bays should reduce the amount of beverage rehandling and allow for more products to be loaded.

The ergonomic and safety changes incorporated into the tractor included an upgrade to the air-cushioned seat with lumbar support:

- External grab handles on all bays.
- 3-position drop shelves all bays, plus additional shelves spaced above and below the drop shelves and spaced approximately 3 ft apart.
- Step platform on wheel housing made narrower because of new back-up alarm bell covering the wheel hub (back wheel).
- Pullout step bar for the bay over front wheel of trailer, with lock-down hook to secure the step bar when climbing.
- Anti-slip grit paint on all bay rails.
- Large hand truck holder and "high back rest" for 2 hand trucks.
- New rollers and lubrication of doors.
- Door strips made of soft rubber coated nylon, which lasts longer and is gentler on the hands.

In the tractor cab the printer was moved from the back of the cab to the front, near the dashboard, between the driver and passenger seats. Moving the printer forward in the cab helped to reduce the amount of twisting and the awkward postures to access the printed receipts. Figures 26 and 27 show the 14-bay trailer and detail some of the ergonomic and safety features mentioned above.

Another safety aspect is the concern for robbery of driver-salesworkers. During the NIOSH research project on ergonomic interventions in the soft drink beverage delivery industry, it was noted that the route drivers collect a substantial amount of cash from their delivery accounts in the course of their workday. Many of these accounts do not have established credit histories and as a result pay in cash. While some of the delivery trucks have safes, all of the drivers that were in the research study carried cash from these transactions on their person. The route drivers are instructed to hand over the money if demanded. While robbery had not been a major problem for route drivers at the surveyed plant, the potential for robbery and possible bodily injury to these employees exists. Suggestions to decrease this potential hazard are in the Recommendations section of this report.

While more beverage products and packages were introduced since the previous year, some packages were eliminated or redesigned. The

Figure 26. Fourteen-bay beverage delivery truck with ergonomic controls installed. **[This type of truck will eventually replace the ten-bay delivery truck.]**

Figure 27. Multiple, adjustable height drop shelves installed to reduce beverage crate handling.

16-oz returnable bottles were eliminated. This was the heaviest of all soft drink packages, at 57.5 lb per case, and its absence should significantly reduce the musculoskeletal stress for driver-sales-workers. The 20-oz glass bottles had been replaced by 20-oz plastic bottles, reducing weight per case from 49.5 lb to 37 lb. Because the 20-oz size is a popular beverage package, the change from glass to plastic should significantly reduce stress and strain from the back and shoulders. The 3-gal bag-in-the-box was also introduced in 1994. The two main advantages of this package over the 5-gal BIB are size (approximately 2 in. less in width, height, and length) and weight (approximately 32 lb versus 53 lb). Because of the smaller size and weight, material handling is easier and stress to the back is reduced. The smaller size also benefits the business owner who has to occasionally change the BIB when empty. Many establishments do not have personnel with the strength or training to change the 5-gal BIB without risk of back injury. The 3-gal BIB is favored over the 5-gal BIB for these reasons. Finally, NIOSH researchers were shown a redesigned plastic shell for the 8-pack, 2-L beverage package. The new shell features raised "towers" on the corners and in the center to stabilize the 2-L bottles. It has a larger handhold for easier handling and a smoother base for easier removal (less lift and pull) when stacked on top of one another. These changes should reduce many of the musculoskeletal concerns addressed during this study. The original and new types of plastic shells are shown in Figures 28–31.

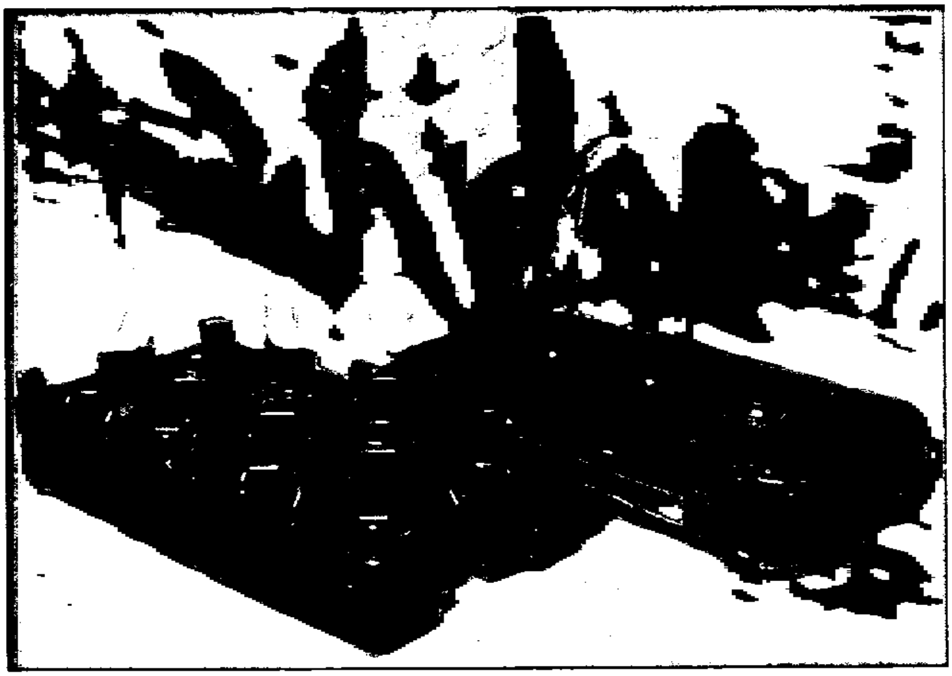

Figure 28. New plastic shells (left) and original plastic shells (right) for 8 pack, 2-L beverage containers.

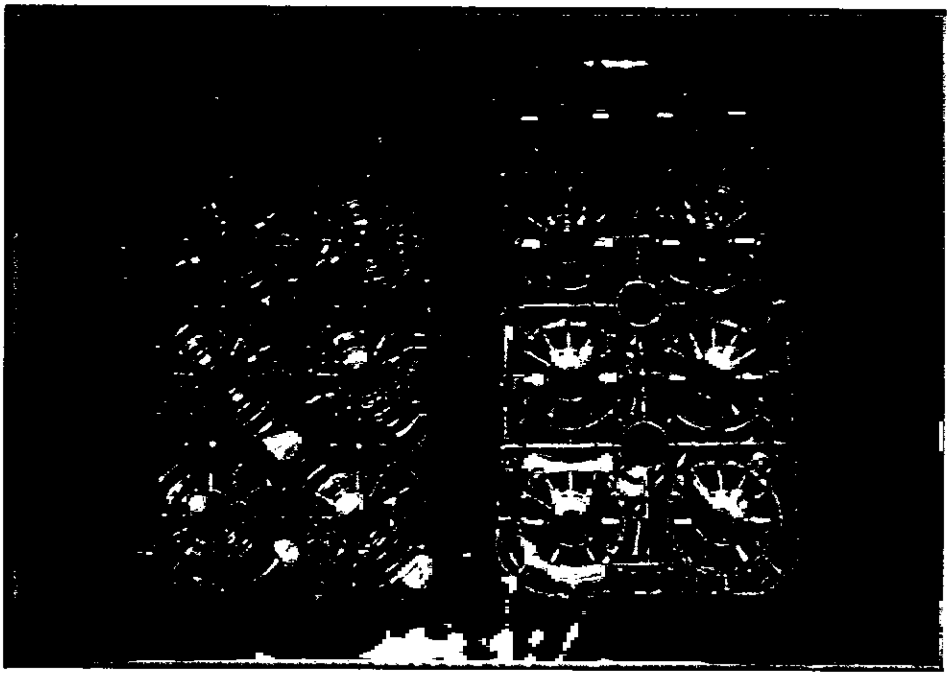

Figure 29. Bottom view of new (left) and original plastic shells (right) for 8-pack, 2-L beverage containers. **[Note: Fewer sharp edges on the bottom of the new shell made it easier to manually slide them when unstacking beverages.]**

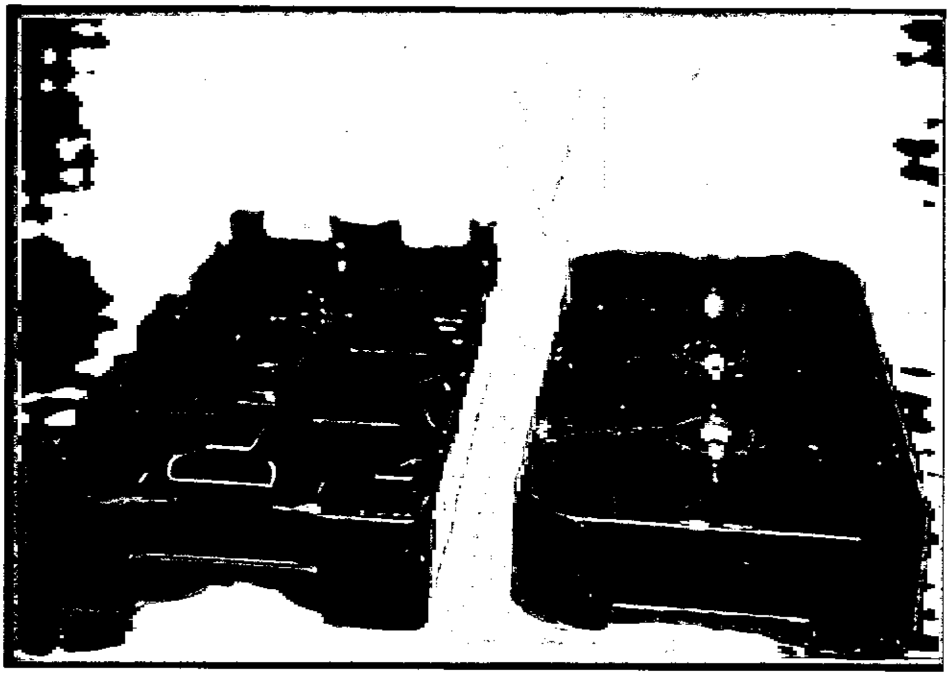

Figure 30. Profile of new (top left) and original plastic shells for 8-pack, 2-L beverage containers. **[Note: "Towers" along the shell perimeter and in the center to stabilize individual 2-L beverages and make the package easier to transport.]**

Figure 31. Easy access handles on new 8-pack, 2-L plastic shell for manual transport.

Currently, there are few job advancement opportunities for the beverage delivery person without going into management. The participants in this study had approximately 20 years' experience in delivering beverage product and averaged 42 years of age. As the driver-salesworkers grow older, the physical and mental demands for beverage delivery do not get easier. As shown with the heart rate data in this study, as the maximum potential heart rate decreases (as a function of the worker's age) and the heart rate range decreases, so does the metabolic capability of the worker. In addition, mental demands need to be considered, such as driving a tractor-trailer and maintaining good reaction time in congested traffic. This is not to say that as workers age they should not be allowed to deliver beverages. However, the company needs to deal with the nature of the job demands and develop strategies to capitalize on the experience, skills, and expertise of these driver-salesworkers. One suggestion is to create transition from driver-salesworkers to pre-sales work, either maintaining or increasing present salaries, and use these experienced workers to train new driver-salesworkers how to best work the route. For this solution to work well, all parties need to be involved, including driver-salesworkers, labor, management, safety, medical, and engineering so that the best interests of the driver-salesworkers and the company are served.

The current computerized billing system used by the driver-salesworkers needs improvement. More advanced systems of light-weight, hand-held units that perform multiple functions such as billing, inventory, and receipts are commercially available. The location of the hand-held units and the printers should also be carefully planned; including the driver-salesworker in the decision-making process will help all concerned. Also, customer orders can be handled more efficiently with telecommunication capabilities where sales, orders, and inventory are transmitted back to the plant or a central office.

Finally, the lessons learned from this study should be considered for other companies involved in beverage delivery. Beverage handling job risk factors are well documented and the widespread implementation of ergonomic and safety controls tested in this study should reduce musculoskeletal stress and fatigue. New procedures and technology in the soft drink industry, such as time-dating products (which means more manual rotation of products) and diversity of beverage products, bring new ergonomic challenges and opportunities. Making ergonomics an integral component of the health and safety system will serve this industry well.

CONCLUSIONS

NIOSH researchers conclude that the ergonomic interventions used in this study reduce musculoskeletal stress and morbidity among driver-salesworkers. Modifications to the beverage delivery truck, hand trucks, and beverage packages and contents, used in combination with improved work practices, will significantly reduce fatigue, the amount of beverage handled per day, and awkward postures during beverage handling, and will improve work efficiency.

Recommendations in this report should be applied in order to meet the goals of the company, while not exceeding the metabolic and biomechanical abilities of driver-salesworkers. Favorable reports from the driver-salesworkers in the study about the effectiveness of these controls helped convince management that all new trucks should have these controls installed. Many of the lessons learned from this study and recommendations herein may be applied to other beverage delivery companies to control and prevent musculoskeletal disorders among driver-salesworkers. The following summarizes the major findings of this study.

The participants in this study who have suffered a musculoskeletal injury while delivering beverages had done this job, on average, for 20 years and were considered a "survivor" population with highly developed skills in beverage material handling. These workers may not be typical of the average beverage driver-salesworkers in this industry because of their considerable experience.

