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IN-DEPTH SURVEY REPORT

ERGONOMIC INTERVENTIONS FOR THE SOFT DRINK BEVERAGE DELIVERY INDUSTRY

AT

Pepsi-Cola™ Company
Dayton, Ohio

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SIC CODE	2086
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DISCLAIMER

Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention (CDC)

SUMMARY

The objectives of this National Institute for Occupational Safety and Health (NIOSH) study were to investigate, identify, and remove risk factors which may cause musculoskeletal disease and injury in the soft drink beverage delivery industry

A field study of nine soft drink beverage deliverymen (ages 34 to 58) was conducted over a four month period in 1993 Ergonomic evaluations of the truck bays showed that they exceeded the normal reach limit of workers Extended reaches for heavy beverage cases can significantly increase the risk of musculoskeletal injuries

During the field survey several ergonomic interventions to reduce and prevent musculoskeletal injuries were implemented, which included 1) engineering controls for easier access to beverage products, such as A) pullout steps, B) external handles, and C) multilevel shelving units, 2) two-wheel handtrucks with counter-balancing devices, 3) substitution of plastic beverage containers for glass containers to reduce weight, and 4) 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, and analysis of psychophysical discomfort assessment surveys Measurement differences 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 deliverymen developed experience with the ergonomic controls, the frequency and magnitude of body discomfort reporting decreased

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 deliverymen from the beginning versus the end of the survey, despite an increase in the product volume handled The ergonomic interventions, in combination with improved work practices, reduced fatigue, the amount of beverage handled per day, and awkward postures during beverage handling Favorable reports from the deliverymen in the study about the effectiveness of these controls helped convince management that all new trucks should have ergonomic changes made

Other beverage delivery companies would also benefit from the lessons learned in this study and the resulting recommendations since the risk of a musculoskeletal injury during beverage delivery was found to be 100 percent among those deliverymen surveyed The NIOSH lifting criteria showed that most of the beverage lifting tasks exceeded the Recommended Weight Limit (RWL) Heart rate results and indirect measurements of metabolism showed that the job of beverage deliverymen is physically demanding, especially during peak delivery periods Statistically speaking, the probability of such musculoskeletal injuries, in terms of days lost, is twice as high for the beverage deliverymen as for those in general manufacturing jobs Engineering controls are recommended, along with rest breaks during peak delivery periods to prevent fatigue and reduce injuries

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), it was established by the Occupational Safety and Health Act of 1970 This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) 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

Since the discovery 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 gallons 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 nonalcoholic beverages [3] Added to this is the changing consumer tastes and needs which create an ever-increasing selection of products in various shapes and sizes Many small bottlers have gotten out of 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]

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 1990, the injury and illness rate for this industry was 20 3 per 100 full-time workers This was above the 12 7 rate in manufacturing as a whole, and more than double the private industry rate of 8 4 per 100 full-time workers [1] Moreover, nearly three-fifths of the injury and illness cases in the soft drink industry were serious enough to require time off from work

Soft drink manufacturers are among the most hazardous industries based on lost worktime incidents At 12 2 cases per 100 full-time employees, its 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] Soft drink workers had a comparatively high risk for sustaining a serious (lost worktime) injury or illness, but they returned more quickly than workers in other industries with an average of 18 workdays per lost workday cases 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 lost workdays per 100 workers for private industry, manufacturing, and soft drink beverage industries from 1980 to 1991

The Supplementary Data System (SDS), which is comprised of injury and illness information from 14 states, 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, and source of injury or illness 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 percent of the injury and illness cases reported, another two-fifths were evenly divided between the lower extremities (legs, 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 percent of all soft drink cases compared to 33 percent 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

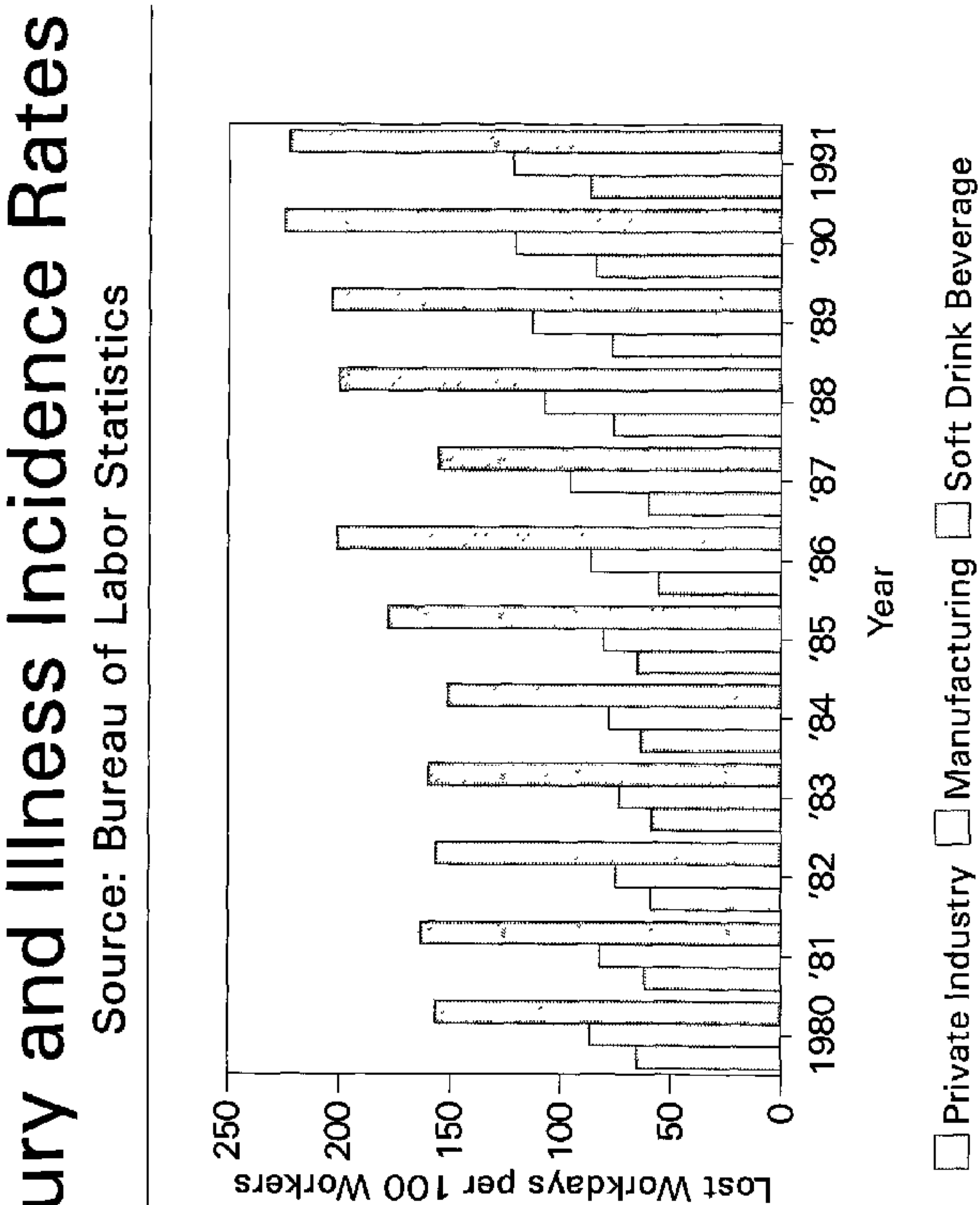

Figure 1. Injury and Illness Incidence Report

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.[1]

Beverage delivery (also known as driver-salesworkers) was the leading occupation of the injured or ill worker 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 deliverymen. 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] Injuries to drivers-salesworkers related to manual material handling, such as unloading trucks filled with soda cans and bottles, carting and stacking the containers on customers' premises. Repeatedly maneuvering heavy loads eventually lead to sustained serious sprains due to overexertion.[1]

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. The group most at risk for injury and illness is the beverage deliveryman. Competition in this industry is expected to continue to be high, resulting in competitively priced soft drink products and packages offered to consumers. The combination of competition, price, product, package, and profit may put these workers at increasing risk for more injuries and illnesses in the coming years

Because of the potential for more injuries and illnesses to the soft drink deliverymen, the goal of this study was to apply engineering controls and to measure their effectiveness 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 Pepsi-Cola™ plant studied by NIOSH personnel is located in Dayton, Ohio This plant was purchased approximately five years ago from General Cinema by the Pepsi-Cola™ Company of Sommers, New York There are approximately 240 employees at this plant, including 8 express 4 transit and 57 route drivers This plant is a full-service facility which delivers a broad line of soft drink products, from individual servings for vending machines to bulk delivery for grocery stores Delivery normally is Monday through Friday Most driver-salesworkers, referred to as beverage deliverymen in this report, 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 deliveryman can vary from 150 to over 500 cases of soft drink product per day This variability occurs for many reasons, including *route structure* (the driver's delivery volume balance of small customers, i e , gas stations, to large, i e , independent grocery store customers), *beverage sales and promotions*, and *delivery time* (time of week, time of month, i e , paydays, holidays, and time of year, i e , seasonal [significantly more in summer than winter]) The delivery drivers have some flexibility in how much they want to deliver on a daily basis, providing that 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 deliverymen 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 deliverymen 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) 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

Figure 2 Profile of Ten Bay Delivery Truck (with Retrofit Controls Installed) Used in Study

Figure 3 Profile of Fourteen Bay Delivery Truck (with Retrofit Controls Installed) Used in Study

JOB DESCRIPTION

The beverage deliveryman is responsible for the following tasks (1) driving a prestocked route truck from the plant to designated retail/grocery stores, (2) unloading the various cases of soft drink beverages from the truck and delivering them to the store, and (3) stocking shelves and displays within the store 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 deliveryman (1) manually lifts boxes, cases, or tanks piece-by-piece from the truck and places them on a handtruck, (2) wheels the handtruck to the point of delivery specified by the customer, and (3) manually unloads the handtruck 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-liter bottles, pre-mixed tanks, bag-in-the-box, and 16-oz returnable bottles, with weights of 22 to 58 lbs Table 1 lists the principal soft drink products and respective weights

JOB RISK FACTORS

The beverage deliveryman 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, (2) pushing and pulling loads, which can exceed 350 lbs, up and down stairs, ramps, confined areas, and rough terrain, (3) repetitive

Table 1 Principal Soft Drink Products and Respective Weights Delivered by Deliverymen

PRODUCT	WEIGHTS (lbs)
10 oz nonreturnable glass (case of 24)	23
12 oz cans metal alloy (case of 24)	22
16 oz returnable tall glass bottle (case of 24)	57 5
16 oz returnable tall glass bottle (case of 24) empty	29
16 oz sport drink plastic (case of 24)	30
16 oz tea drink glass (case of 24)	39
20 oz soft drink glass (case of 24)	49 5
20 oz soft drink plastic (case of 24)	37
32 oz sport drink plastic (case of 12)	30
1 liter soft drink glass (case of 15)	45
2 liter soft drink plastic (case of 8)	39
Pre-mix Tanks (aluminum) - soft drink	53 5
Post-mix Tanks (aluminum) - soft drink	57
Pre- and Post-mix tanks (aluminum) - empty	10
Bag in the Box (BIB)	53
Carbon Dioxide cylinder (cast iron) - full	45
Carbon Dioxide cylinder (cast iron) - empty	26
Cups (1,000 carton)	34
Lids (2,500)	11
Lids (1,000)	7
Wood Pallets	55

lifting, lowering, stacking, and unstacking beverages in various size crates, and (4) removing product from the truck bays For example, the bays are approximately 7 ft high x 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 Slip and fall injuries can also occur from climbing in and out of the truck (approximately 38 in from the ground to cab floor), and the bays (24 in for regular bays, 50 in for bays over wheels) Other risk factors include slips, trips, and falls on wet or icy surfaces while drivers transport product, beverage product falling on drivers as they open bay doors, sharp glass from broken glass bottles, and robberies

EXPOSURE EVALUATION CRITERIA

HEALTH EFFECTS OF MANUAL MATERIALS HANDLING

Cumulative Trauma Disorders

Reports of chronic musculoskeletal disorders have been documented for centuries [5] However, only recently have epidemiologic studies attempted to examine the association between job risk factors, such as repetition, awkward postures, and force with excess musculoskeletal morbidity [6,7,8,9] Several cross-sectional and case-control retrospective studies of occupational Cumulative Trauma Disorders (CTDs) have been done [10,11,12,13,14,15] The conclusions from these studies have strengthened the association between identifying 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, and (5) use of vibrating hand-held tools. Because repetitive movements are required in many service and industrial occupations, including the beverage delivery industry, new occupational groups at risk for developing cumulative trauma disorders continue to be identified.

