ERGONOMIC INTERVENTION FOR THE SOFT DRINK BEVERAGE DELIVERY INDUSTRY

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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.

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Manuscript Authored by: **James D. McGlothlin, Ph.D., C.P.E.**

Prepared by:

Bernice L. Clark   Debra A. Lipps
Deanna L. Elfers

Edited by:

Anne L. Votaw   Denise Hill

Survey and Technical Assistance by:

Cheryl Fairfield Estill, M.S., P.E   Ronald J. Kovein
Sheila Krawczyk, Ph.D., C.P.E., C.I.H   Stephen S. Smith, M.S.

Graphics by:

Richard A. Carlson   Donald J. Murdock, Jr.

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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]

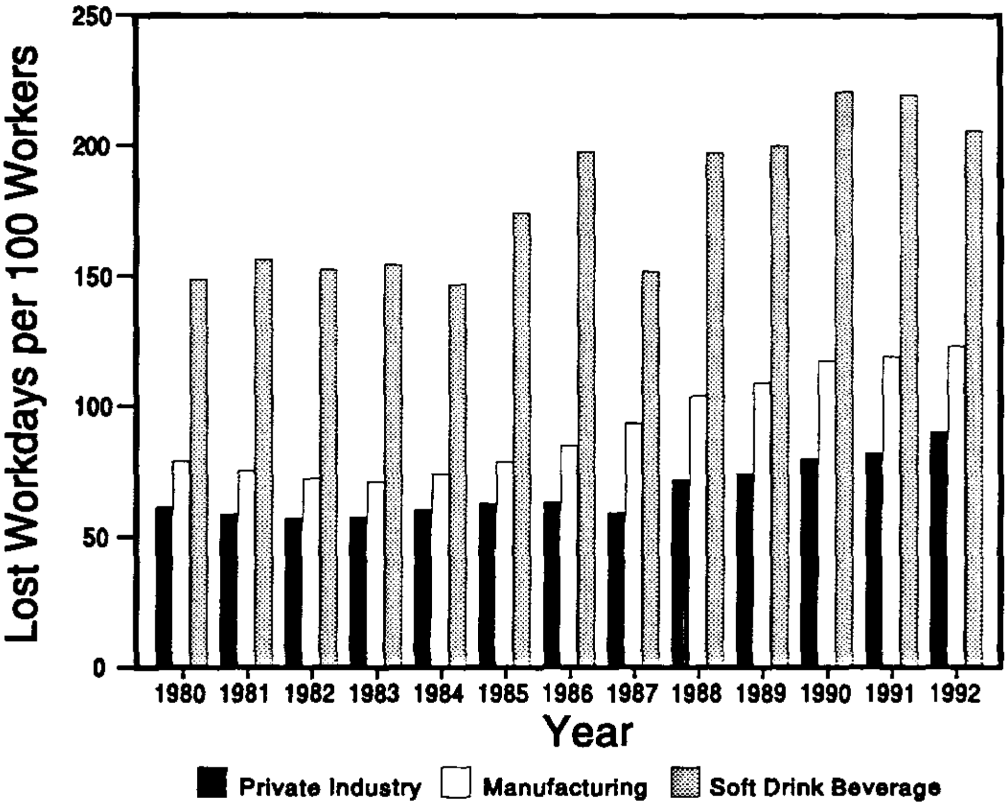

Figure 1. Bureau of Labor Statistics (BLS) Injury and Illness Incidence Report for Private Industry, Manufacturing, and the Soft Drink Beverage Industry from 1980 to 1992. **[Note: The BLS no longer publishes total lost workdays by industry beginning in 1992. The 1992 lost workdays data was acquired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