- Musculoskeletal hazards and metabolic demands were evaluated through the use of the Discomfort Assessment Survey, heart rate monitoring, biomechanical models, and observation of work practices. Based on this information, a computer analysis of psychophysical discomfort assessment surveys, the SDS data, and workers' compensation data, it is theorized that the beverage delivery person has a high probability of suffering a job-related musculoskeletal injury. According to BLS data the probability of such musculoskeletal injuries, in terms of days lost, is twice as high as for those in general manufacturing jobs.

- The Discomfort Assessment Survey (DAS) showed the key areas where workers experienced discomfort. In decreasing order these are:

    a. the lower back,
    b. back right shoulder,
    c. knees,
    d. left elbow, and
    e. neck.

  The assessment of physical demands of removing beverages from the truck supported an association between these activities and the location of reported musculoskeletal discomfort.

- The NIOSH lifting criteria showed that most of the beverage lifting tasks exceeded the recommended weight limit (RWL). This was based on a combination of beverage package weight and worker posture during beverage handling. Exposures, which were over 3 times the NIOSH RWL or lifting index (LI) exceeding 3.0, were common when beverage cases exceeding 40 lb were handled, especially when the cases were being removed from the truck.

- Beverage handling tasks were divided into high (beverage cases exceeding 51 lb), medium (above 38 lb to 51 lb), and low (38 lb and less) handling risks. Most tasks performed were high and medium risk for low-back injuries. The highest risk occurred when handling 16-oz glass returnable, 20-oz glass nonreturnable, 8-pack 2-L bottles, pre- and postmix tanks, and 5-gal bag-in-the-box. Handling individual cases of 12-oz cans produced the least amount of risk.

- Based on heart rate measurements, the beverage delivery person's job is classified as physically demanding. This indirect measurement of metabolism showed that the energy demands may exceed normal metabolic demands for an 8-hour day during peak delivery periods, especially during the summer and just before holidays. Work exceeding the normal demands, (i.e., average heart rate of approximately 120 bpm) translates to moderate or heavy work for most healthy workers.

- Ergonomic evaluations showed that the depth in the truck bays exceeded the normal reach limit of the workers (average reach 30 in., truck bay depth 40 in.). Extended reaches for heavy beverage cases may significantly increase the risk for musculoskeletal injuries. A good work practice is to move the beverage cases forward to the edge of the bay openings before lifting to reduce some of the risk.

- Avoidance of injury depends on several factors: (1) good work practices, such as parking trucks close to the entry area and not overloading the hand trucks; (2) pre-planning to minimize handling; (3) using and maintaining material handling equipment, such as hand trucks, conveyors, and hoists; and (4) providing and using ergonomic controls on the beverage trucks such as pullout steps, step holes, external handles, and slip-resistant surfaces.

- The ergonomic interventions applied during this study were successful in reducing metabolic and biomechanical demands during beverage delivery. Feedback from the driver-salesworkers about ergonomic controls was relayed to plant management and labor. In a one-year follow-up evaluation of the ergonomic interventions at this plant, it was observed that these improvements were made to the new trucks. If these ergonomic interventions were to be applied to the entire beverage delivery driver work force, a decrease in injury and illness incidence and in severity should occur.

RECOMMENDATIONS

Based on the findings of this study, the widespread implementation of the following recommendations should benefit most of the driver-salesworkers in the soft drink industry.

ENGINEERING CONTROLS

A. Drop-down shelves should be used when possible to separate beverages and reduce multiple handling. Additional shelving spaced at least 3 ft above and below the adjustable drop shelves should be used as needed, especially when new products are introduced to the market (see Figure 27). Careful shelving placement will reduce multiple handling of beverages.

B. Tank and bag-in-the-box (BIB) delivery should be considered when applying engineering controls. Tank cages should be kept in good repair with working latches that are lightly lubricated. Full pre- and post-mix tanks should be stored on the bottom of the bays; empty tanks and boxes for cups and lids should be stored in upper level bays. Tank and BIB driver-salesworkers should encourage customers to purchase 3-gal BIBs because they are easier to handle for all concerned.

C. Increasing the fleet of "low boy" tractor-trailers with 14 bays should help reduce injuries. Approximately 20–25 additional products and packages are introduced to the plant each year. Larger trucks with adjustable height shelving can help accommodate this variety of products and packages and reduce multiple handling of beverages. Ergonomic features that will facilitate beverage handling and reduce musculoskeletal stress include the following:

    1. External grab handles should be installed between all bay doors to improve biomechanical leverage when handling beverages in the truck.

    2. Anti-slip grit should be painted on all bay rails, foot wells, platforms, and steps

(including those for the tractor cab). Anti-slip grit should be reapplied when worn or when needed by the driver-salesworker.

3. Multiple-height drop shelves should be installed for all bays. An inventory of such shelves should be available and installed as needed for the delivery person. Shelves should be straight and well maintained. Shelf lock pins should be lubricated for easy installation and removal. Drop shelves should be properly aligned from front to back, and from left to right when installed in bays. Beverage loading operators should check shelves for proper alignment before loading beverage on the truck. If the delivery person determines that shelves are not properly aligned or that product is wedged between shelves, then shelves should be realigned before the truck leaves the plant.

4. Additional foot wells or pullout step bars with hooks to secure the step bar should be installed around tire wells for easier access to beverages stored above the wheels.

5. Pullout steps (stand-on platforms) should be considered on a case by case basis. Workers who request the pullout step should be given the opportunity to try them out, especially when heavy packages are stored in the upper levels of bays. The prototype pullout step used in this study should be modified with larger hand-hold openings to allow for foot clearance (4 in. × 6 in). The pullout step should be portable so that it can be moved to any bay of the delivery person's choosing. Rather than welding the step in place, lock pins similar to the drop-down shelves could be used.

6. A dual hand truck holder with high back should be installed. One 2-wheel and one 4-wheel hand truck should be offered to each delivery person so that they have more beverage transportation options with the hand trucks. Slot openings on the hand truck holders should be wide enough for the hand truck foot plate to easily slide in and out during storage and use.

7. Bay doors should be well maintained and repaired immediately if damaged. Bay door rollers should be replaced when needed and lubricated at least 4 times per year or more often as directed by the delivery person.

8. Bay door straps should be maintained and replaced when worn.

9. Adjustable-height, air-cushioned seats with lumbar support should be installed to reduce whole body vibration from the road.

10. The current computerized beverage billing and printing system on the trucks should be replaced. The driver-salesworkers indicated that the current method is slow, inefficient, and stressful. The printer is bulky and is located at the back of the cab; this requires the worker to assume a twisted position to download information from the hand-held computer unit. The printer also drains the truck battery overnight when it is cold since the printer draws current to keep the printing mechanism warm. A light-weight, rugged, portable, hand-held computer unit which meets the needs of the delivery person and company should be considered. Printers should be smaller, self-contained, and easy to access when printing receipts. The location of the printer and hand-held downloading device should be accessible on either side of the truck. Possible locations to consider are in the left and right front bays, or in the cab adjacent to and below driver and passenger seats. The present system of climbing in and out of the truck cab for each transaction is inefficient and may cause problems to the worker's knees due to repetitive climbing. Hand-held field units with telecommunications capability should be considered so that information can be transmitted directly to the plant. This would facilitate preparation of inventory for the next delivery.

Safety Features

A. Five-inch spot mirrors on the right and left door, a five-inch spot mirror mounted on the right side of the hood, and heated and motorized external rear-view mirrors would improve visibility for the delivery person, especially in the city deliveries where other motor vehicles can pass the truck on either side.

B. The 3-point seat belt is generally used for driving longer distances, but driver-salesworkers seldom used them in the city because they do not "buckle up" for just a few blocks. Driver education and input is recommended so that seat belt systems are used more frequently and do not encumber the delivery person.

C. The motion back-up alarm system used during this study was faulty. The driver-salesworkers did not receive training on how the device worked. When the alarm was activated, it was not clear to either the delivery person or the NIOSH personnel riding along when the truck was in reverse. A wide-angle camera mounted on the top rear of the truck, or an audible bell located at the rear of the truck to warn others that the truck is backing up may be a better system. Driver-salesworkers should be consulted for ideas to improve back-up safety systems.

D. Because delivery may take place early in the morning and may continue into the evening and because these beverage trucks make frequent stops in congested areas, the raised tail light package, wide-turn signal, and reflective safety tape around the trailer may make the truck more obvious to other motorists and pedestrians and may reduce the potential for accidents.

E. All safety enhancements to the truck must be in accordance with Department of Transportation and state motor vehicle regulations.

Hand Trucks

Two hand trucks should be available for each delivery person: one 2-wheel hand truck and one 4-wheel hand truck. If rough terrain is encountered or in snow, the 4-wheel hand truck can be used in the upright position as a 2-wheel hand truck. Balloon tires should be kept in good repair and properly inflated. Tire pressure should be checked on a quarterly basis or more often if needed. A pressure gauge and conveniently located air compressor and pressure hose (located next to the delivery person's hand truck storage area) should be available for these workers to use. L-shaped tire stems should be avoided; straight stems are easier to access when inflating tires. All moving parts on the hand trucks should be lubricated as needed. Replacement hand trucks should be available for driver-salesworkers to use when their own hand truck is being repaired. An ergonomically designed 2-wheel hand truck was not used enough for its performance to be judged. It did show promise in reducing biomechanical stress for the one worker who used it during beverage delivery. If such hand trucks are purchased, operators need training and practice before using them on a full-time basis. Feedback from the driver-salesworkers about performance is important because slight modifications may make the units more acceptable. One concern about the Equalizer™ was that it required more "foot" clearance (from the counterbalancing mechanism) and was less maneuverable in tight spaces.

Beverage Packages

The recommended weight limit under ideal lifting conditions (i.e., standing knuckle-height with the load next to the body) should not exceed 51 lb. Beverage handling should be analyzed using the revised NIOSH lifting equation to identify highly stressful tasks and to determine alternatives and optimum weight material handling options. Such options include repackaging beverages in smaller units, such as the 5-gal bag-in-the-box to the 3-gal bag-in-the-box; elimination of some beverage packages, such as the 16-oz glass returnable bottles; replacing glass containers with plastic containers, such as the 20-oz beverages; and use of material assist devices, such as gravity conveyors, hoists, fork lift trucks, and pallet jacks.

A. Beverage packages that are handled and are in excess of the NIOSH Lifting Index (LI) of 3.0 should be a priority for material handling limitations through engineering controls. Task analysis should be done first where posture (no twisting or excess forward bending) and location of the load (small horizontal distance between the load and body and at knuckle height) are optimized. Based on task analysis, heavy loads should be stored in the trailer bays that capitalize on the best posture and location for retrieval of these loads. During material handling, if the LI still exceeds 3.0, then engineering controls such as hoists, fork lift trucks, and gravity conveyors are encouraged. This approach should be used for all beverage packages stored in the bays to reduce biomechanical stress to the driver-salesworkers. Package weight reduction and better package design for easier handling, may be the most cost/effective improvements toward reducing musculoskeletal disorders among driver-salesworkers.

B. Plastic shells, such as the 2-L 8-pack, should be redesigned to a lighter 6-pack package or designed to better contain the 2-L beverages and make handling easier. The bottom of the 8-pack plastic shells should be redesigned so that the delivery person does not have to lift and pull the package forward when removing it from the truck. The redesigned 8-pack plastic shell observed during the follow-up survey appears to be an improvement over the shells evaluated during this study.

C. Lighter weight plastic pallets should be considered instead of heavy wooden pallets.

Work Practices

A. Ergonomic principles should be applied when loading the beverage truck; heavier beverage packages should be accessible from knee to mid-chest height. Examples include cases of 20-oz nonreturnable, 2-L, 16-oz returnable, pre- and post-mix tanks, and bag-in-the-box. Packages that are lighter in weight, such as cases of 12-oz cans and 16-oz sport drink (plastic containers), can be stored above shoulder level, but should not be more than 60-in. high from the base of the bay. This height will enable most driver-salesworkers the leverage to manually handle the cases of beverage. For safety reasons, glass containers should ***not*** be stored above shoulder level. Such packages are best kept at waist level or below to avoid head and eye injuries from falling bottles and broken glass.

B. Driver-salesworkers should park the truck as close to the delivery point as possible to reduce manual transportation distance.

C. Driver-salesworkers should take the time to turn the truck around if large orders are removed from both sides of the truck.

D. Driver-salesworkers should preplan the most efficient way for unloading the truck to minimize trips to and from the truck, without overloading the hand truck.

E. Beverage loads should not be double-stacked (i.e., side by side) on 2-wheel hand trucks nor should beverages be stacked above the hand truck support bar. This is of special concern when loads are transported up or down hills, ramps, or stairs.

F. Hand trucks and tractor trailers must be in good repair. When inspecting the truck for beverage inventory in the morning, driver-salesworkers should also perform a walk-around of the truck and look for problems, such as missing grab bars, shelving and shelving alignment, dented bay doors, etc. They should inspect the hand trucks, as well as ensure the tires are properly pressurized and in good repair. Problems should be fixed before the truck leaves the plant. Hand trucks that are not working properly in the field should be given to maintenance when drivers return to the plant. Another hand truck should be issued to the delivery person until the hand truck is repaired.