One of the most commonly reported disorders of the arms is carpal tunnel syndrome (CTS). CTS is a median neuropathy of the wrist that can be caused, precipitated, or aggravated by repetitive, awkward postures and forceful motions.[14] CTS symptoms 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 intervention, CTS can lead to severe discomfort, impaired hand function, and disability. Workers who perform repetitive tasks are at risk of CTS and include automobile manufacturers and assemblers, electrical assemblers, metal fabricators, garment makers, food processors, grocery checkers, typists, musicians, housekeepers, and carpenters.[16,17,18]

The diagnosis is confirmed by physical examination and/or electrodiagnostic studies.[17] CTS can be managed with conservative measures, such as wrist immobilization and nonsteroidal anti-inflammatory medications.[16] 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.[16] 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. For all patients with symptoms suggestive of CTS, an occupational history should be obtained that includes a description of tasks involving the hands. Failure to eliminate contributory job factors can result in recurrence or progression of symptoms, impaired hand use, and surgical treatment. Redesign of tools, workstations, and job tasks can prevent occurrence of CTS among workers.[16] Surveillance of work-related CTS, including health care reports, can aid in identifying high-risk workplaces, occupations, and industries, and in directing appropriate preventive measures.[19]

While some theoretical models showing the relationship between repetition, force, posture, and recovery time have been developed,[20,21] there are no evaluation criteria for predicting risk of injury to the arms at this time.

Back Injuries

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 lbs) handled, and the stressful positions (*posture*) needed to retrieve the product from the truck. The combination of these factors increases the risk for back injury. The following is a brief overview of possible back injury causes, strategies to reduce and prevent them from occurring, and evaluation criteria to judge effectiveness.

Beverage delivery, construction, mining, transportation, and manufacturing are the occupations which show high rates of low back injuries [22] Despite the trend toward automation, a significant portion of the work force currently is engaged in manual materials handling tasks Injuries associated with these manual material 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 percent of the cases, pushing, 9 to 16 percent, pulling, 6 to 9 percent, and carrying, 5 to 8 percent Twisting the trunk has been reported in 9 to 18 percent of low back pain, bending in 12 to 14 percent, and falling in 7 to 13 percent [25]

Return to work following a back injury is dependent on the extent of injury as measured by 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 [37,38] In addition, a worker who has already suffered back pain is three to five times more likely to be reinjured [39] Some deterrents to returning to work include psychological disability, no follow-up or encouragement, rigid work rules, too much medical treatment,[40] and attorneys [41]

Industry has used three general approaches to attempt to reduce the problem of low back pain (1) training and education, (2) job design, and (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, twisting, and reaching by the worker, the work should be at the optimum work level, from waist to elbow height to reduce excessive bending and reaching, the workplace should be laid out to reduce twisting, sit/stand workstations should be allowed where possible with good seat design to reduce prolonged sitting or standing, package should be redesigned to include hand holes for better coupling by the worker, small package size so the worker can hold the load close to the body, and low package weight so as not to exceed human capabilities [42] Interim changes to reduce back injuries include job placement,[43] strength and fitness testing,[44,45,46] strength and fitness training (work hardening),[47 48] and work enrichment, enlargement, or rotation to reduce cumulative exposure In addition to educating and training the worker, unions, and management about risk factors that cause back injury and pain, there appears to be no clear, single solution other than good initial job design Multiple approaches, such as job redesign, worker placement, and training may be the best methods for controlling back injuries and pain [49]

Evaluation Criteria for Risk of Back Injury

The revised NIOSH lifting equation reflects new findings for lifting and 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 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 that is considered safe for an "ideal" lift This weight is 51 pounds and is adjusted down 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 [50]

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 result is the LI, the higher the LI the greater the risk for back injury An LI of three or more is considered significant If the original NIOSH formula (1981) is used, an LI of 3 would be representative of the MPL When the LI is greater than 3 0, or in the case of the original NIOSH formula above the Maximum Permissible Limit (MPL), engineering controls are strongly recommended to reduce potential for injuries The following outlines the specific criteria for the revised NIOSH guidelines

The 1981 NIOSH Work Practices Guide for Manual Lifting,[42] and the 1991 Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks[50] 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/container coupling guidelines Because of the additional parameters for evaluating manual materials handling and slight adjustments in the equation, the 1992 equation was used for evaluation of beverage material handling

The new guide has one weight limit which is called the recommended weight limit (RWL) 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 2, 3, and 4

Table 2   Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks

COMPONENT	METRIC	U S CUSTOMARY
LC = Load Constant	23 kg	51 lbs
HM = Horizontal Multiplier	(25/H)	(10/H)
VM = Vertical Multiplier	$(1-(\ 003\lvert V-75\rvert))$	$(1-(\ 0075\lvert V-30\rvert))$
DM = Multiplier	(82+(4 5/D))	(82+(1 8/D))
AM = Multiplier	(1-(0032A))	(1-(0032A))
FM = Multiplier	(see Table 3)	(see Table 3)
CM = Multiplier	(see Table 4)	(see Table 4)

Where

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

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

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

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

F = Average frequency rate of lifting measured in lifts/min Duration is defined to be $\leq$ 1 hour, $\leq$ 2 hours, or $\leq$ 8 hours assuming appropriate recovery allowances (see Table 3)

Table 3 Frequency Multipler

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 4 Coupling Multiplier

COUPLINGS	V < 75 cm (30 in)	V ≥ 75 cm (30 in)
	COUPLING MULTIPLIERS	
Good	1 00	1 00
Fair	0 95	1 00
Poor	0 90	0 90

To determine relative risk for the material handling tasks evaluated, the Lifting Index (LI) was also used The lifting index 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 lbs, and the RWL is 25 lbs, 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 A

EVALUATION DESIGN AND METHODS

SITE SELECTION

This beverage delivery site was chosen on the basis of the beverage delivery driver work force size (i e , > 30), willingness to participate in the evaluation process to implement controls, and proximity to NIOSH research facilities because of study duration and repeat visits to the site

CONDUCT OF SURVEY

Worker Selection and Study Orientation

Ten deliverymen were selected from company volunteers The request for volunteers was made in cooperation with the company and union The volunteers were experienced in urban beverage delivery, had good job performance records, and were in good physical condition (based on company records) NIOSH representatives met with all potential volunteers before and at the beginning of the study to present an overview of the project NIOSH representatives also showed the 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 caused problems 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 deliveryman was instructed on (1) the initial objectives of this study, (2) the use of the self-administered computerized Discomfort Assessment Survey (DAS), and (3) the wearing of a portable noninvasive heart monitor (Polar Vantage XL)™ to determine metabolic demands (indirectly) of the job

Questionnaire Past Work Experience and Medical History

At the beginning of the study a questionnaire (Appendix B) was completed before the workers started their delivery The descriptive information gathered included age, height, forward reach, and weight The work history included the date when workers started with the Pepsi-Cola™ Company and how long they had delivered beverages Injury histories disclosed job-related musculoskeletal disorders and amount of time off resulting from such injuries

Discomfort Assessment Survey

The DAS developed by researchers at the University of Michigan, Center for Ergonomics, was used to collect musculoskeletal discomfort data from selected workers 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, and (3) a discomfort score from 0 (nothing at all) to 10 (worst imaginable) The discomfort score is based on work performed by Borg,[51] Seymour et al ,[52] and Corlett and Bishop [53]

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 [54] Deliverymen entered their musculoskeletal discomfort data into the computer at the beginning, middle, and end of the beverage delivery workday

Deliverymen received individual training, consisting of a demonstration on using the DAS, which they practiced on their own Throughout the study NIOSH researchers were available when the deliverymen entered data in the DAS None of the deliverymen 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 C illustrates the different DAS screens shown on the computer

Discomfort data were systematically collected from the deliveryman 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, and (3) at the end of the study when the deliveryman had adjusted to the controls Data were collected from three deliverymen per week, usually in the middle of the week (Tuesday, Wednesday, and Thursday)

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

Metabolic Measures

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 stores 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 stopwatch in the portable videocamera was synchronized with the time of day on the hear 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 of beverage delivery inventory reports that indicated the amount of product loaded and sold, (2) videotaping the beverage delivery process, from activities performed at the plant to activities performed at delivery sites, (3) biomechanical evaluating of musculoskeletal stress during manual handling of beverage containers, (4) recording of delivery truck dimensions, and (5) discussing with the deliverymen about musculoskeletal hazards associated with their jobs

Biomechanical Evaluation

Biomechanical evaluation of the back was performed using the revised NIOSH lifting equation [50] The purpose of this evaluation was to determine if certain tasks exceed a worker's biomechanical and static strength capabilities, and to determine if such tasks are putting 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 workers performing beverage handling tasks The six tasks analyzed were selected on the basis of weight range, volume sold, and container size

The six tasks evaluated were

- Lifting 12-oz 24-can cases of beverage from truck
- Lifting 2-liter 8-pac 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-lbs aluminum tanks containing pre-mix beverage
- Lifting 53-lbs, 5-gal Bag-in-the-Box (BIB) containing pre-mix beverage

In addition to the NIOSH RWL, the LI was used as a measure of relative risk for back injury An LI of less than 1 is a low risk, 1 to 3, medium risk, greater than 3, high risk [50] To determine biomechanical forces on the shoulders during beverage material handling a University of Michigan, Center for Ergonomics, software program (3D Static Strength Prediction Program™) was used [55]

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 10 bay delivery trucks are the standard for city delivery because they are easier to handle on urban streets compared to the larger trucks However, 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), larger trucks are becoming necessary Therefore the 14-bay tractor-trailer was retrofitted with similar controls as in the smaller trucks to determine the benefit of such features for the larger ones Table 5 shows the ergonomic retrofit to four Beverage Delivery Trucks These retrofit are divided into two categories safety and ergonomic (i e , musculoskeletal) The safety features include 5-in spot mirror on right and left door, 5-in spot mirrors mounted on right side of hood, heated mirror installed on driver side, heated/motorized mirror passenger side, 3-point seat belt, bay liners all bays, motion back-up alarms with guards, raise stop/taillights and back-up lights to hood level, recess license place brackets, and new caution "wide right turn" sign The ergonomic features include cush-n-aire^{R} driver seat, exterior grab handles for all bays, 3-position drop shelf holes for all deep bays, installed hand grips in vertical (single sheet divider) divider in bay, wider step platform on wheel housing step bar, extra wide recessed steps front and rear, anti-slip installed on bottom rail and step holes, pullout step rear bays, large handtruck holder and high back rest for 2 handtrucks, new rollers in all bay door slats and lubricated doors, and new door straps

Table 5 Safety/Ergonomic Retrofits of Beverage Delivery Trucks

5" spot mirror on right and left door
5" spot mirrors mounted on right side of hood
heated mirror installed on driver side
heated/motorized mirror passenger side
cush-n-aire drive seat
3-point seat belt
exterior grab handles all bays
3 position drop shelf holes/all deep bays
install hand grips in single sheet divider
wider step platform on wheel housing step bar
extra wide recessed steps, front and rear
bay liners all bays
anti-slip installed on bottom rail and step holes
pullout step rear bays
motion back-up alarms with guards
large handtruck holder and high back rest for 2 handtrucks
raise stop/tail lights and back-up lights to hood level
recess license plate brackets
new rollers in all bay door slats and lubricated doors
new door straps
new caution "wide right turn" sign

Two-wheel handtrucks--

The majority of deliverymen preferred to use the trucks they had rather than the ergonomically designed 2-wheel handtruck called the "Equalizer" (Magliner Inc) However, some data were gathered with one deliveryman using the "Equalizer " Most drivers had one two-wheel handtruck, while others had a two-wheel and a four-wheel (for bulk delivery) NIOSH researchers performed maintenance on the handtrucks 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 handtrucks

Data Analysis

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

Variables from the ergonomic controls (i e , ergonomic retrofit, and handtrucks) were tested to determine differences in musculoskeletal risk Measured outcomes included changes in reporting in the Discomfort Assessment Survey, heart rate, and biomechanical stress Lotus 123 and the Statistical Graphics Package were used for analyses [56,57] Student t-tests and McNemar's test were used to compare before and aftereffects of controls

RESULTS

DESCRIPTION OF BEVERAGE DELIVERYMEN

Nine deliverymen 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 All deliverymen were experienced, healthy males ranging in age from 34 to 58 years

QUESTIONNAIRE DEMOGRAPHICS, PAST WORK EXPERIENCE, AND MEDICAL HISTORY

Characteristics of the nine deliverymen, including weight, height, functional reach (from the back of the shoulder to finger pinch), and seniority with the company and for delivery, are summarized in Table 6

Demographics

Workers who participated in this study ranged in age from 34 to 58 years, average 42 4 years They ranged in weight from 164 to 256 pounds (lbs), average, 210 4 lbs Height ranged from 67 to 76 inches (in), average height was 72 in Functional reach (distance from the back of the shoulder to finger tip pinch) was 28 to 33 in, average 30 5 ins

Table 6   Descriptive Characteristics of Deliverymen at the Beginning of Study

Subject*	Age (yrs)	Weight (lbs)	Height (in)	Funct 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

Work Experience

Worker seniority ranged from 15 to 34 years, average, 19 6 years With the exception of one worker, all reported that they started with the company as beverage deliverymen and had been performing the same job while with the company The average seniority for delivering beverages was 19 3 years The one worker had a management position for a short time, but returned to beverage delivery This company does not have a career track that advances employees from beverage delivery to another job that pays as well or better Several of the workers indicated that they had been delivering beverages for a long time, but could not recall anyone in their organization who retired as a beverage deliveryman Most were either injured or found other jobs