G. Seasonal trends should be kept in mind for self-pacing to avoid heat-related illnesses such as heat cramps and heat exhaustion. In the summer workers should drink plenty of water, take rest breaks when needed, and use air conditioning in the cab when available. They should have air conditioning in the cab if heat stress is a recurrent problem. When possible, drivers should adjust routes to reduce the work load on hot days.

H. Appropriate personal protective equipment can make the job safer and easier to perform. Such equipment includes gloves, safety shoes (light weight), and knee pads (for kneeling on floors to load vending machines or individual merchandising units).

I. Other items to consider include a retractable utility knife to cut shrink wrap and tape from palletized beverage packages; door wedges to keep doors open when bringing beverages into store or storage areas; and a light-weight, high-strength portable ramp when 4-wheel hand trucks are used to transport large orders over door thresholds.

WORK ORGANIZATION

A. Coordination between employees who load beverages on the delivery trucks and driver-salesworkers should be done on a weekly basis. Problems with loads, shortage of product, and suggested modifications to trucks for improved beverage handling for both groups should be documented. Strategies to minimize beverage handling for both groups of workers should be incorporated.

B. Light-duty jobs should be made available for injured workers. The jobs should be designed to facilitate their returning to work and to gradually integrate them back to full-time work. This can be done by having a second person in the truck to help service the route, or by assigning lighter loads to be delivered individually and heavier loads with a helper. Return-to-work policies following an injury should be medically managed by a qualified physician and physical therapist team who are experienced in occupational medicine and musculoskeletal injury prevention.

C. Consideration should be given to standardizing loads to reduce excess beverage handling by the warehouse loaders and driver-salesworkers. A standardized load may vary between driver-salesworkers, the type of route they have, seasonal demands, and new products offered. Analysis of the load sheets over time should suggest minimum choices for the core load (what is taken to the customers on a consistent basis) which could be modified as required.

D. Development of career progression jobs should be considered for the delivery person. Currently there are few jobs available, other than management, that are attractive to the delivery person. The independence, interaction with the public, outside work, and incentive salary make this job very appealing. On the other hand, the physical demands of the job are among the highest in private industry. The day-to-day manually handling 25,000 to 50,000 lb of beverages, driving a truck, maintaining a professional and pleasant disposition under all circumstances, and dealing with many other annoyances take their toll. As the delivery person ages, the job demands remain. The nature of this business is that the more successful the delivery person is, the more beverage is sold. One suggestion is to create a pre-sale position as the next career level move. The pre-sale position would be available to experienced driver-salesworkers who have established rapport with customers and know how to sell their product. The experienced driver-salesworkers could phase out of these jobs by training new employees on the delivery business and phasing the new employees in over time.

E. Loading the beverage trucks with a product that does not sell should be avoided. On average, 25% of the product loaded on the truck during this study was not sold on a daily basis. The end of day reports should be used to determine what is not moving and to avoid unnecessary loading of these products. This will reduce multiple handling by both the warehouse loaders and driver-salesworkers (and also save on fuel costs). If a customer is in need of extra beverage product(s), another delivery person can perform this service.

F. As more beverage packages are introduced to the market, there may come a time when it would be cost effective to split beverage routes, for example, one for carbonated beverages and one for others, such as juices, teas, etc. Experimenting with routes may be beneficial and may offer another career option for the experienced delivery person.

G. When an ergonomic or safety control is installed on a beverage vehicle, hand truck, or at a customer's establishment, the advantages and disadvantages to the driver-salesworkers and company should be evaluated; if found to be beneficial, the control should become standard operating procedure. For example, the external grab handles, adjustable height shelves, and slip-resistant grit paint for the trailer bays should be entered into the master book of standards by company fleet managers. This will ensure controls will be available for all trucks in the company fleet.

ROBBERIES

Suggestions for Decreasing the Chances of Being Robbed

1. Form a task force of experienced driver-salesworkers, safety specialists, immediate supervisors, labor, and management to discuss methods to avoid robbery and bodily harm of driver-salesworkers. Contacting local law enforcement agencies for suggestions may also help.

2. Develop an outline of the best strategies for decreasing opportunities for robbery and avoiding bodily harm. From this, develop an emergency preparedness and action plan. Successful strategies should be shared with all in the beverage delivery industry. Dissemination of this information can be done in the form of a newsletter and shared with route driver-salesworkers during periodic safety and/or sales meetings. The types of interventions which could be included for discussion or publication during the strategy sessions include:

   a. Scheduling deliveries during the daylight hours whenever possible;

   b. Installing directional spot lights on the front, side, and rear of trucks to "light up" the delivery area. This may be helpful during winter months when days are short;

   c. Training on conflict resolution and nonviolent response to robbery attempts;

   d. Working with the delivery stops to implement various types of engineering and administrative controls to reduce the risk of robbery. Examples of controls include improved lighting, work areas openly visible to the public, and increased staffing.

3. Work more closely with accounts to develop a reliable system of payment other than cash such as credit cards, business checks, and/or money orders. Because some businesses do not have established credit histories, development of a tracking system to encourage and establish a credit history is suggested.

4. When possible, coordinate route schedules so that deliveries are conducted when other driver-salesworkers are at the same account. For example, if a route stop looks unsafe, and there are no other delivery trucks at this account, then stop at another account and backtrack. If this is not convenient, then delivery on another day, at another time, or when a prearranged time is suggested.

5. Before entering high crime areas where some accounts are located, schedule a stop at an account with a good credit history and exchange cash for a business check. Banks and loan institutions are an alternative but exchange must be done with care. Employees have been followed by an assailant to these institutions and subsequently robbed. Vary times and routes for delivery to avoid a predictable, set schedule.

6. Other suggestions which may benefit the beverage delivery person include:

   a. Installation of safes on all trucks

   b. A credit-only transaction system

   c. Refusal of delivery to accounts where driver-salesworkers have been robbed

   d. Refusal of delivery where threat of bodily harm has occurred, or could occur.

Since a single solution may not fully address these safety concerns, the implementation of multiple interventions is recommended.

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APPENDIX A

REVISED NIOSH LIFTING EQUATION

This equation was used for selected manual materials handling tasks. The calculation for the recommended weight limit is as follows: RWL = Load Constant (LC) * Horizontal Multiplier (HM) * Vertical Multiplier (VM) * Distance Multiplier (DM) * Asymmetric Multiplier (AM) * Frequency Multiplier (FM) * Coupling Multiplier (CM) (* indicates multiplication). The multipliers in this equation are described in Tables A1, A2, and A3.

Table A1

Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks

COMPONENT	METRIC	U.S. CUSTOMARY
LC = Load Constant	23 kg	51 lb
HM = Horizontal Multiplier	(25/H)	(10/H)
VM = Vertical Multiplier	(1-(.003 V-75))	(1-(.0075 V-30))
DM = Distant Multiplier	(.82+(4.5/D))	(.82+(1.8/D))
AM = Asymetric Multiplier	(1-(.0032A))	(1-(.0032A))
FM = Frequency Multiplier	(see Table A2)	(see Table A2)
CM = Coupling Multiplier	(see Table A3)	(see Table A3)

Where:

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

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

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

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

F = Average frequency rate of lifting measured in lifts/min. Duration is defined to be: ≤ 1 hour; ≤ 2 hours; or ≤ 8 hours assuming appropriate recovery allowances (see Table A2).

Table A2

Frequency Multiplier

Frequency lifts/min	Work Duration					
	≤ 1 Hour		≤ 2 Hours		≤ 8 Hours	
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

Table A3

Coupling Multiplier

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

APPENDIX B*

INFORMATION RELEVANT TO THE DESIGN OF ERGONOMIC CONTROLS IN THE BEVERAGE INDUSTRY INCLUDING CONTAINER PACKAGING, CONTAINER HANDLES, PUSH VERSUS PULL, AND WHOLE BODY VIBRATION

BACK INJURIES

Eighty percent of all Americans will suffer low back pain sometime during their lifetime.[1,2,3,4] Over 30 million Americans currently experience low back pain;[5] 13 million of those cases have resulted in reduced ability to function.[6] Over ten million cases of back impairment have been reported among U.S. employees between the ages of 18 and 64.[6] Each year, seven million people will be added to the total number of Americans who have suffered back injuries.[7] Lost time from work has increased significantly over the past 30 years, while the incidence of low back pain has stayed the same.[8] Estimated total costs for low back pain exceeds 16 billion dollars annually (compensable and noncompensable) in the United States.[5] Low back injuries account for one-third of total workers' compensation claims paid by the Federal Government according to the U.S. Department of Labor Office of Workers' Compensation Programs.[9] The National Council on Compensation Insurance reported low back injuries make up 25% of the claims for indemnity benefits, claims made by workers who have lost time from work because of job-related injuries. A 1983 Massachusetts study by the Massachusetts Health Data Consortium found that back problems and back and neck surgery accounted for approximately one out of every three hospital stays paid for through workers' compensation, with nearly 30% of the total workers' compensation payments being spent on back cases.[9] Current estimates for low back compensation costs are approximately 6,807 dollars as the average or mean costs, and 390 dollars for the median.[10] The large difference between the mean and median shows that costs for low back pain are not evenly distributed; instead, a few cases account for most of the costs.[10] The higher cost for the few cases is attributed to more hospitalization, surgery, litigation, psychological impairment, and extended loss of time from work. Age, gender, and occupation are personal risk factors for the occurrence and severity of low back injuries. Older workers are more likely than younger workers to have severe back disorders.[11] More women than men are likely to have restricted-activity, bed disability, and lost work days.[12]

Hildebrandt[13] performed a comprehensive review of epidemiological studies on risk factors of low back pain. Risk indicators of low back pain include ***general***—heavy physical work and work postures in general; ***static work load***—static work postures in general, prolonged sitting, standing or stooping, reaching and no variation in work posture; ***dynamic work load***—heavy manual handling, lifting (heavy or frequent, unexpected heavy, infrequent torque), carrying, forward flexion of trunk, rotation of trunk, pushing/pulling; ***work environment***—vibration, jolt, slipping/falling; and ***work content***—monotony, repetitive work, work dissatisfaction.

*Special thanks to Tracy M. Bernard for her assistance in assembling the material in Appendix B.

Individual risk factors found by Hildebrandt include age, gender, weight, back muscle strength (absolute and relative), fitness, back mobility, genetic factors, back complaints in the past, depression, anxiety, family problems, personality, dissatisfaction with work or social status of work, tenseness and fatigue after work, high degree of responsibility and mental concentration, degree of physical activity, smoking, alcohol, coughing, and work experience.

Container Packaging and Container Handles

Container packaging and their handles are very important to the delivery person in making it easy to grasp, lift, carry, and position soft drink packages. Unfortunately, many of the packages are designed with poor material handling specifications, such as narrow handle clearance, pre-formed grips, and sharp edges. As a result, beverage material handling is less than optimal. The following is a summary of what is known about container packaging and handles.

Soft drink beverage products are sold in steel and aluminum cans (52%), plastic bottles (30.1%), and glass containers (17.9%) accounting for 53.3, 32.0, and 20.5 billion containers, respectively.[14] Beverage containers are sold in paperboard or plastic packages, or loose. In 1990, 36.5% of cans were packaged in paperboard, 56.7% in plastic, and 6.8% were loose. PET (plastic bottles) were packaged as 6% paperboard, 84% plastic, and 10% loose. Returnable glass containers were 95% paperboard packaging and 5% loose.[15]

Improving the operator/container coupling by providing handles has been recommended consistently. Handles can increase the maximum force exerted on the container and reduce task energy expenditure.[16] Drury, Law, and Pawenski studied more than 2,000 different box-handling tasks including beer and soft drink distribution, paper products manufacturing, and food distribution. Despite the evidence in favor of handle usage, only 2.6% of the containers have handles.[17]

Box handling is a task consisting of seven steps: pregrasp, grab, pickup, move/carry, put down, adjust, and release. Factors, such as handle position and handle angle, have a large effect on body angles (i.e., posture), physiological measures, and psychological measures.[18] In studying 2,000 industrial tasks, the most commonly used hand positions were one hand at the upper front corner of the box and the other hand at the lower rear corner. One of the many task factors that has been linked to back injuries is the amount of twisting of the upper torso relative to the hips. Drury, Law, and Pawenski also cataloged the amount of twisting which occurred during the 2,000 box handling tasks.[17] The observed pattern shows a considerable amount of twisting being performed, usually to the right, at the start of the task; almost no twisting during the task; and considerable twisting favoring the left at the end of the task.[17] Fewer than 20% of lifts are free from twisting at the start of the task.

Drury and Deeb studied two-handed dynamic lifting tasks to determine the best handle positions and handle angles.[18] There were nine possible hand positions defined on each side of the container. Positions 1 to 3 were at the top of the box, 4 to 6 were at the middle of the box, and 7 to 9 were at the bottom of the box. Positions 1, 4, and 7 were closest to the worker's body. Normally, the hand accommodates to handle angles both by deviating the wrist and by allowing slippage between the hand and handle.[16] However, Drury and Deeb allowed the handles to pivot in order to find the best handle angle which caused the wrist to maintain a neutral angle. Handle positions at the front of the box required optimum angles that were nearly vertical, while positions along the bottom required more horizontal angles. The height at which the box was held above the floor had a large effect on handle angle, so that no single angle was optimum at all heights.[18] In static holding tasks, angles of 70 degrees to the horizontal are recommended.[19] However, in the dynamic lifting task, a biomechanical analysis of the lifting resulted in the following recommendation: place handles in positions 6 and 8 with angles of 60 and 50 degrees, respectively, to the horizontal.[18]

The most common placement of handles in industry is in the 2/2 position (i.e., located near the top of the box at the center). With handles in this position, Drury and Deeb recommended that the optimum angle, which would give neutral wrist and slippage angles averaged over all stages of the lift, is 83 degrees.[18] Subjects' heart rates, rated perceived exertion (RPE), and body-part discomfort were also measured to determine whether the biomechanical recommendations were supported by the physiological and psychophysical responses. In a floor to waist lifting task, the symmetrical handle position 2/2 showed minimum discomfort. An angle of 70 degrees showed much less discomfort severity for all body regions as compared to 35 degrees.[20] The shape of a cutout handle (cutouts were 25 mm [1 in.] wide and 100 mm [4 in.] long with 25 mm [1 in.] diameter rounded ends) in a cardboard box was varied; a straight handle accommodated the hand shape better and a curved handle showed no significant differences when compared to a straight handle.

PUSH VERSUS PULL

Cart or hand truck pushing and pulling are common dynamic tasks in the beverage delivery process. In these tasks, a worker must exert enough force to push or pull the cart, but must also be ready to regain balance in case the cart moves unexpectedly. The potential instability of a moving cart often causes the worker to adopt awkward postures, resulting in over-exertion injuries.[21]

Chaffin et al. [1983] tested for maximal isometric position in one-handed and two-handed push and pull tasks at three different handle heights.[22] Previously, Ayoub and McDaniel found that optimal handle heights for pushing and pulling tasks should be between 91 (35.4 in.) and 114 cm (44.5 in.) above the floor;[23] Martin and Chaffin recommended maximum push/pull handle heights of between 50 (19.5 in.) and 90 cm (35.1 in.).[24] In the Chaffin et al. [1983] study, the maximum push/pull strengths were set to the strength level which the subjects themselves considered they exerted greatest push/pull strengths. The results showed that mean push strength (372 N) was significantly greater than mean pull strength (267 N).[22] When pushing, the subjects would incline the torso more than when pulling, thus using the body weight more effectively to assist in counteracting the push force on the hands.[25] Also demonsting that using two hands as opposed to one hand to perform the task significantly increased both push and pull strengths. Two-handed push strength was 42 percent greater than one-handed, while pull strength was 25% greater.[22] The height of the handle also significantly affected push/pull strengths when heights of the handle from the floor were 68 (26.5 in.), 109 (42.5 in.), and 184 cm (71.8 in.). A similar trend developed in both pushing and pulling strengths. The greatest strengths occurred at the lowest handle height, followed by the medium height, then the highest height. Strengths at the lowest handle height were significantly greater than at the highest handle height. However, through a biomechanical analysis, Chaffin et al. determined that the body posture required by the lower handle created the largest mean L5/S1 spinal compression (3600 N) which is greater than the NIOSH Action Limit (AL) for spinal compression.[22]

Lee et al. [1991] investigated the effects of dynamic hand truck pushing/pulling tasks on lower back stress resulting from both personal and task factors, including pushing and pulling force, cart moving speeds, and subject body weight.[21] Results indicated that at all handle heights, pulling resulted in a significantly greater compressive force on the L5/S1 disc than pushing for all subjects. Handle heights of 109.0 cm (42.5 in.) and 152.0 cm (59.3 in.) reduced lower back loading for pushing and pulling, respectively. Results also showed that the compressive force on the L5/S1 disc increased with increasing cart speed (1.8 km/h (1.1 mile/hour) vs. 3.6 km/h (2.2 mile/hour)).[21] Finally, peak compressive forces were most affected by subject weight and height.[21]

Whole-body Vibration

Beverage driver-salesworkers are subject to whole-body vibration from the delivery truck. Beverage delivery routes can vary from 40 km (25 miles) to over 124 km (200 miles). Often the truck cabs are not well insulated from the road, but the seats are insulated to absorb road shock. As a result, much of this vibration is transmitted to the driver. The following is a brief overview of whole-body vibration.

Whole-body vibration is harmful to the spinal system with the most frequently reported effects being low back pain, early degeneration of the lumbar spine, and herniated lumbar disc.[26] Gruber[27] tested the hypothesis that certain physical disorders develop with undue frequency among interstate truck drivers and that some of this excess morbidity is due in part to the whole-body vibration factor of their job. Vibration resonances occurring in the 1 to 20 Hertz (Hz) frequency region is transmitted to the whole body, mainly in the vertical direction, through its supporting surface as a result of direct contact with a vibrating structure. Maximum biodynamic strain is associated with trunk resonances occurring at about 5 Hz. A typical worker may be exposed to over 40,000 hours of occupational vibration over a 30-year period.[28] Biodynamic strain, microtrauma, and intraluminal/intra-abdominal pressure fluctuations that are known to be produced by truck vibrations have been postulated as being at least partially responsible for the development of certain musculoskeletal, digestive, and circulatory disorders among interstate truck drivers with more than 15 years of service. The combined effects of forced body posture, cargo handling, and improper eating habits, along with whole-body vibration, are considered contributory factors for such truck driver disorders as spine deformities, sprains and strains, appendicitis, stomach troubles, and hemorrhoids.[27]

The effects of whole-body vibration have been studied in several jobs, including crane operators,[29] personal motor vehicles,[30] and forklift operators.[31]

The incidence of permanent work disabilities due to back disorders in crane operators exposed to vibration was compared with a control group by Bongers et al. [1988]. This study concluded that crane operators with more than five years of exposure have almost three times the risk of incurring a disability due to intervertebral disc as a control group, and the risk increases to five in crane operators with ten years of experience.[29]

A case control study of the epidemiology of acute herniated lumbar invertebral disc in the New Haven, Connecticut area was conducted.[30] This study compared the characteristics of persons who had acute herniated lumbar intervertebral disc with characteristics of two control groups of persons who were not known to have herniated lumbar disc. It was found that the driving of motor vehicles was associated with an increased risk for developing the disease. It was estimated that men who spend half or more of their on-job time driving a motor vehicle are about three times as likely to develop an acute herniated lumbar disc as those who do not hold such jobs.

Brendstrup and Biering-Sorensen studied the effect of forklift truck driving on low back trouble.[31] The occupation of forklift truck driving submits workers to five conditions which can be assumed to increase the risk for contracting low back trouble, including assuming a static, sedentary position while driving; twisting the trunk in relation to the pelvis; stooping; bending the trunk in deep sideways positions; and vibrating the whole-body. Brendstrup and Biering-Sorensen used the responses to a questionnaire concerning low back trouble of 240 male forklift truck drivers who drove at least four hours daily as compared to two reference groups: skilled workers and unskilled workers. Forklift truck drivers had a statistically higher occurrence of low back trouble (65%) as compared to the control group of skilled working men (47%); however, no statistical difference occurred when compared to unskilled workers (52%). The forklift truck drivers had a significantly higher rate (22%) of absence from work due to low back trouble than both control groups (7% and 9%). It was concluded that forklift driving can be a contributing cause of low back trouble.

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APPENDIX C

Questionnaire Used in NIOSH Study to Determine Past Work Experience and Medical History

Data Sheet—Employee Job Description

The National Institute for Occupational Safety and Health Study at this facility

SUBJECT ID NUMBER. ______

LAST NAME ______ **FIRST NAME** ______ **SOCIAL SECURITY NUMBER** ______

AGE ______ **HEIGHT** ______ **FORWARD REACH** ______ **WEIGHT** ______

MAXIMUM HAND GRIP STRENGTH: LEFT HAND ___ ___ ___ **RIGHT HAND** ___ ___ ___

WORK HISTORY

When did you begin working with the company? ______ (MONTH) ______ (YEAR)

When did you begin delivering beverages for this company? ______ (MONTH) ______ (YEAR)

Since working for this company has this been your only job? ____ (yes) ____ (no)

Have you been continuously performing this job since you started (any other jobs)? ____ (yes) ____ (no)

Did you deliver beverages for any other company or at another facility? ____ (yes) ____ (no)

List any other previous work experience you have done in the last five years.

COMPANY NAME ______

COMPANY LOCATION ______

WORK ACTIVITIES

WHEN STARTED ______ (MONTH) ______ (YEAR)

HOW LONG AT JOB ______ (MONTHS) ______ (YEARS)

COMPANY NAME

COMPANY LOCATION

WORK ACTIVITIES

WHEN STARTED ______ MONTH ______ YEAR

HOW LONG AT JOB ______ MONTHS ______ YEARS

COMPANY NAME

COMPANY LOCATION

WORK ACTIVITIES

WHEN STARTED ______ MONTH ______ YEAR

HOW LONG AT JOB ______ MONTHS ______ YEARS

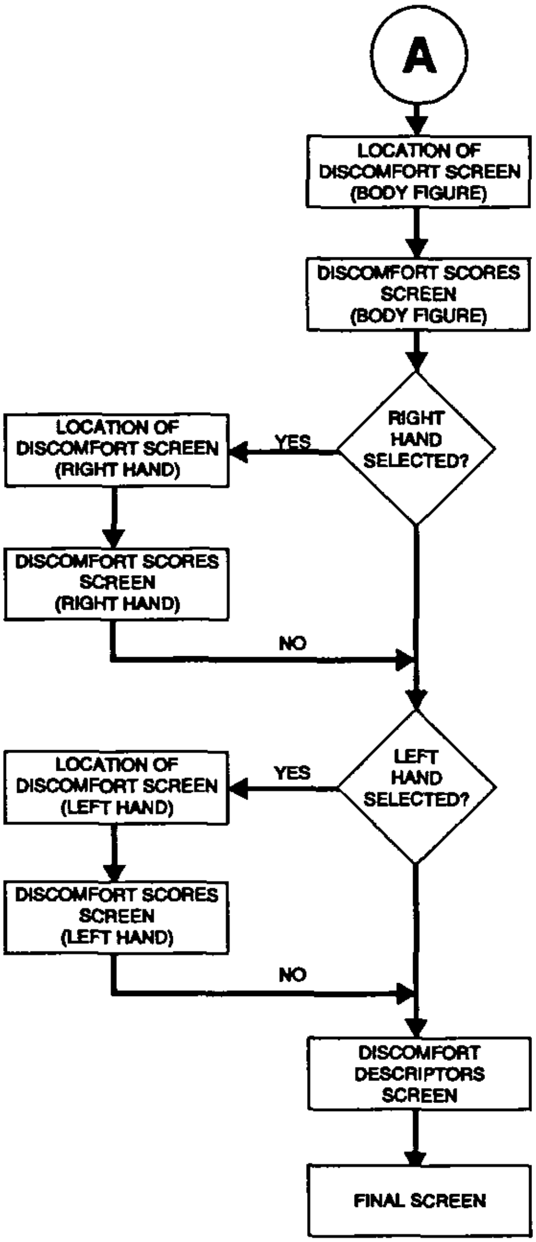
Do you have, or did you ever have, any musculoskeletal disorders while performing your job?
If yes, please explain.

Did you ever have time off as a result of a musculoskeletal injury? If yes, how long?