Medical History

At the beginning of the study all 9 workers were asked about past injuries related to their beverage delivery job

During their career as beverage deliverymen with this company

All 9 deliverymen reported that they had suffered a 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, and

The average time off was 2 8 months

DISCOMFORT ASSESSMENT SURVEY

Body Location

DAS was conducted to record the employees' discomforts and fatigue resulting from their delivery jobs, and to compare differences in reporting after ergonomic interventions were implemented

During data analysis, it was discovered that 3 DAS reports for one of the conventional deliverymen had been inadvertently destroyed (two morning, and one midday DAS report) Because the incomplete reporting would bias the overall results for the group, data analysis was conducted on only the 8 deliverymen who had all reports available

As shown in Table 7, the back was indicated by most deliverymen (six of eight) as having discomfort during the survey The shoulders, elbows, and legs (knees) were next (four of eight), with neck and hands least reported by the deliverymen (two of eight)

The legs (44) were selected more often than any other aggregated body part with discomfort This was followed by the back (21), shoulders (20), elbows (17), hands (8), and neck (3) There were an additional 17 responses for the specific areas of the hand These responses were not added to the initial count of 8 for the hands since these responses provided detailed information about specific parts of the hand As shown in Table 7 the body segments most frequently cited with discomfort for each body aggregate were the right and

Table 7 Number, Percent, and Body Part Location of Discomfort Responses Reported by Deliverymen During Field Study

	NECK	SHOULDERS	ELBOWS	HANDS (Including Wrists)	BACK	LEGS
# responses reported	3	20	17	8*	21	44
#, and % of specific body part discomfort	3 (100%)	13 (65%)	10 (59%)	8 (100%)	18 (86%)	25 (57%)
specific body part discomfort	back neck	back right shoulder	back left elbow	right and left hands, back	lower back	right and left knees, front
% Deliverymen (from n=8)	25	50	50	25	75	50

*Within the hand/wrist aggregate where there were 17 responses for specific parts of the hand 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 deliverymen 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 is believed to be real and may be due, in part, to the ergonomic controls installed on the truck and to good maintenance of the handtruck, such as proper inflation of the tires and lubrication of moving parts

When the body parts were examined by time of day, there was no significant difference in reporting between the beginning (45 reports), middle (41 reports), and end of the workshift (44 reports)

When the body parts were examined by survey, 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 reporting (t statistic $p < 05$) Detailed examination of these data showed that 50 percent of the deliverymen reported a decrease in body part discomfort, the other 50 percent reported an increase The difference was a greater number of reports by individual deliverymen over the survey period, showing a decrease in discomfort reporting (15 reports) rather than increase (6 reports) The decrease was not dominated by any one

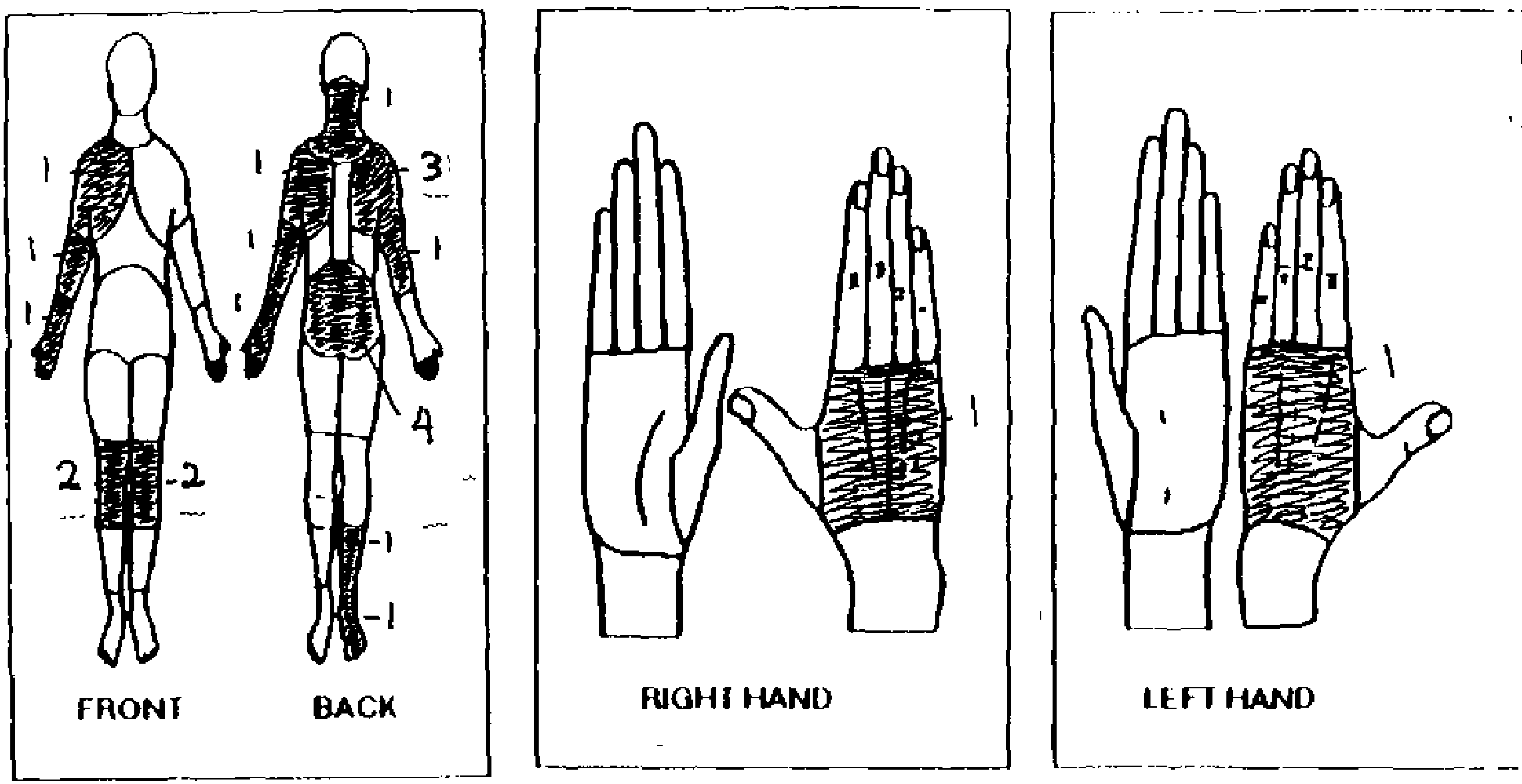

Figure 4 First Survey Results from Discomfort Assessment Survey (DAS) (Numbers Next to Body Part Indicate How Many Drivers (*from n=8*) Reported Discomfort in that Location)

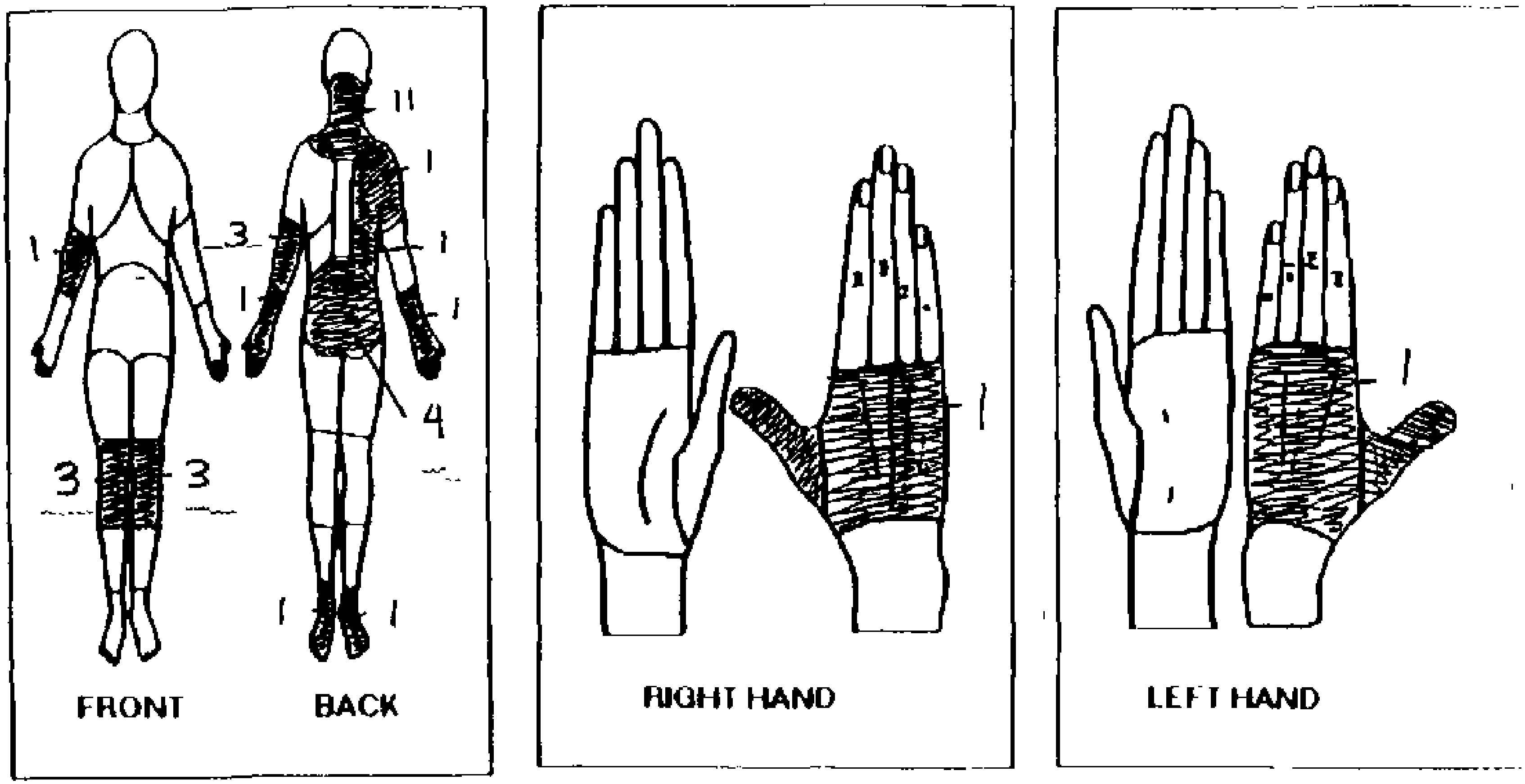

Figure 5 Second Survey Results from Discomfort Assessment Survey (DAS) (Numbers Next to Body Part Indicate How Many Drivers (from n=8) Reported Discomfort in that Location)

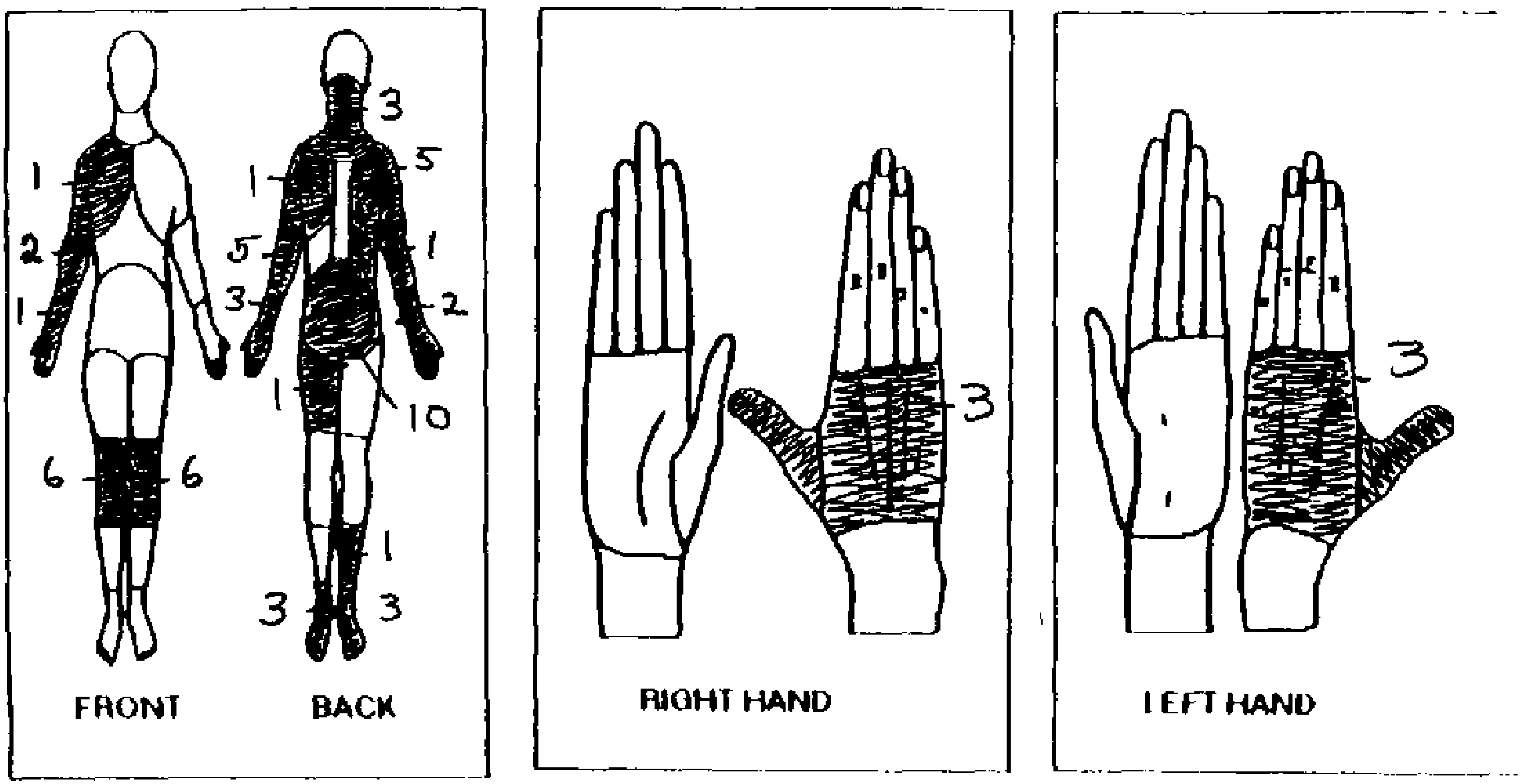

Figure 7 Composite Survey Results (All Three Surveys) from Discomfort Assessment Survey (DAS) (Numbers Next to Body Part Indicate How Many Deliveryman (from n=24, i e , 3x8) Reported Discomfort in that Location