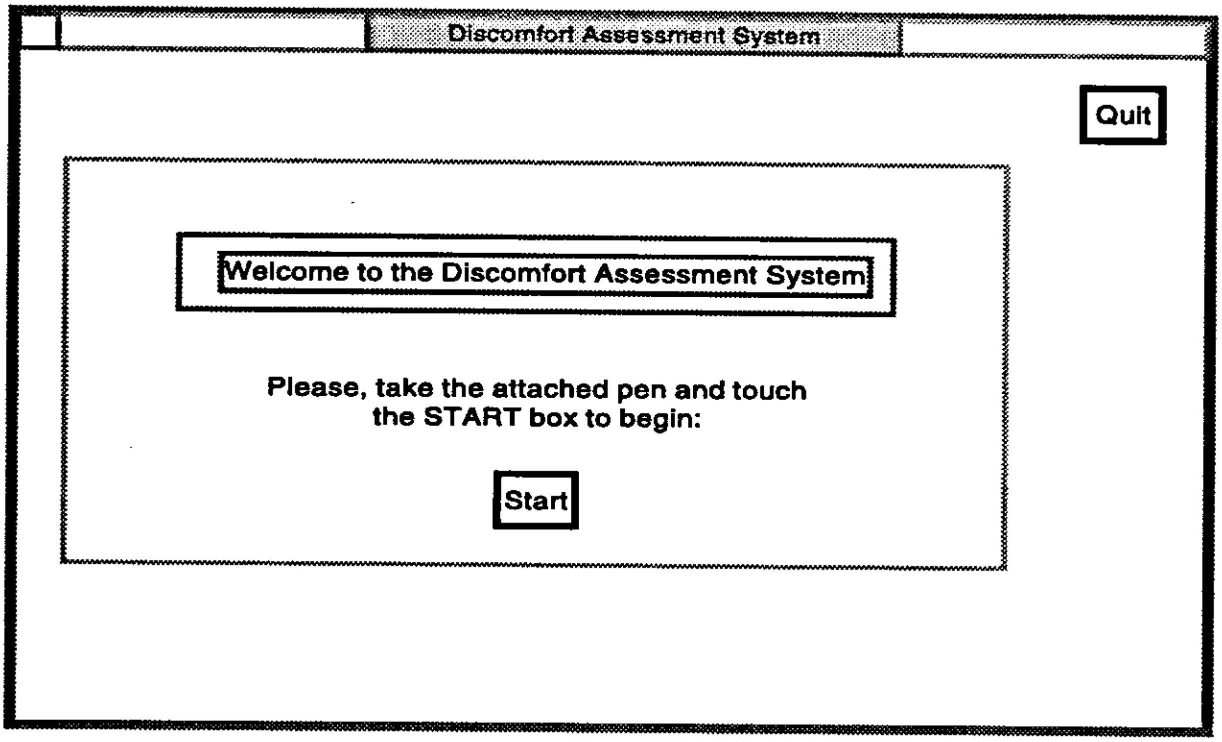
APPENDIX D

Figures Showing the Different DAS Screens Shown on the Computer

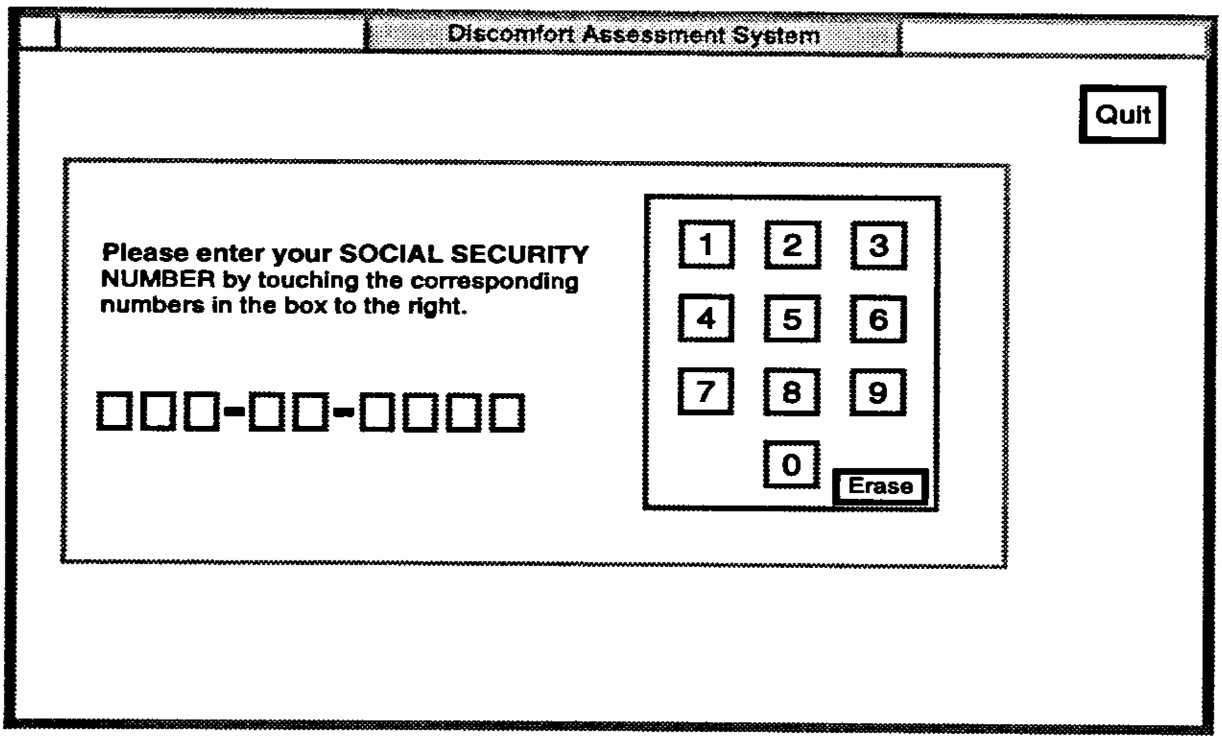
[Software program developed by Norka Saldana, Ph.D. in Partial Fulfillment of Dissertation
University of Michigan, Center for Ergonomics, Ann Arbor, Michigan]



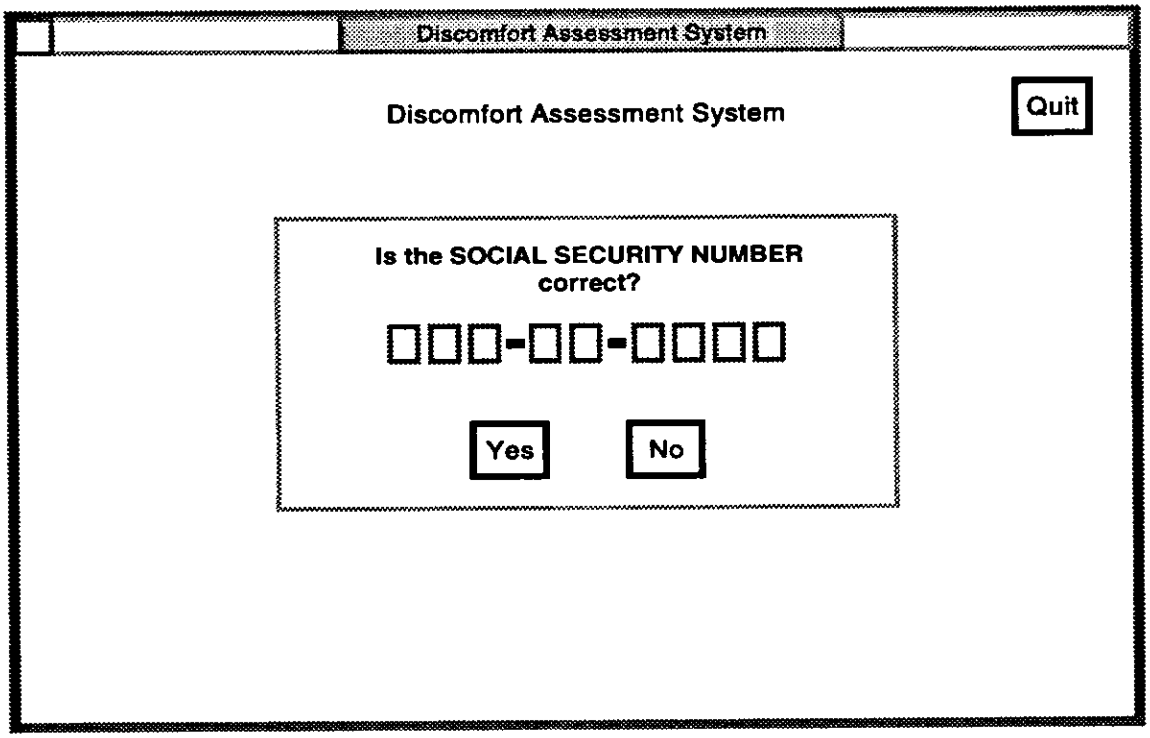
Architecture of Software Program



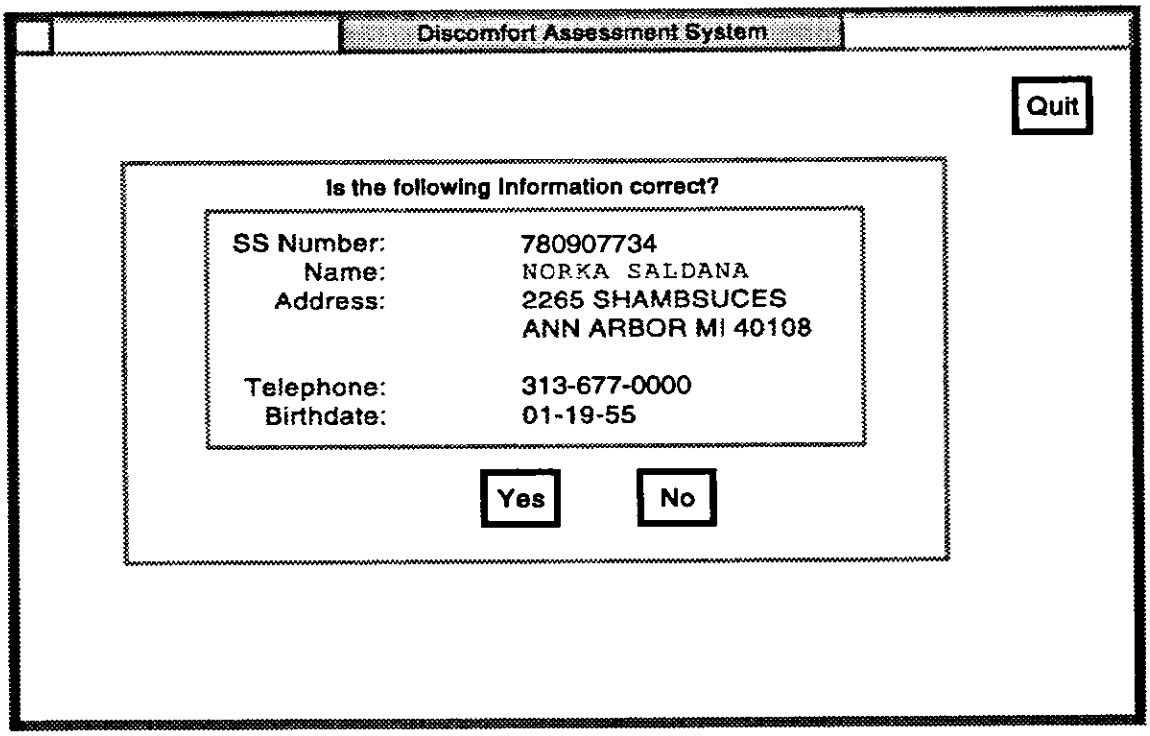
Welcome Screen



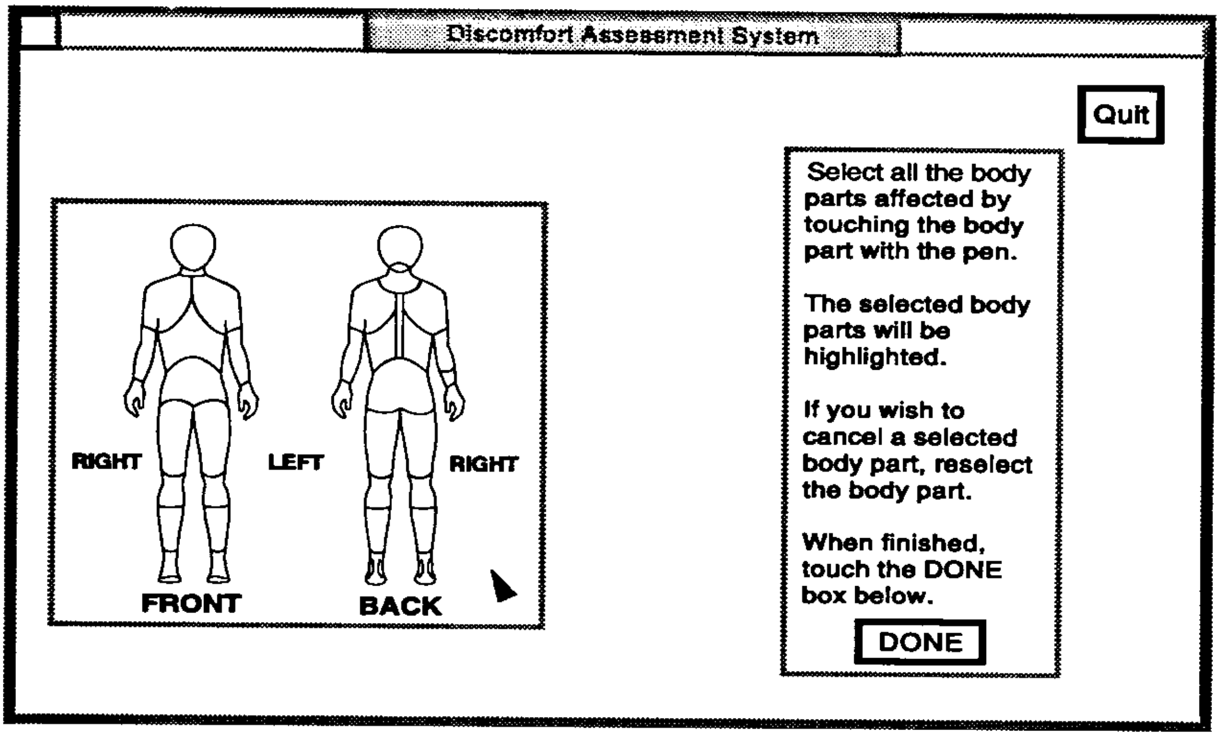
Social Security Number Screen



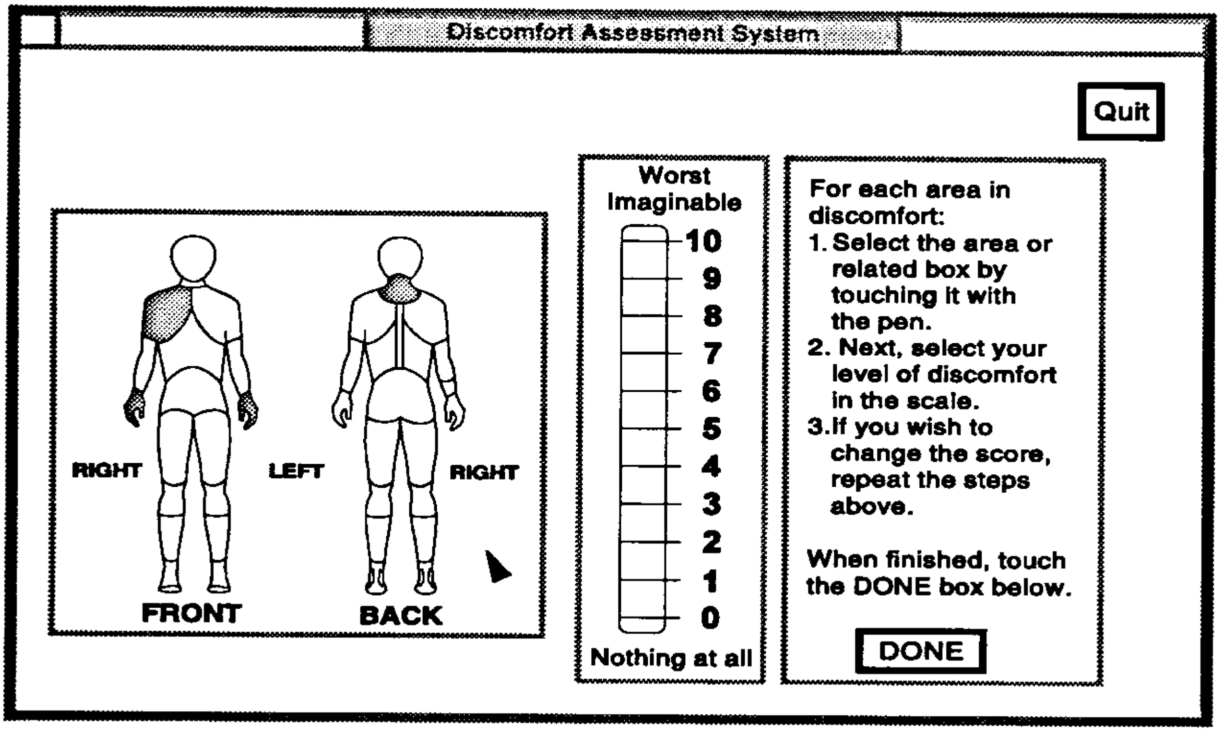
Social Security Number Confirmation Screen



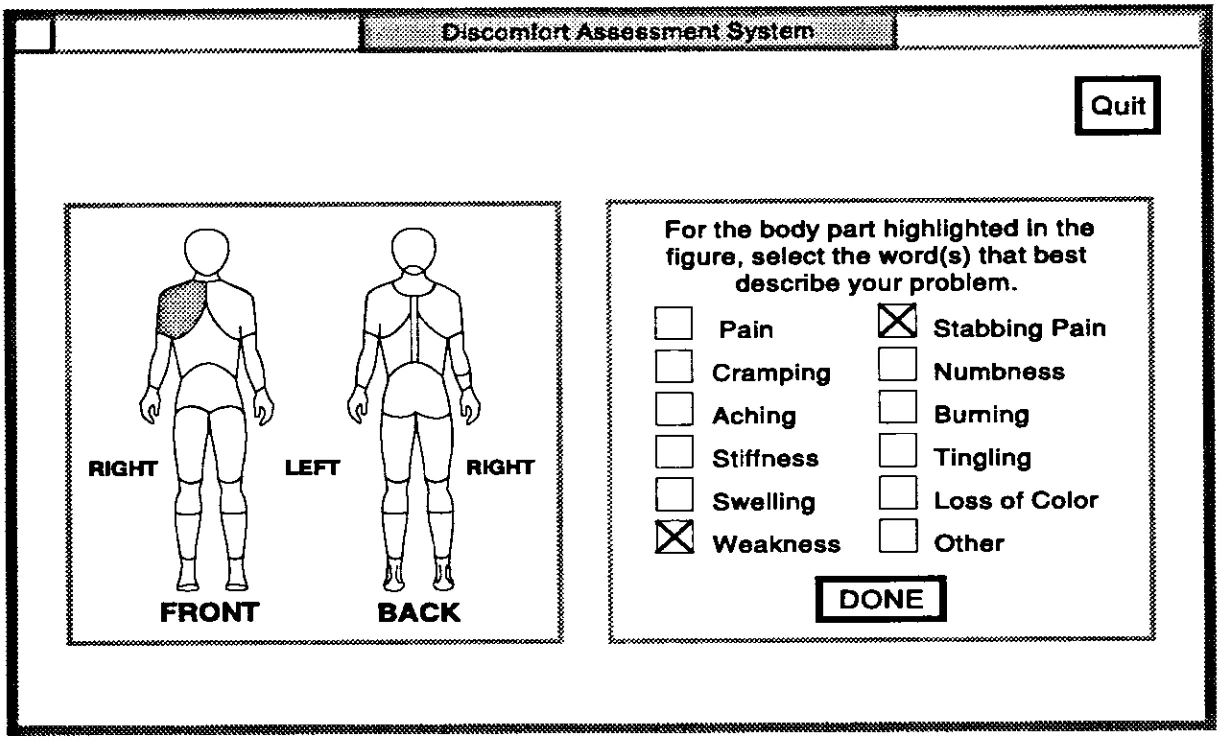
User Information Confirmation Screen



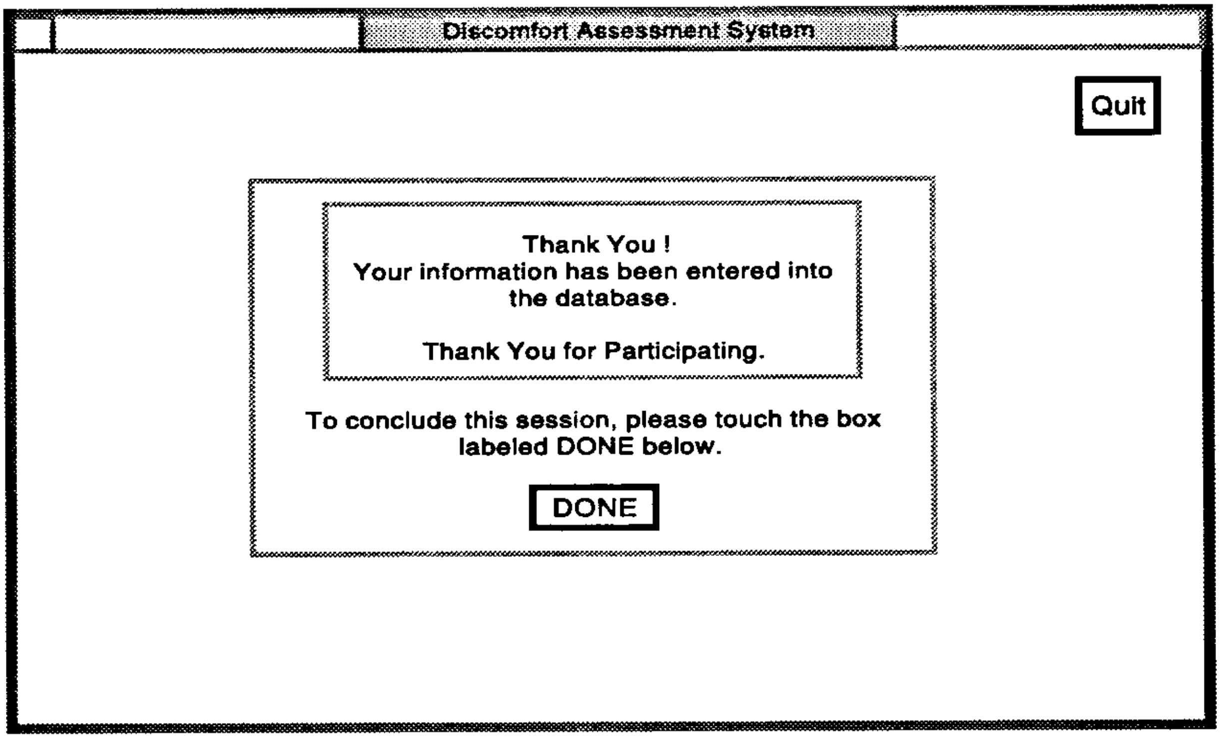
Location of Discomfort Screen (Body Figures)



Discomfort Scores Screen (Body Figures)



Discomfort Descriptors Screen



Final Screen

APPENDIX E

SELECTED PICTURES OF ACTIVITIES AND ASSOCIATED RISK FACTORS FOR MUSCULOSKELETAL INJURIES

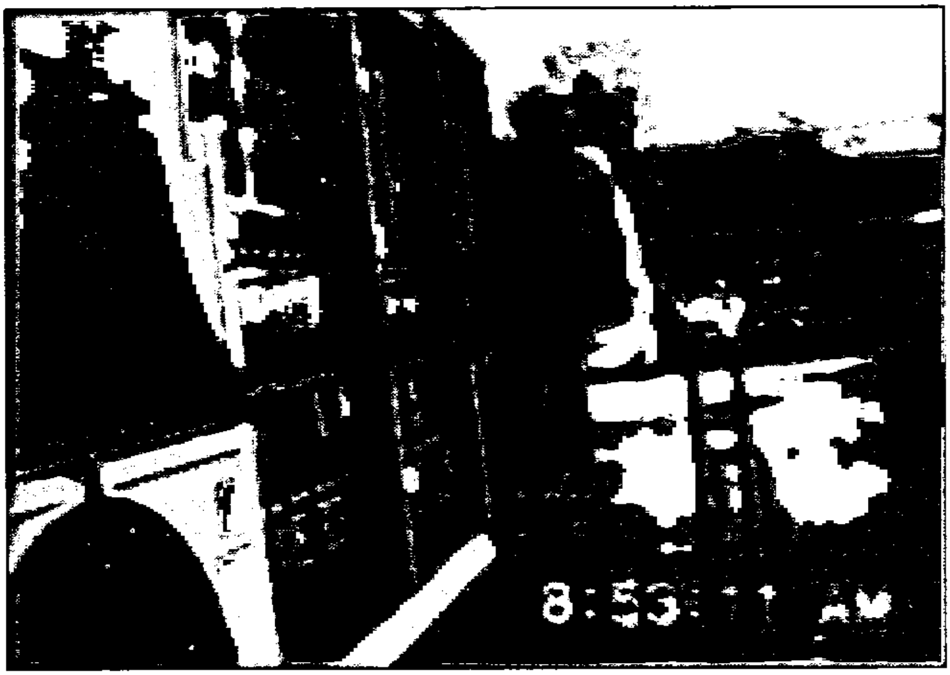


Figure E1. *Driver-salesworker lifting 24-bottle case of 20-oz glass soft drink beverages from truck while standing on platform.* **[Comment: Excessive reach was reduced by standing on platform. This reduces biomechanical stress on shoulders.]**

Figure E2. *Driver-salesworker placing 24-bottle case of 20-oz glass soft drink beverages on platform.* **[Comment: Driver-salesworker does not have to step off truck to place beverage case on ground.]**

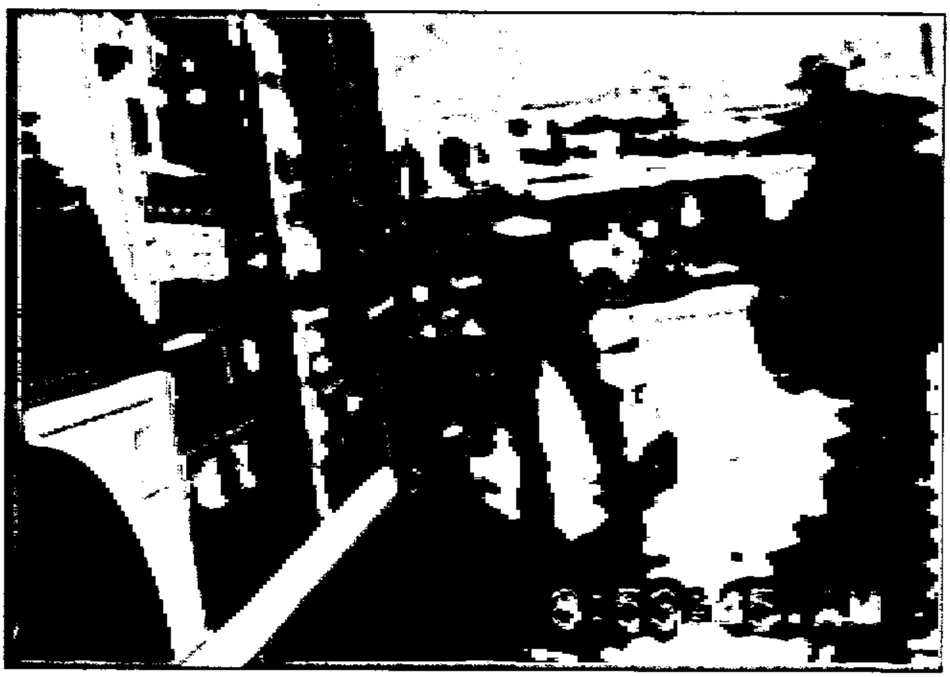


Figure E3. *Driver-salesworker lifting 24-bottle case of 20-oz glass soft drink beverages from truck platform.* **[Comment: Excessive reach was reduced; lowered biomechanical stress on shoulders.]**