deliveryman There was no significant decrease in back discomfort reporting between the first and third survey (McNemar's Test, one sided p > 05) The shoulder and elbow were the most affected body parts accounting for the decrease in discomfort However, the decrease was not significant for the shoulder and elbow No pattern was seen in the slight increase in discomfort reporting by the other deliverymen

Symptom Reporting

More than one symptom could be reported for a body part selected by the deliverymen Up to twelve symptoms could be reported per body part (pain, cramping, aching, stiffness, swelling, weakness, stabbing pain, numbness, burning, tingling, loss of color, and other) During this survey, 186 symptoms (186 reports) 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 reports), these data accounted for 86 percent of all reports Reporting of these symptoms was evenly distributed Remaining symptoms accounted for 14 percent of the reports

There was no significant difference in symptom reporting by time of day However, there was a difference in symptom reporting by survey Symptom reporting increased between the first and second survey from 65 to 74 reports, and decreased for the third survey to 47 reports Aching and pain reporting increased and stiffness decreased, from the first to second survey Stiffness decreased significantly from the first to third survey, aching returned to first survey levels, and pain stayed at second survey levels The decrease in stiffness reporting between the first and third survey was reported by several workers, however, the increase in pain reporting was dominated by one worker

Pain Level Reports

Only one pain score could be selected per body part selected Therefore, 130 responses were given for this study Pain levels for body part discomfort could be coded on a scale from 1 to 10 No pain score was above 8 The total pain score reports for this study are the following 1 (19), 2 (25), 3 (51), 4 (23), 5 (7), 6 (4), 7 (0), and 8 (1)

For time of day, there was no significant change in pain responses When pain scores were compared by category between the first and third survey, there was a decrease in pain reporting for pain levels 1, 3, 4, 8, an increase in categories 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 responses 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 two categories 4 and 6, and no changes for level 8 None of the changes in pain level reporting by survey were significant

Table 8 summarizes the results of the DAS

Table 8 Summary of Discomfort Assessment System Survey

Examined by time of day and survey

- 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

Symptom Reporting

- 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

Pain Level Reports

- 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, increased in pain levels 2, 5, and no change in pain level 6 The changes in pain level reporting were not significant

METABOLIC MEASURES

Average, Minimum, and Maximum Heart Rate Values

Table 9 shows the heart rate data collected on the deliverymen at the beginning and end of the study Average heart rate at the beginning of the study ranged from 93 6 to 113 8 beats per minute (bpm) The average heart rate at the end of the study, when ergonomic controls were in place, ranged from 93 1 to 114 9 bpm The average heart rate for the 9 workers at the beginning of the study was 104 ($\pm$ 8 4) and at the end was 99 9 ($\pm$ 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) beats per minute At the end the minimum range was 49 to 78 with an overall average of 66 (+ 9 9) beats per minute 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 Paired Student t-tests for before and after differences were significant ($p <$ 05) The difference in cardiovascular demands may be attributable to a number of factors, including ergonomic interventions Whether this decrease is attributable to the interventions alone is doubtful

Table 9 Heart Rate[1] Results for Beverage Deliverymen at the Beginning and End of the Field Study

	Average Heart Rate		Minimum Heart Rate		Peak Heart Rate		Standard Deviation	
Subject[2]	B[3]	E[4]	B	E	B	E	B	E
1	93.6	93.8	62	61	152	157	14.6	17.1
2	99.9	98.5	66	75	147	133	11.7	11.1
3	108.6	100.9	71	65	152	152	16.6	17.1
4	94.6	96.2	58	55	149	139	23.2	20.3
5	113.5	112.6	79	76	163	163	16.5	16.2
6	113.8	114.9	71	71	164	149	14.8	13.0
7	98.7	87.8	59	49	137	135	15.1	16.9
9	99.3	93.1	62	64	167	123	15.1	12.2
10	113.7	101.7	77	78	155	144	15.2	12.7
Average	104.0	99.9	67	66	154	144	15.9	15.1
S.D.[5]	8.4	8.9	7.7	9.9	9.5	12.7	3.1	3.0

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 = Before Ergonomic Interventions, beginning of study
4 E = End of study After Ergonomic Interventions
5 Standard deviation (based on values reported in this table)

Age and Heart Rate Values Before and After Ergonomic Interventions

Table 10 shows the workers' ages, maximum heart rate based on age, resting heart rate, heart rate range, and 50 percent of the maximum potential heart rate The maximum potential heart rate (220 - age) range was 162 to 186, with an average maximum value of 178 beats per minute The resting heart rate ranged from 63 to 92, average 77 bpm at the beginning of the study, and ranged from 60 to 87, average 74 at the end of the study

The heart rate range for these deliverymen 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 percent 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 percent of the maximum potential heart rate, and at the end approximately 30 percent of the maximum potential heart rate When the heart rate exceeds 50 percent of the maximum heart rate over an 8-hour day, rest periods should be implemented to reduce fatigue [58] 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

Percentage of maximum heart rate (a measure of cardiovascular demand for work performed) decreased on average at the end of the study versus the beginning when compared with the average and peak heart rate values This decrease is most evident when comparing the actual maximum heart rate values (Table 9) at

Table 10 Maximum, Resting, Range, and 50 Percent Potential Maximum Heart Rate Results for Beverage Deliverymen 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 Max Potential Heart Rate[7] (B)	50% of Max 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 1	178	77	74			127	126
S D [5]	7 8						6 0	6 0

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 = Before Ergonomic Interventions, beginning of study
5 E = End of study After Ergonomic Interventions
6 Heart rate range determined from difference between resting and maximum potential heart rate
7 50 percent of potential maximum heart rate determined from resting heart rate plus 50 percent of the heart rate range

the beginning (87%) versus the end (81%) of the study, and the percent maximum potential heart rate values (Table 10) While the amount of beverage delivered varied from the beginning versus the end of the study, the overall weight of beverage delivered increased slightly at 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 D

Biomechanical

Stop-action analysis of videotapes of the workers delivering beverage product were used for biomechanical analysis Selected work activities for each deliveryman 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 11-16 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 As noted earlier, when the lifting index (LI) exceeds 3, the risk for injury increases substantially Because of the workers' postures and weight of many of the beverage products being removed from the truck, the LI often exceeded 3 (Tables 11-16)

Biomechanical analysis of shoulder strength for a deliveryman lifting a 8-pack, 2-liter beverage case (see Appendix A, Figure A5), showed that 25 percent of the males (Subject #8, weight 239 lbs, height 69 inches), and 0 percent of the females (50 percentile female, weight 137 lbs, height 63 8 inches) were capable of lifting and moving such cases in this posture [55] When the 2-liter case weight was reduced from approximately 40 pounds to 30 pounds (simulating a 2-liter 6-pack case), 65 percent of the males, and 1 percent of the females had the shoulder strength to lift and move such cases When the deliveryman used the pull-out shelf as shown in Appendix Figure A7, 63 percent of the males and 3 percent 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 pounds simulating a 2-liter 6-pack, 84 percent of the males, and 24 percent of the females had the shoulder strength to lift and move such cases Add to this the instability of the 8-pack, 2-liter bottles due to the low height of the cases, and the combination of weight and poor case design makes material handling more difficult and increases the potential for injuries to the shoulders

Table 11 Calculations Using 1991 NIOSH Lifting Formula for Manual Material Handling of Soft Drink Beverages

Job Analysis Worksheet

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

STEP 1 Measure and record task variables

Object Weight (lbs)		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	Freq 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 50 x 93 x 89 x 97 x 75 x 90 = 13 8 lbs

DESTINATION RWL = 51 x 59 x 89 x 89 x 95 x 75 x 90 = 15 5 lbs

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 $= \frac{\text{Object Weight}}{\text{RWL}} = \frac{44\ 0}{15\ 5} = 2\ 8$

Table 12 Calculations Using 1991 NIOSH Lifting Formula for Manual Material Handling of Soft Drink Beverages

Job Analysis Worksheet

Job Description Conventional Beverage Delivery
Risk Factor Evaluated Lifting 39 lbs 2 liter 8-pac soft drink package
(See Figures 10 and 11)
Height of Worker 71 5 functional reach 30

Step 1 Measure and record task variables

Object Weight (lbs)		Hand Location (in) Origin See Figure 10		Destination See Figure 11		Vertical Distance (in)	Asymmetric Angle (degrees) Origin	Destination	Freq 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 x HM x VM x DM x AM x FM x CM

ORIGIN RWL = 51 x 1 0 x 85 x 86 x 1 0 x 75 x 95 = 28 0 lbs

DESTINATION RWL = 51 x 50 x 80 x 86 x 95 x 75 x 95 = 12 0 lbs

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 = $\frac{\text{Object Weight}}{\text{RWL}} = \frac{39\ 0}{12\ 0} = 3\ 2$

Table 13 Calculations Using 1991 NIOSH Lifting Formula for Manual Material Handling of Soft Drink Beverages

Job Analysis Worksheet

Job Description Conventional Beverage Delivery
Risk Factor Evaluated Lifting 49 5 lbs case of 24 20-oz soft drink in glass bottles
(See Figures 12 and 13)
Height of Worker 70", functional reach 31"

Step 1 Measure and record task variables

Object Weight (lbs)		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	Freq 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	60	20	5	45	0	0	6	<1	Fair

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 67 x 85 x 86 x 1 0 x 75 x 1 0 = 18 7 lbs

DESTINATION RWL = 51 x 50 x 81 x 86 x 1 0 x 75 x 95 = 12 7 lbs

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 $= \frac{\text{Object Weight}}{\text{RWL}} = \frac{49\ 5}{12\ 7} = 3\ 9$

Table 14 Calculations Using 1991 NIOSH Lifting Formula for Manual Material Handling of 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
[Note Container weight exceeds NIOSH RWL of 51 lbs]
(See Figures 14 and 15)
Height of Worker 70" functional reach 31"

Step 1 Measure and record task variables

Object Weight (lbs)		Hand Location (in) Origin See Figure 14		Destination See Figure 15		Vertical Distance (in)	Asymmetric Angle (degrees) Origin	Destination	Freq 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 x HM x VM x DM x AM x FM x CM

ORIGIN RWL = 51 x 77 x 85 x 86 x 95 x 75 x 1 0 = 20 4 lbs

DESTINATION RWL = 51 x 50 x 81 x 86 x 1 0 x 75 x 95 = 16 1 lbs

Step 3 Compute the Lifting Index

ORIGIN Lifting index = $\frac{\text{Object Weight}}{\text{RWL}} = \frac{57\ 5}{20\ 4} = 2\ 8$

DESTINATION Lifting index = $\frac{\text{Object Weight}}{\text{RWL}} = \frac{57\ 5}{16\ 1} = 3\ 6$

Table 15 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 lbs Bag in-the-Box Post mix soft drink beverage drink
[Note Container weight exceeds NIOSH RWL of 51 lbs]
(See Figures 16 and 17)
Height of Worker 76 5 , functional reach 32

Step 1 Measure and record task variables

Object Weight (lbs)		Hand Location (in) Origin See Figure 16		Destination See Figure 17		Vertical Distance (in)	Asymmetric Angle (degrees) Origin	Destination	Freq 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 x HM x VM x DM x AM x FM x CM

ORIGIN RWL = 51 x 50 x 89 x 87 x 90 x 75 x 90 = 12 0 lbs

DESTINATION RWL = 51 x 67 x 85 x 87 x 1 0 x 75 x 90 = 17 0 lbs

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 $= \frac{\text{Object Weight}}{\text{RWL}} = \frac{53\ 0}{17\ 0} = 3\ 1$

Table 16 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 lbs]
(See Figures 18 and 19)
Height of Worker 76 5", functional reach 32

Step 1 Measure and record task variables

Object Weight (lbs)		Hand Location (in) Origin See Figure 18		Hand Location (in) Destination See Figure 19		Vertical Distance (in)	Asymmetric Angle (degrees) Origin	Asymmetric Angle (degrees) Destination	Freq 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 x HM x VM x DM x AM x FM x CM

ORIGIN RWL = 51 x 1 0 x 85 x 86 x 95 x 75 x 1 0 = 26 6 lbs

DESTINATION RWL = 51 x 67 x 78 x 86 x 95 x 75 x 1 0 = 16 3 lbs

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 8 Deliveryman Lifting Two 12-oz 24-can Cases of Soft Drink Beverage (total weight 44 pounds) from Truck

Figure 9 Deliveryman Placing Two 12-oz 24-can Cases of Soft Drink Beverage (39 pounds) from Truck

Figure 10   Deliveryman Lifting 2-liter 8-pack Soft Drink Beverage from Truck

Figure 11 Deliveryman Placing 2-liter 8-pack Soft Drink Beverage on Handtruck

Figure 12 Deliveryman Lifting 20-oz 24-pack Glass Bottled Soft Drink (49.5 pounds) Beverage from Truck

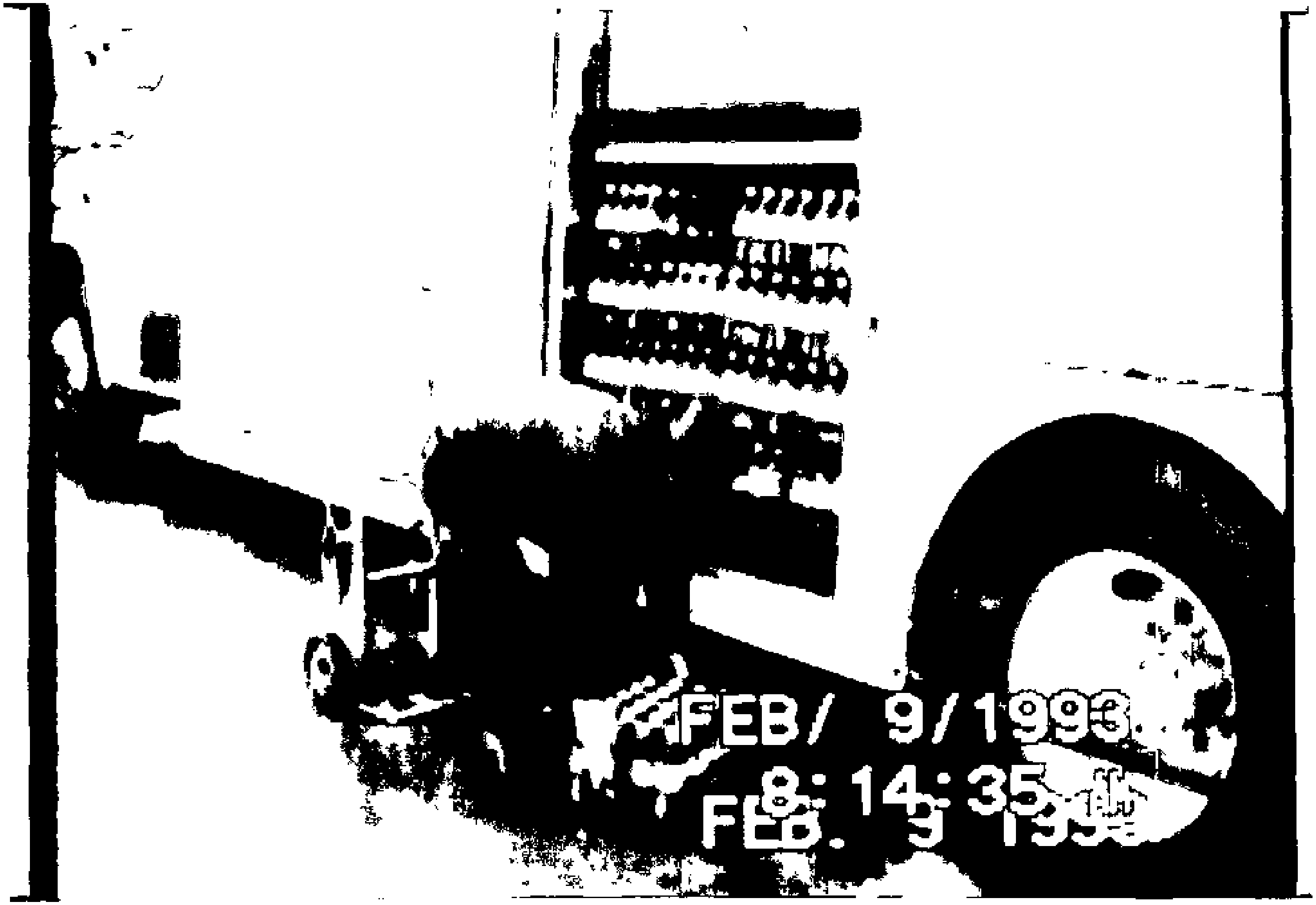

Figure 13 Deliveryman Placing 20-oz 24-pack Glass Bottled Soft Drink Beverage on Ground

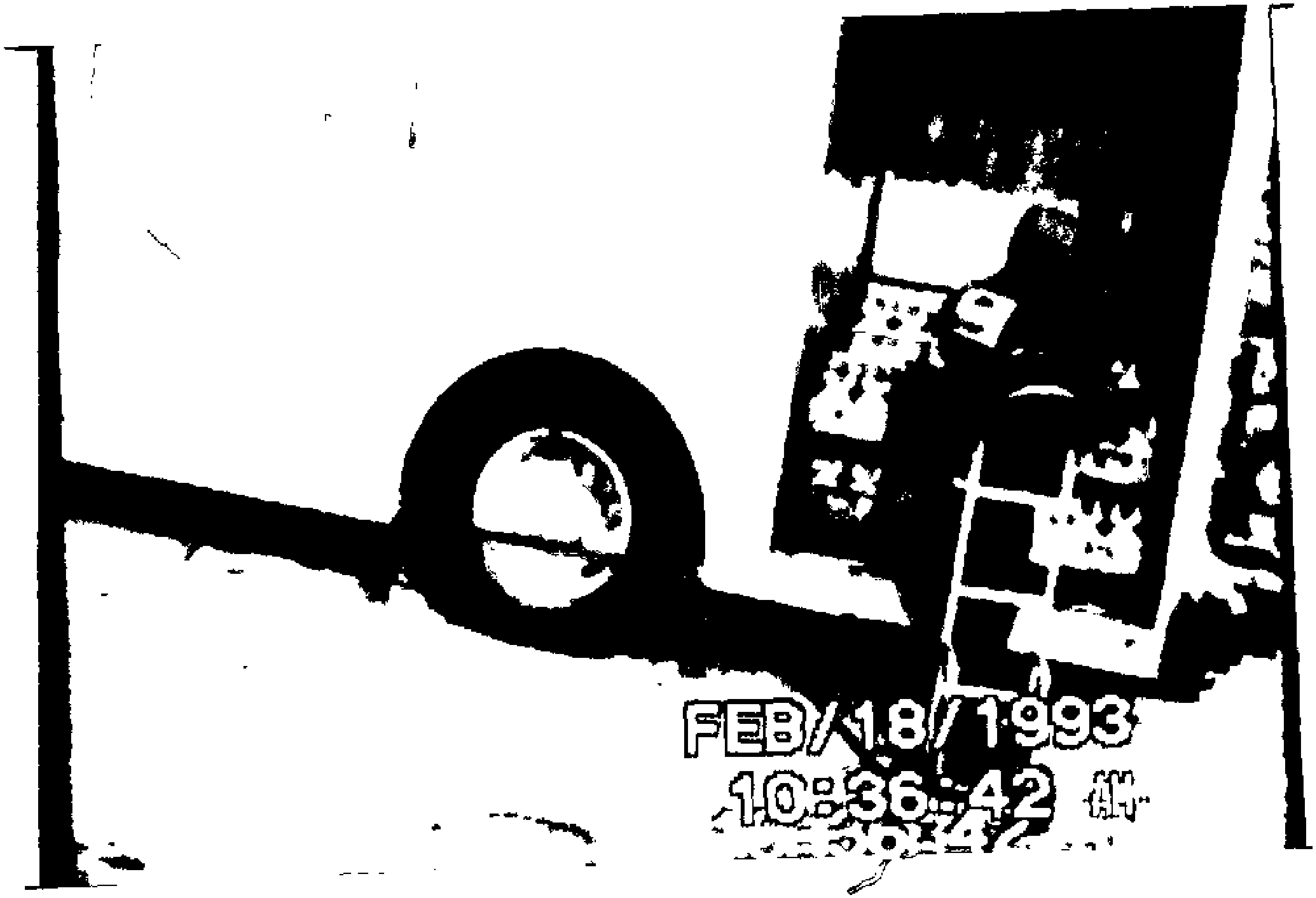

Figure 14 Deliveryman Lifting 16-oz 24-pack Glass Bottled Soft Drink Beverage (57.5 pounds) from Truck

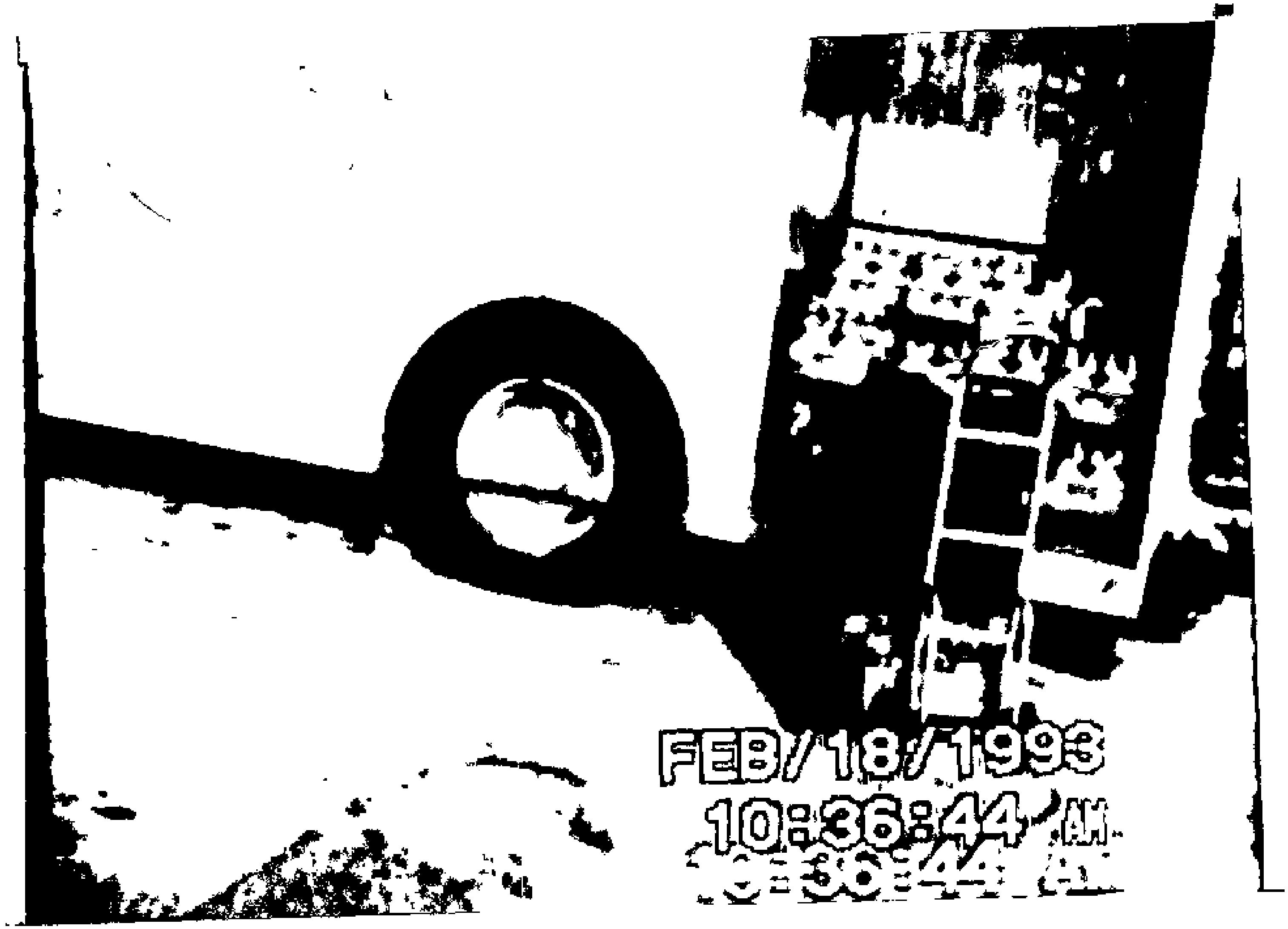

Figure 15 Deliveryman Placing 16-oz 24-pack Glass Bottled Soft Drink Beverage on Handtruck