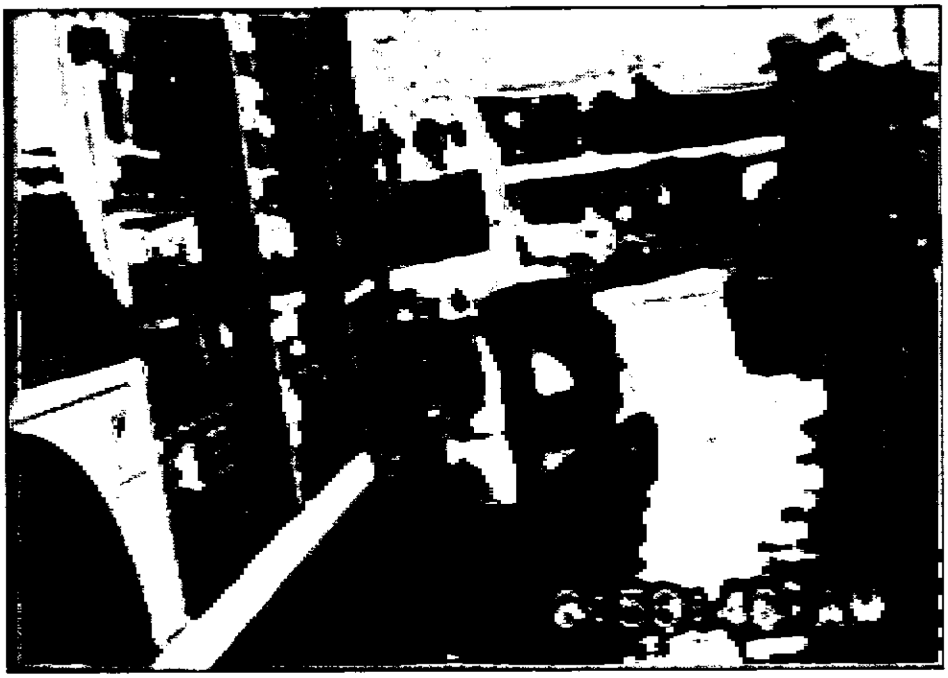


Figure E4. *Driver-salesworker placing 24-bottle case of 20-oz glass soft drink beverages from truck platform on hand truck.* **[Comment: Figures E1 through E4 show that beverage cases are handled twice by using truck platform. However, metabolic costs are less than biomechanical costs when beverage cases are handled once.]**

Figure E5. *Driver-salesworker lifting 8-pack case of 2-L beverages from truck not using truck platform.* **[Comment: Extended reach to access 8-pack 2-L beverage case. Driver-salesworker initially does not use platform, but later remembered to use platform (see Figure E6).]**

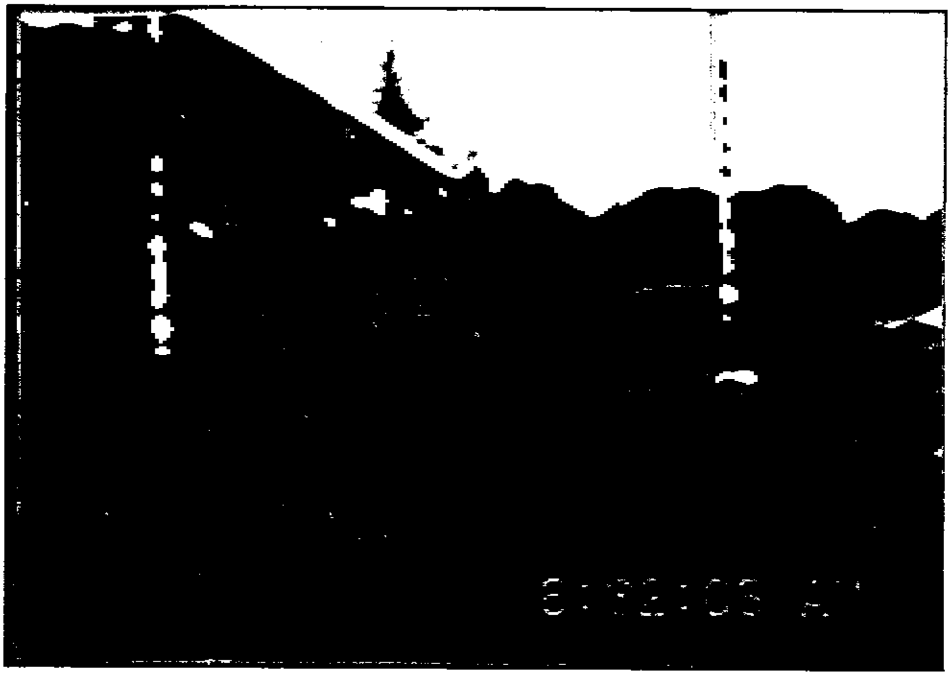


Figure E6. *Driver-salesworker using truck handhold to stand on platform to access 8-pack, 2-L beverage cases.* **[Comment: Driver-salesworker uses truck handholds to step on platform for easier access to beverages.]**

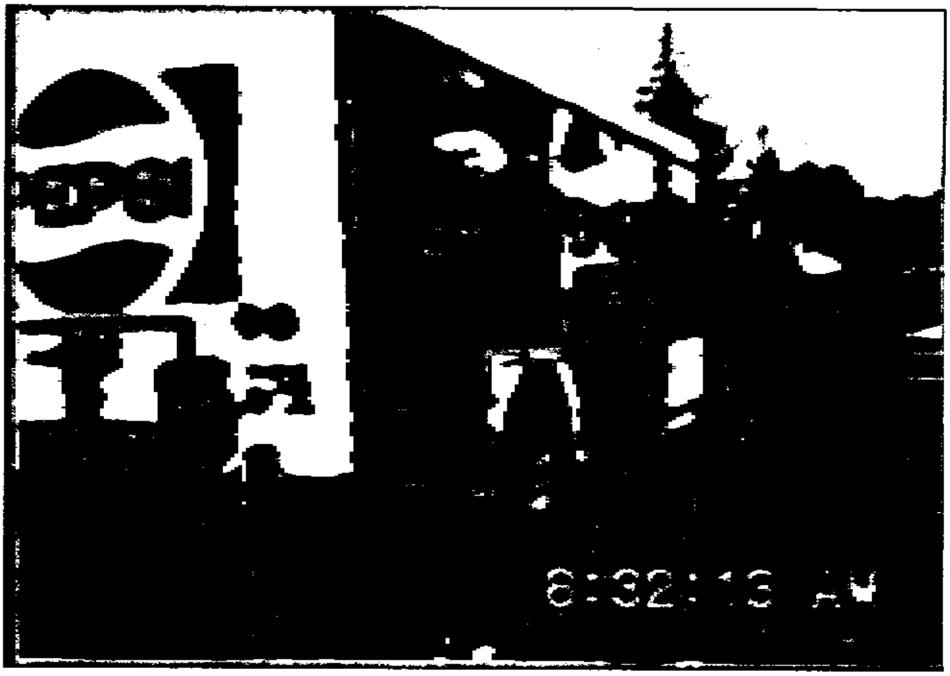


Figure E7. *Driver-salesworker lifting 8-pack, 2-L case from truck using truck platform.* **[Comment: Driver-salesworker uses platform to unload beverages from truck.]**

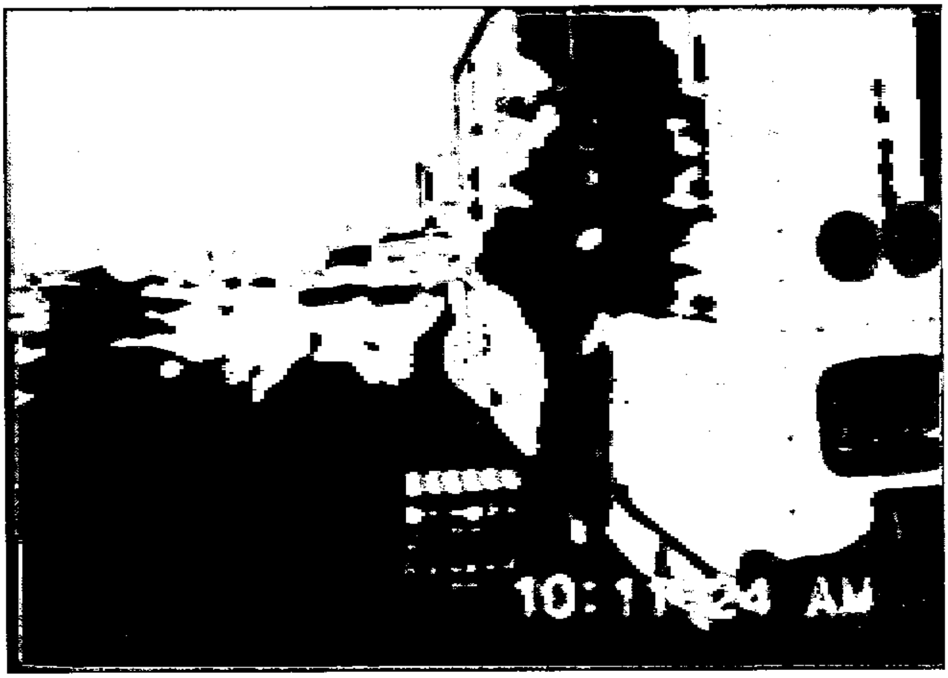


Figure E8. *Driver-salesworker using truck wheel bar and using handhold to improve leverage for lifting 24-pack case of 20-oz soft drink beverages from truck.* **[Comment: Driver-salesworker uses truck handles for leverage while getting 24-pack case of 20-oz beverage crates from truck.]**

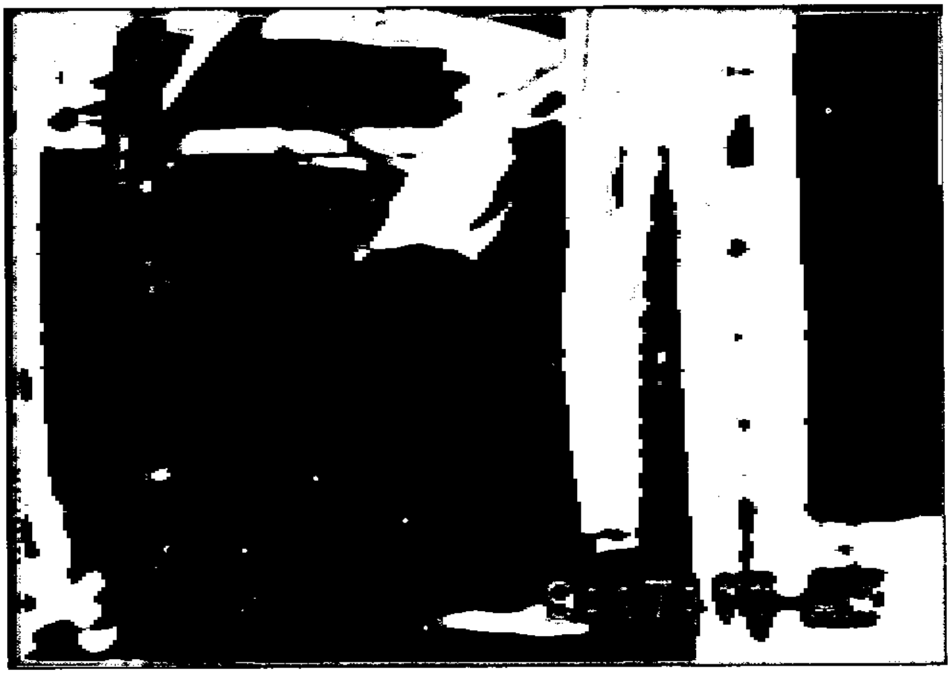


Figure E9. *Driver-salesworker getting printed receipt from printer located in the middle, back wall of truck cab.* **[Comment: Driver-salesworker is in an awkward posture to access the printer to get receipt. This may increase stress to the back. Excessive twisting was also observed when the driver operated the printer from the driver's seat.]**