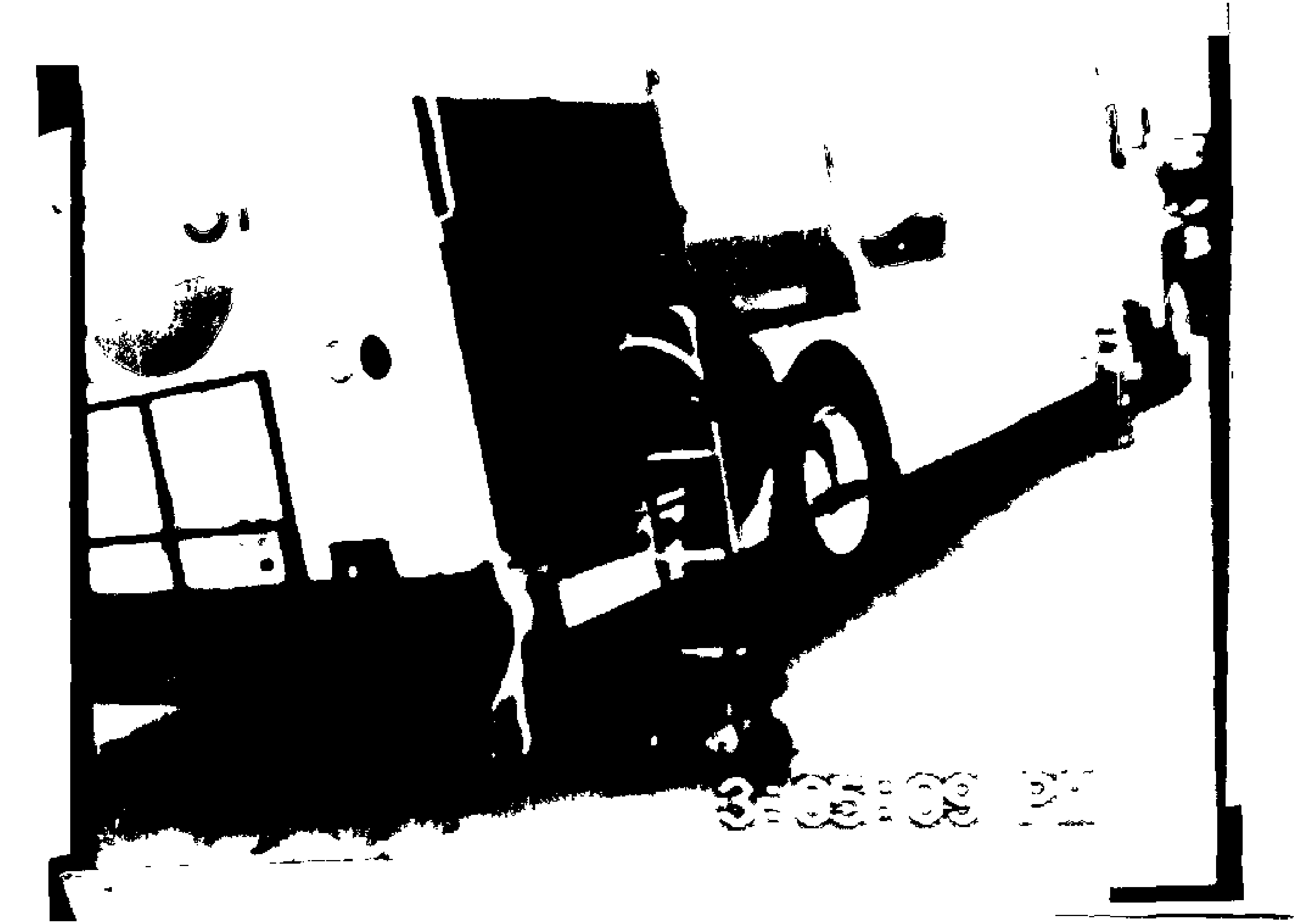

Figure 16 Deliveryman Lifting Bag-in-the-Box (BIB) Beverage Syrup (53 pounds) from Truck

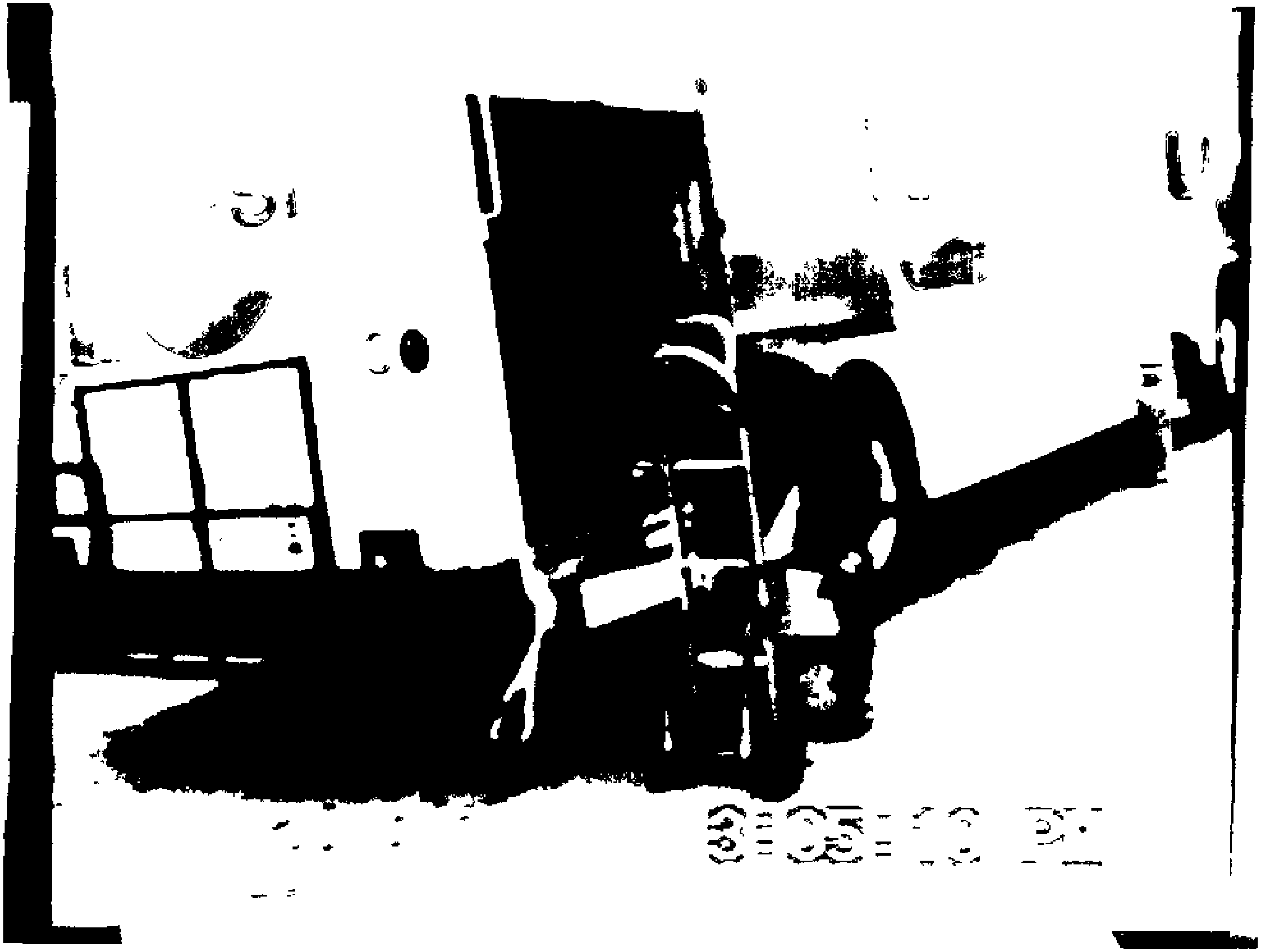

Figure 17 Deliveryman Lifting Bag-in-the-Box (BIB) Beverage Syrup (53 pounds) from Truck

Figure 18 Deliveryman Lifting Aluminum Cylinder Containing Pre-mix Soft Drink Beverage (34 5 pounds) from Truck

Figure 19   Deliveryman Placing Aluminum Cylinder Containing Pre-mix Soft Drink Beverage (54 5 pounds) on Ground

Hand Grip

Table 17 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, compared to the beginning On average, grip strength increased at the end of the day, compared to the beginning 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 worker 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) lbs, and for the right hand 106 (+ 29) lbs At the end of the day the grip strength

Table 17 Hand Grip Strength -- Beginning and End of Workday

	Begin Left	Begin Right	End Left	End Right
Average (lbs)	103	106	107	112
Std Dev	23	29	29	29
Maximum	150	151	174	166
Minimum	70	65	73	74

Not Statistically Significant Comparing Beginning with End Grip Strength Table for the left hand was 107 (+29), and for the right hand 112 (+29) lbs The range of grip strength was 65 lbs for the right hand at the beginning of the day to 174 lbs for the left hand at the end of the day

MATERIAL HANDLING

Beverage Material Loaded and Delivered

Table 18 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 in cases loaded was from 345 to 681, the range of cases sold was 162 to 381 This represented a range of 47 to 74 percent of the beverages loaded on the trucks sold to customers The tank

and bag-in-the-box route data is also shown in Table 18 A similar pattern is seen for this deliveryman where an excess amount of beverage 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

Table 19 shows the **minimum** (handled twice -- remove beverage packages from truck and load on handtruck, 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 handtruck on loading dock, moving beverage

Table 18 Truck Inventory Beverages Loaded, Sold

Does Not Include Bag-in-Box / Tank Route	
Avg # Cases Loaded	517 (s d 94)
Avg # Cases Sold	332 (s d 116)
Maximum # Cases Loaded	681
Maximum # Cases Sold	581
Minimum # Cases Loaded	345
Minimum # Cases Sold	162
Bag-in-Box (BIB) and Tank route	
Avg number of 5-gal pre-mix tanks delivered	72
Avg number of 5-gal post-mix tanks delivered	35
Avg number of 5-gal Bag-in-the-box delivered	325
Avg 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

Table 19 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

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 multiplied by two This equation accounts for removing the beverage from the delivery truck, loading it on the handtruck, transporting it the store, and unloading it from the handtruck 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 that 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

As shown in Table 19 the minimum weight handled at the beginning of the study averaged 23,815 (± 7,253) lbs per worker, probable weight handled was 35,722 (± 10,880) lbs, and the maximum weight handled 47,629 (± 14,505) lbs The average amount of product handled in the middle of the study (at the beginning of ergonomic interventions) was 20,436 (± 5,926) lbs, 30,655 (± 8,888) lbs, and 40,873 (± 11,851) lbs, respectively At the end of the study after the deliverymen adjusted to controls, the minimum weight handled averaged 24,005 (± 6,512) lbs per worker, probable weight handled was 36,008 (± 9,767) lbs, and maximum weight was 48,010 (± 13,023) lbs 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 from the beginning, middle, and end 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 The overall average for the three surveys are the following minimum 24,630 (± 11,056), probable 33,826 (± 10,333), and maximum 43,617 (± 12,223) lbs

Beverage and Type of Load

Table 20 shows the number of cases delivered per day, and may not be a good indicator of the deliveryman's work load For example, the first survey load comparisons between two deliverymen (Subject 4 versus Subject 10) showed nearly equal total weights for beverages sold (26,202 lbs versus 26,870 lbs) during a routine delivery day But the difference in cases sold was significant 306 versus 451 Subject 10 sold many more cases of the 12-oz, 24-case can beverages (which average 22 lbs each), compared to Subject 4 who sold less canned soft drinks, but substantially more 20-oz nonreturnable (49 9 lbs) and 16-oz returnable (57 5 lbs) packages of 24 glass bottles Another example is shown in the second survey when Subject 3 sold 400 cases (23,330 lbs), versus Subject 4 who sold 218 cases (21,023 lbs) Subject 4 sold more 16-oz returnable, and 20-oz nonreturnable glass bottles, and 2-liter plastic

Table 20 Beverage Cases and Loads Handled Comparing Deliverymen

Beverage Package (Cases & Weight in lbs)		First Survey		Second Survey		Third Survey	
		Subj 4	Subj 10	Subj 3	Subj 4	Subj 4	Subj 7
10-oz bottles	(23)	0	0	0	0	4	0
12 oz cans	(22)	77	299	342	15	40	175
1 liter glass	(45)	4	0	0	2	0	0
16 oz Returnable glass	(57 5)	67	11	0	55	59	0
16-oz Sportdrink 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-liter plastic	(39)	85	94	30	74	99	88
TOTAL CASES		306	451	400	218	308	312
TOTAL WEIGHT = PRODUCT WT x 3		39,303	40 303	30 495	31 535	41 415	29,429

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 versus 312), however, the weights are significantly different (41,415 versus 29,429 lbs, respectively), a difference of nearly 12,000 lbs 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 21 summarizes the evaluation of safety and ergonomic interventions for the four beverage delivery trucks. Each truck had 21 modifications, designed to make beverage delivery safer and reduce 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.

The 21 engineering changes to each truck were a mix of ergonomic and safety features. The ergonomic features were (1) cush-in-air® ride seats, (2) exterior grab handles, (3) 3-position drop shelves, (4) handgrips on the inside of the single sheet divider, (5) wider step platform on the wheel housing, (6) extra-wide recessed steps front and rear, (7) anti-slip strips on the bottom rail and step holes, (8) pullout step rear bays, (9) larger handtruck holder and high back rest for 2 handtrucks, (10) new rollers in all bay door slats and lubrication of doors, and (11) new door straps to open and close bay doors. The safety features included (1) 5-in spot mirror on right and left doors, (2) 5-in spot mirrors mounted on right side of hood, (3) heated mirror on driver's side, (4) heated/motorized mirror passenger

Table 21 Beverage Truck Ergonomic Intervention Results

MIDDLE VERSUS END	SCORES[1]		COMMENTS
Safety/Ergonomic Retrofits for Beverage Trucks	Begin	End	
5"-spot mirror on right & left door	1 44	1 22	missing right spot mirror
5"-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
cush-n-aire driver seat	1 0	1 0	stiff
3-point seat belt	1 0	1 0	
exterior grab handles all bays	1 0	1 1111 1	missing grab handle
3-position drop shelf holes/all deep bays	1 221 0	1	some not in
install handgrips in single sheet divider		1 0	only applied to one truck
wider step platform on wheel housing step bar	1 0	1 0	
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 skid rest grit
pull-out step rear bays	1 11	1 0	pullout rear bay
motion back up alarms with guards	1 0	1 22	faulty back-up alarm
large handtruck holder and high back rest for 2 handtrucks	1 0	1 0	
raise stop/tail lights and back up lights to hood level	1 0	1 0	
recess license place brackets	1 0	1 0	
new rollers in all bay door slats and lubricated doors	1 22	1 0	all lubed but, some stick
new door straps	1 33	1 11	bay door straps replaced
new "caution wide right turn" sign	1 0	1 0	

7 interventions improved from initial to final evaluation, 2 got worse, 12 stayed the same

1 Scores calculated from number of yes=1, versus no=2 for safety/ergonomic retrofit changes for the four trucks from the beginning (i e , retrofits first installed), versus end of the NIOSH study 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 in End score compared to Begin score shows deterioration of retrofit changes

side, (5) 3-point seat belt, (6) bay liners all bays, (7) motion back-up alarms with guards, (8) raise stop tail lights and back-up lights raised to hood level, (9) recess license plate brackets, and (10) new "caution wide right turn" sign

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 12 show that 12 of 21 modifications to each truck were done without any problems. Safety retrofits that were not done or needed fixing were the spot mirrors on the right and left door and heated/motorized mirror on passenger side. Ergonomic retrofit problems were absence of some 3-position drop shelf holes in the deep bays, extra wide recessed steps on front and rear areas of wheels to access high bays, 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, and missing door straps to open and close bay doors. At the end of the study several of these problems were fixed. For safety retrofit, most of the spot mirrors on the right and left doors and most motorized mirrors were in place. Ergonomic retrofits included bays fitted with 3-position drop shelves, anti-slip surfacing in bays and improved step holes, more installed pullout steps on rear bays, lubricated doors and fixed rollers, and installed bay door straps. When maintenance of retrofit was compared with the beginning and end of the intervention phase of this study, only two retrofits deteriorated over time a missing external grab handle on one of the trucks (caused by a fork lift truck hitting it), and the back-up alarm system Video pictures in Appendix D show the various ergonomic retrofit controls used by the driver-deliverymen in this study

Bay Door Forces for Opening and Closing

Table 22 shows the differing forces needed to lift and lower the bay doors at the beginning, middle, and end of the study There was a significant reduction in the amount of force needed to lift and lower the bay doors from the beginning of the study versus the end There was not a significant reduction in the amount of force needed to lift and lower the doors after the intervention study began and at the end of the study On average, there was a 7 8 (+ 1 1) lb decrease in the amount of force needed to lift and lower the bay doors at the end of the study compared to the beginning

Handtrucks

Table 23 shows the results of tire pressure on the handtrucks at the beginning and end of the study In general, the tires were under pressure, and not evenly pressurized During the intervention study, tire measurements were made with a small tire pressure gauge, and then the tires were inflated from 28 to 32 lbs with a tire pump When pressurized, the tires usually maintained

Table 22 Bay Door Force, Before, During, and After Ergonomic Interventions
(Bay Door Force (lbs)

	Up Left (Driver Side) lbs & (s d)	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)

t-statistic Significant reduction in up and down bay door forces for left and right sides between first and third surveys
Nonsignificant reduction in up and down bay doors forces for left and right sides between second and third surveys

Table 23 Tire Pressure From Handtrucks
Tire Pressure (lbs)

	2-Wheel Balloon		4-Wheel Balloon	
	Left	Right	Left	Right
Begin	21	20	26	20
End	28	28	31	32

their pressure over the study period Other findings about the type of handtruck used by the deliverymen are summarized below

2-wheel hard tire handtruck only used by 3 out of 9 deliverymen,

2-wheel hard tire and 4-wheel balloon tire handtrucks used by 5 out of 9 deliverymen,

2-wheel balloon and 4-wheel balloon tire handtruck used by 1 out of 9

DISCUSSION

The goal of this study was to apply ergonomic controls and measure their effectiveness in reducing musculoskeletal injuries through psychophysical, physiological, and biomechanical methods Ten deliverymen participated in this study One of the ten injured his back after the initial survey, leaving nine participants to evaluate once ergonomic interventions were implemented The average deliveryman participating in this study was 42 years old, weighed 210 lbs, was 6 feet tall, and had a 30 5 inch arm reach He worked for the company for 20 years, nearly all of it as deliveryman Back injuries were his most common job-related injury The average time off over his career was 3 months for musculoskeletal injuries At the beginning of this study, NIOSH researchers requested 9 healthy volunteers who were experienced as deliverymen The company pledged their support and offered their best deliverymen the opportunity to participate in this study As the results have shown, the participants are unique and highly qualified professionals performing their job Much was learned from their experience and suggestions to reduce job-related injuries in the performance of beverage delivery

As reported in the introduction, this industry ranks among the highest in the nation with injury and illness rates, especially for lost workdays per 100 employees The majority of these injuries and illnesses occur among drivers-salesworkers The injuries, location of injuries, and risk factors for these injuries reported by the participants in this study were similar to those reported in the Supplementary Data System (SDS) database noted earlier in this report The association between the SDS literature about possible risk factors for injuries and illnesses in this industry and what risk factors were documented through the NIOSH study was in close agreement The following is a brief summary of the findings from this study

DISCOMFORT ASSESSMENT SYSTEM

The computerized instrument was very useful in documenting body location, symptom and pain level of the participants at the beginning, middle, and end of the study As shown in Table 7, the frequency of discomfort reporting 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 results in increased reporting of injuries among workers Then after workers adjust to the controls, discomfort reporting decreases [18]

The low back was most frequently indicated for discomfort by the deliverymen, followed by the back right shoulder, left elbow, and knees While discomfort reporting decreased by 50 percent between the first and third survey for the low back, the decrease was not significant, small sample size was the problem However, shoulders and elbow reporting did decrease significantly The reasons for this may be attributed to some of the ergonomic interventions, such as the external handles, pullout shelves, adjustable height shelves, and heavier load beverage cases on lower shelves for easier access with less lifting This economic retrofit could have reduced the overall stress for the shoulders and arms There was no significant decrease in reporting for the knees Most deliverymen said the knee problems were aggravated by climbing in and out of the truck to access the printer for each sales transaction No changes occurred regarding the printer and, therefore, the problem did not go away

There was no significant change in the level of pain between the first and third surveys The majority of responses for pain were 4 and below on a scale of 1 to 10 Because the pain levels were generally low, it is not surprising that the overall difference was not significant

METABOLIC MEASURES

The average heart rate decreased from 104 to 99 9 beats per minute (bpm) from the beginning versus the end of the study, despite a slight increase in the average load handled by the participants The decrease in heart rate was not significant Resting heart rate at the beginning and end of the study was about the same 67 versus 66, respectively However, the peak heart rate range for the deliverymen was noticeably less, from 154 to 144 bpm Changes in heart rate were significant for the beginning versus end when paired for each individual This difference may be attributable to several factors, including the ergonomic interventions on the truck and use of well-maintained handtrucks

Fifty percent of the maximum predicted heart rate is cited in the literature as a bench mark for determining weather rest breaks should be taken from a job over an 8-hour day Data from this study show that the average heart rate was approximately 32 and 30 percent of the maximum predicted heart rate, at the beginning and end of the study, respectively These data do not suggest that the deliverymen do not need a rest during their delivery schedule The data do suggest that because of their experience they know how to pace themselves, and if more time is needed to perform deliveries during that day, then they have the option to do so Also, it should be recognized that the heart rate data were taken in the winter and early spring when the volume of beverage delivery is low, compared to late spring, summer, and early fall During the warm seasons, the temperature and increased load may exceed the 50 percent of the predicted maximum heart rate values These deliverymen are aware of this fact and drink plenty of water Self-pacing allows rest breaks when needed to reduce fatigue and the potential for injuries Deliverymen without as much experience may not be aware of the need to replenish body fluids or have the experience to pace themselves For the inexperienced workers, rest breaks should be encouraged and education that fluid replacement will reduce fatigue and injuries should be given

BIOMECHANICAL ANALYSIS OF VIDEOTAPES

When the NIOSH equation was compared to the beverage package weights evaluated in this study they were arbitrarily divided into 3 categories those packages above the 51 lbs limit (category 1), those packages less than 51 lbs, but 39 lbs and above (category 2), and packages less than 39 lbs

Packages in category 1 were pre-mix tanks (53 5 lbs), post-mix tanks (57 lbs), bag-in-the-box (53 lbs), 16-oz returnable (57 5 lbs), and wood pallets (55 lbs) Those packages exceeded the ideal load, and according to the NIOSH guidelines should be handled using mechanical aids As shown in Table 16, Figures 18 and 19, when the task-related factors were computed, the ideal weight was adjusted down to 26 6 lbs at the beginning of the lift, and 16 3 lbs at the end of the lift The LI, a ratio of the product weight divided by the NIOSH RWL shows an LI of 2 0 at the beginning of the lift, and 3 3 at the end However, if the pullout step is used, analysis of this same task shows that the ideal weight is 27 2 lbs at the beginning, and 31 6 lbs at the end (Table 24, Figure 20 and 21) The LI does not change at the beginning, but decreases substantially to 1 7 at the end This is because the deliveryman does not have to reach as far to set the tank down Another example is the bag-in-the-box (BIB) material handling The BIB weighs 53 lbs, (Table 15, 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 lifting index was higher at the beginning of the lift than at the end The decreased LI results from the worker twisting and reaching for the BIB at the beginning, and releasing the load approximately 8" above the handtruck at the end Analysis of material handling for the other packages (wooden pallets) in category 1 show similar results on risk for back injury Even though wooden pallets are not handled often, their weight (55 lbs) and awkward size (approximately 40 x 40 x 5 in) mean that they should 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 would be reducing the 5-gallon BIB to a 3-gallon BIB The smaller and lighter BIB would reduce risk for the deliveryman, as well as for the customer who may need to change the BIB when empty The BIB now comes in a 3-gallon package which weighs approximately 32 lbs Using the example given in Table 15,

Table 24 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 lbs aluminum tanks containing pre mix soft drink
(See Figures 20 and 21)
Height of Worker 76 5", functional reach 32"

Step 1 Measure and record task variables

Object Weight (lbs)		Hand Location (in) Origin See Figure 20		Destination See Figure 21		Vertical Distance (in)	Asymmetric Angle (degrees) Origin	Destination	Freq Rate lifts/min	Duration Hours	Object Coupling
L(avg)	L(Max)	H	V	H	V	D	A	A	FM		CM
53 5	53 5	1 0	85	1 0	94	88	95	1 0	75	<1	Good

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 1 0 x 85 x 88 x 95 x 75 x 1 0 = 27 2 lbs

DESTINATION
RWL = 51 x 1 0 x 94 x 88 x 1 0 x 75 x 1 0 = 31 6 lbs

Step 3 Compute the Lifting Index

ORIGIN
Lifting index = Object Weight / RWL = 53 5 / 26 6 = 2 0

DESTINATION
Lifting index = Object Weight / RWL = 53 5 / 16 3 = 3 3

Figure 20 Deliveryman Lifting Aluminum Cylinder Containing Pre-mix Soft Drink Beverage (54 5 pounds) from Truck While Standing on Pull-Out Platform

Figure 21 Deliveryman Placing Aluminum Cylinder Containing Pre-mix Soft Drink Beverage (54 5 pounds) on Pull-Out Platform

Figures 16 and 17, the LI changes to 2.7 (from 4.4) at the beginning of the lift and 1.9 (from 3.1) at the end. 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 lbs) included 20-oz glass bottles (package of 24 was 49.5 lbs), 1-liter glass (package of 15 was 45 lbs), 2-liter plastic 8-pack (39 lbs), and 16-oz glass (package of 24 was 39 lbs). While these beverage packages are less than the NIOSH ideal weight of 51 lbs, risk for back injury can be high depending on the worker's posture when handling these packages. For example, Table 13, Figures 12 and 13, show that the weight should be 18.7 lbs and 12.7 lbs at the beginning versus the end of the lift. The LI is 2.6 and 3.9, respectively. However, if the weight of the package were made lighter by substituting plastic containers for glass, then the weight would be reduced from 49.5 lbs to 37 lbs. 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 is a substantial reduction when repetitive lifting of a popular package is multiplied over time. For example, if the deliveryman 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 versus 9,900 lbs, and per week 37,000 versus 49,500 lbs. A difference of 12,500 lbs/week is substantial, even if the number of cases sold were cut in half to 6,300 lbs/week, the reduction is still impressive. Putting beverage into plastic containers also benefits the warehouse worker who loads and unloads the beverage on the trucks.