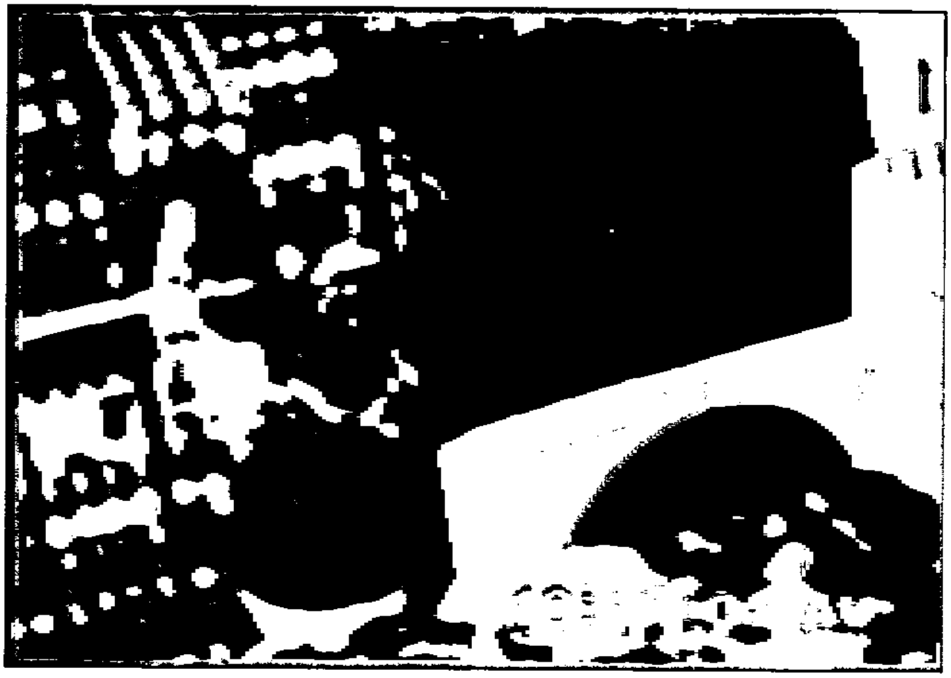


Figure E10. *Driver-salesworker unloading 24-pack case of 20-oz soft drink beverages from truck during snow storm.* **[Comment: Poor weather conditions add stress to job. Snow and ice may increase chances for beverages to slip out of hands and fall on driver-salesworkers.]**

Figure E11. *Driver-salesworker loading 8-pack, 2-L soft drink beverages on hand truck on high dock during snow storm.* **[Comment: Beverages are loaded on high dock on 4-wheel hand truck during poor weather conditions. The combination of extended reach, ice, snow, and cold increases stress to the arms and shoulders and may increase slip and fall injuries. Covered docks may help reduce slippery conditions and reduce some stress.]**

Figure E12. *Driver-salesworker lifting loaded hand truck (350 lb—includes weight of hand truck) up steps to store.* **[Comment: The combination of a heavy load, control of load, posture, and effort to pull load up steps create significant biomechanical loads on the back.]**

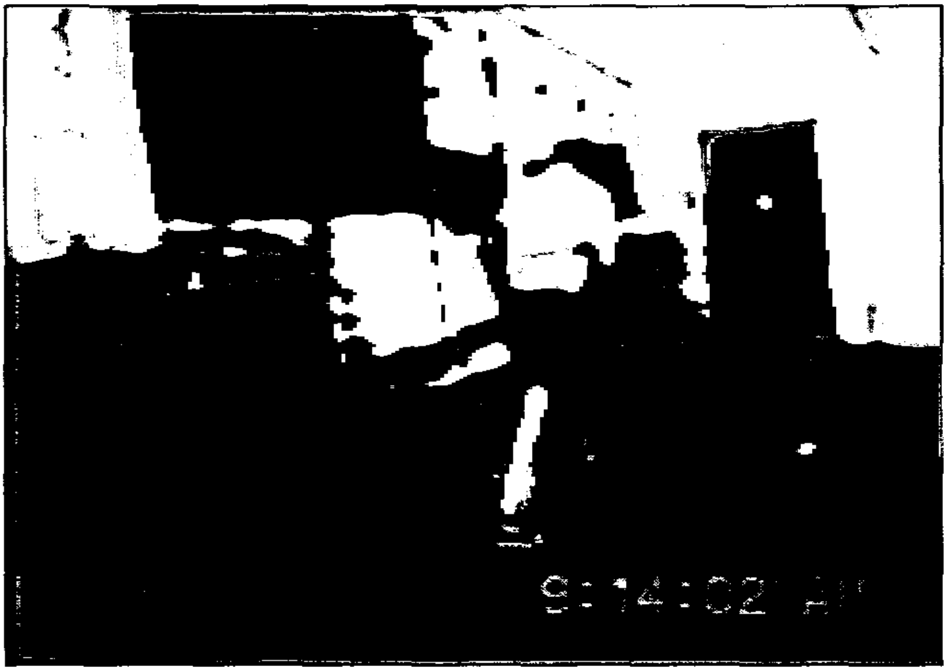


Figure E13. *Driver-salesworker pushing loaded 4-wheel hand truck (approximately 680 lb—includes weight of hand truck) up low grade hill to store service entrance.* **[Comment: Pushing or pulling loads up hill cause significant stress to the back and increase chances for slip and fall injuries if the foot and ground contact is not good.]**

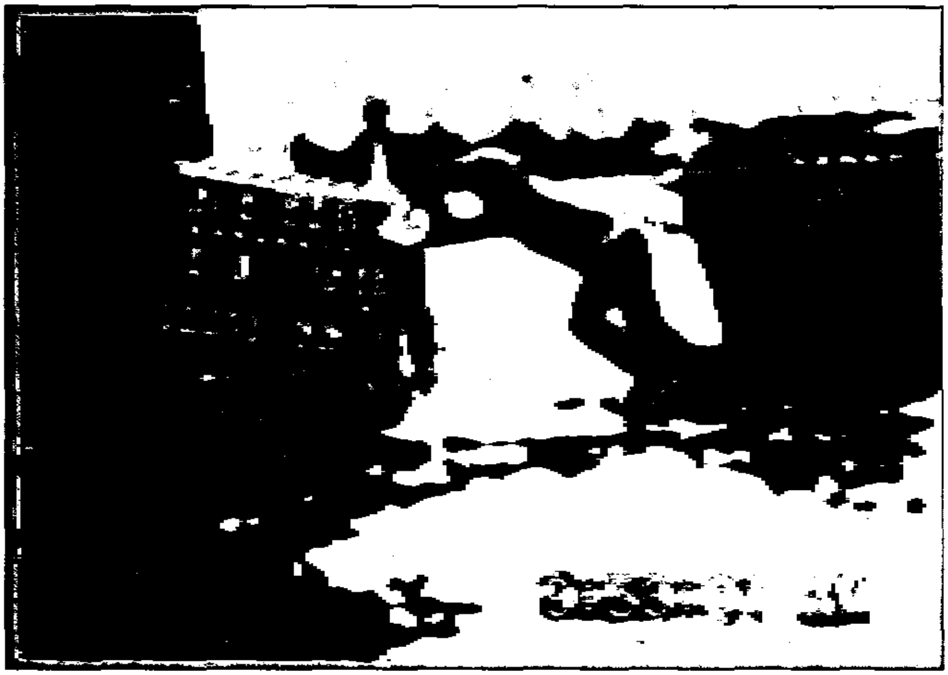


Figure E14. *Driver-salesworker pushing loaded 4-wheel hand truck (approximately 680 lb—includes weight of hand truck) up 6 degree ramp to store service entrance.* **[Comment: Pushing or pulling loads up ramps cause significant stress to the back and increase chances for slip and fall injuries if the foot and ground contact is not good. Longer, lower grades are recommended over short, steep grades.]**

Figure E15. *Driver-salesworker stooped over while loading beverage cooler with individual servings of 20-oz soft drink.* **[Comment: Stooped over posture increases stress to the back even though materials handled are low in weight. It is recommended that driver-salesworkers kneel on one knee and keep back more erect to perform this task.]**

Figure E16. *Driver-salesworker stocking shelves with 24-can cases of 12-oz soft drink.* **[Comment: Stooped over static postures with heavy loads significantly increases stress to the back. It is recommended that driver-salesworkers kneel on one knee, handle one case at a time, and keep back more erect to perform this task.]**

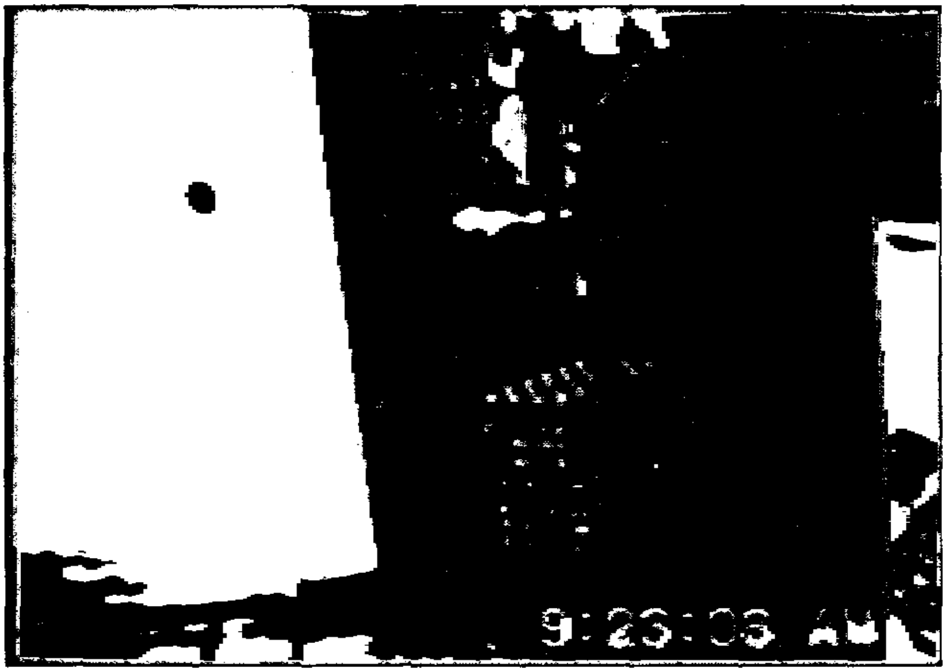


Figure E17. *Driver-salesworker loading beverage cooler with individual servings of 20-oz soft drink.* **[Comment: Driver-salesworker loads beverages in cooler while kneeling. This work practice reduces stress to back. However, knee pads may help reduce stress to knees.]**

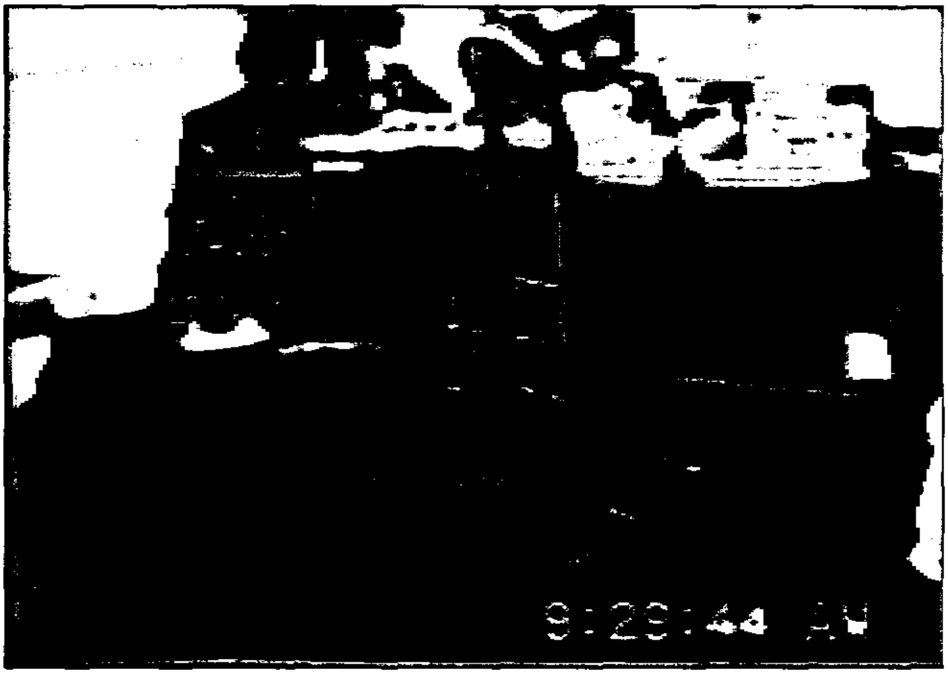


Figure E18. *Driver-salesworker loading 53-lb bag-in-the-box (BIB) under the counter.* **[Comment: Driver-salesworker has to get into awkward posture to position the BIB under the counter. This causes stresses to back and knees. The BIBs can be loaded on a small cart with wheels and moved in and out of this space.]**

Figure E19. *Driver-salesworker lifting 8-pack of 2-L beverages from truck.* **[Comment: Slip and fall hazard exists from standing on narrow ledge while removing beverages. Pullout platform may reduce slip and fall hazards.]**

Figure E20. *Driver-salesworker stepping off truck with 8-pack of 2-L beverage load.* **[Comment: Driver-salesworker steps off truck with load. Load is unstable and 2-L containers may fall from the 8-pack shell causing injury to the deliveryperson. Also, unloading the beverage cases in this manner causes significant strain on the back and legs when cases contact the ground. Pullout platform should help reduce strain to back and legs.]**

 ★ U.S. GOVERNMENT PRINTING OFFICE: 1996 750-176/40011