The 2-liter, 8-pack package used during this study is poorly designed. The package is heavy (39 lbs) and is awkward to handle. The instability of the 2-liter containers in the plastic shell makes handling awkward and more stressful to the deliverymen. The plastic shell is long (18 in) and narrow (8 in) relative to its height (5 in). At the base of each end of the shell, there are two openings (4 in wide x 1 in high x 1 in deep) which serve as handles. Approximately 25 percent (4 in) of the bottom half of the 2-liter containers fit into the base of the plastic shell. The bottom of the shell has ribbed circular rings which are concave to fit over the tops of the 2-liter bottles when stacked on top of each other. This design helps to hold the packages in place during delivery from the beverage plant to the customer. However, the design also makes it hard for the deliverymen to remove the packages from the truck because they have to lift and pull each package forward. This strain, which could result in injury, causes repeated stress to the worker's shoulders. Figures 10 and 11 show a deliveryman removing this package from a truck. Two options for reducing musculoskeletal stress to the shoulders and back are suggested for this package (see biomechanical analysis results presented earlier). The first is 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 lbs, and also make the package more stable during manual handling. The other option is to redesign the plastic shell by making the 2-liter pods deeper, smoothing ribs on the underside of the shell, and improving the handles by making them deeper and wider. This should 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 15 1-liter beverage, are not handled in enough volume to be of concern

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

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 11, 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 deliveryman's posture and the absence of handles This worker was handling 2 cases at a time for this analysis which put him at a LI of 3 2 at the beginning of the lift, and 2 8 at the end of the lift However, when the packages are handled one at a time, the LI is reduced to 1 6 and 1 4, respectively This change reduces the risk of back injury significantly Therefore, deliverymen 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 lbs), and 15-oz glass sport drinks, empty cylinders, cups and lids, are either light enough not to be a priority for controls or are 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 against the worker's head

MATERIAL HANDLING

On average 75 percent of the beverages loaded on the trucks were sold during the NIOSH study This figure means that 25 percent of the load that left the plant was carried around from one establishment to another, moved about by the deliverymen to access other beverage packages, and brought back to the plant on a daily basis Such an inefficiant 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 deliveryman The deliverymen say management wants the beverages available for customers, and to "push" new products that are brought on line, such as the new line of iced tea drinks introduced during this study Management says that the deliverymen may take more than needed of a product because they want to have it available should the need 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 deliveryman, as well as the warehouse worker

BEVERAGE MATERIAL HANDLED

As shown in Table 19, an average of 34,000 lbs (assuming each case was handled 3 times) of beverage was handled on a daily basis by the deliverymen for conventional delivery in the city during this study. Accounting for the variability in material handling, a standard deviation of 10,000 pounds, the amount of beverage handled ranged from as little as 24,000 lbs to as much as 44,000 lbs. This is remarkable in that the study was done in the winter when soft drink beverage sales are relatively slow. In the summer, especially before holidays, delivery of soft drink beverages may commonly exceed 500 cases per day per deliveryman. Therefore, the estimates of load handled during this study may be conservative. For example, one deliveryman 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 the deliverymen took two weeks off for vacation per year). 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, then the estimate for the average beverage weight handled during the period of this study was approximately 60 percent of the peak work load that may be seen in the summer. This means that approximately 56,000 lbs of beverage is handled, on average, by these deliverymen during the summer.

BEVERAGE AND TYPE OF LOAD

As shown in Table 20 the number of cases delivered per day is not a good indicator of the deliverymens' work load. The three examples shown in this table show that neither the number of cases sold, nor total weight handled are good indicators to determine musculoskeletal stress When determining weight handled for deliverymen, 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-liter 8-pack, and the 16-oz glass returnable, add to the stress and strain on the deliverymen The cumulative trauma from repeated exposure to the musculoskeletal system can result in costly injuries to the deliverymen and the company

ERGONOMIC INTERVENTIONS

In evaluating the ergonomic controls over the intervention period, the only one that deteriorated was the external grab handles (a missing external grab handle which was hit, bent, and broken loose by a fork lift truck) The only safety control that deteriorated was the back-up motion alarm system The deliverymen did not know what the audible signals meant They received no training on these devices Other problems, such as dirt getting into the electronic eye of the motion detector in the rear of the truck, also caused problems with the audible signal Over time, the deliverymen ignored the signal and relied on visual cues when backing up

There were seven improvements over the intervention phase of the study, including five ergonomic features (1) 3-position drop shelf holes, (2) anti-slip strips installed on bottom rail and step holes, (3) pullout step in rear bays, (4) new rollers in all bay doors and doors lubricated, and (5) new door straps The two safety features included 5-in spot mirrors on right and left door, and heated/motorized mirror on the passenger side

As for the ergonomic interventions, the deliverymen who participated in the study liked all of the ergonomic features, especially the cush-in-air ride seats, exterior grab handles, 3-position drop shelves, anti-slip strips, the extra wide recessed steps front and rear of wheels, and wider step platform, new rollers and 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 deliverymen 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 deliverymen This feature reduced the musculoskeletal stress to the shoulders and backs Taller deliverymen 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 handtruck Another concern was that the deliverymen would sometimes forget to slide the platform back in its pocket in the bay and other deliverymen 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 deliverymen suggested that the platforms might be better used in the center of the trucks since this is where the truck tends to be higher, and the position might 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 deliverymen include the 5-in spot mirrors, and the heated/motorized mirror on the passenger side All deliverymen 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 deliverymen 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 of the truck was to replace rollers and lubricate the bay doors to make the doors easier to open and close Over a delivery day, it would reduce stress and strain 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 because they are hard to open and close, and when done repeatedly over the workday can be very stressful As shown in Table 22, bay door forces for the driver and passenger side decreased an average of 20 percent from the beginning to the end of the study Average forces for lifting the bay doors decreased by 17 percent (48 6 lbs versus 40 4 lbs), and lowering the bay doors decreased by 24 percent (30 7 lbs versus 23 3 lbs) The decrease in forces needed to raise and lower the bay doors was significant over the day since the doors are opened and closed 100 to 150 times Therefore, it is important that doors be repaired immediately when damaged by fork lift trucks, and they must be lubricated on a regular basis See figures and comments presented in Appendix D for more details on musculoskeletal stress during beverage handling and ergonomic controls

HANDTRUCKS

Handtrucks are indispensable when delivering beverages from the truck to the customer Beverage loads for a 2-wheel handtruck can range from 240 lbs (11 cases of 24-can 12-oz beverage) to over 350 lbs (6 cases of 16-oz returnable) Beverage loads for a portable 4-wheel handtruck can range from 585 lbs (15 2-liter 8-packs) to over 700 lbs (12 cases 16-oz returnable) When loads are pushed up hill or up ramps, or pulled up steps, the musculoskeletal stress can be significant Add to this a poorly maintained handtruck and the difference in stress is much greater For example, when loads on handtrucks with balloon tires are pulled or pushed two problems emerge Tires can be under-pressurized or flat and/or not evenly pressurized Intuitively, it is easy to reason that more force is required to push a loaded handtruck when the tires have low pressure Similarly, it is easy to reason that when handtruck tires are unevenly pressurized the arms, back, and legs have to compensate by moving the load in a straight line Under-pressurized and unevenly pressurized tires will add another 100 to 200 lbs of compressive force to the back during beverage delivery It also can create a safety hazard in that the beverage load is less stable and may fall off the handtruck when corners are turned or stops are sudden Some deliverymen prefer hard rubber tires because they do not have the problems associated with balloon tires, and handtrucks are easier to maneuver in the store 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 handtrucks Handtrucks with balloon tires are better suited for such terrain Based on this study, the deliverymen should have a minimum of two handtrucks, a 2-wheel handtruck and a 4-wheel handtruck The deliverymen should have the option of hard wheels or balloon tires for the 2-wheel handtruck, and balloon tires for the 4-wheel handtruck The installation of dual handtruck holders on the back of the truck makes this possible Maintenance of the handtrucks is important since they are indispensable to the deliverymen 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 handtruck holders should be wide enough to easily slip the foot of the handtruck in and out During this study, one of the retrofitted trucks had a narrow opening in one of the holders and the deliveryman had to force the handtruck in and out of the opening

ONE-YEAR FOLLOW-UP

On March 8, 1994, NIOSH researchers did a one-year follow-up to this plant to observe engineering changes to the delivery truck resulting from the NIOSH study Because of the ever-increasing line of products and packages (24 new products introduced since last year to an existing line of over 200 products and packages), this plant is changing over to 14 bay tractor-trailer trucks and getting rid of the 10 bay 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 to the tractor included an upgrade to the cush-n-air ride 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 feet 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 handtruck holder and high back rest for 2 handtrucks, new rollers and lubrication of doors, insulated bay doors and heaters mounted in bays to keep product from freezing during the winter, and 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

Safety features included the 5-in spot mirrors on right and left side, heated and motorized mirrors passenger side, 3-point seat belts, bay liners, trailer heaters, raised taillight package, and reflective safety tape around the rails of the trailer Figures 22 and 23 show the 14 bay trailer and detail some of the ergonomic and safety features mentioned above

Another aspect of safety was the concern for robbery of deliverymen During the NIOSH research project on ergonomic interventions in the softdrink beverage delivery industry, it was noted that the routemen 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 in the fleet in Dayton, Ohio, have safes, all of the drivers that are in the research study carry cash from these transactions on their person The routemen are instructed to hand over the money if robbed While robbery has not been a major problem for routemen 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 Recommendation section of this report

While more beverage products and packages were introduced since last year, some packages were eliminated or redesigned The 16-oz returnable bottles were eliminated This was the heaviest of all soft drink packages at 57 5 lbs per case and should have significantly reduced the musculoskeletal stress for

Figure 22 Truck of the Future Fourteen Bay Beverage Delivery Truck with Ergonomic Controls Installed [This Type of Truck Will Eventually Replace the 10 Bay Delivery Truck]

Figure 23 Multiple, adjustable height drop shelves installed to reduce beverage crate handling

deliverymen The 20-oz glass bottles have been replaced by 20-oz plastic bottles As mentioned earlier, this replacement is a significant reduction in weight per case from 49 5 lbs to 37 lbs 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-gallon bag-in-the-box was also introduced in the last year The two main advantages of this package over the 5-gallon BIB are size (approximately 2 in width, height, and length), and weight (approximately 32 lbs versus 53 lbs) 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 may have to occasionally change the BIB when empty Many establishments do not have their personnel trained or may not have the strength requirements to change the 5-gallon BIB without risk of back injury The 3-gallon BIB is favored over the 5-gallon BIB for these reasons Finally, NIOSH researchers saw a redesigned plastic shell for the 8-pack 2-liter beverage package The new shell features raised "towers" on the corners and in the center to stabilize the 2-liter 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 significantly reduce many of the musculoskeletal concerns addressed during this study

Other suggestions to decrease beverage material and preserve the health of the deliverymen include standardizing the beverage load so that lifting the packages becomes easier for the beverage loaders and deliverymen Standardization of delivery loads may reduce some of the excess handling of product, but may cause some problems when introducing new product lines, or addressing the changing needs of the consumer as seasons change, or promoting sales of certain products Standardization of beverage loads needs to be carefully thought out and should include input from the deliverymen and beverage loaders

Currently, there are few job advancement opportunities for the beverage deliveryman without going into management The participants in this study had an average of 20 years' experience in delivering beverage product, and averaged 42 years of age As the deliverymen get 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 and the heart rate range decreases, so does the metabolic capabilities 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 deliverymen One suggestion is to create transition from deliverymen to pre-sales work, either maintaining or increasing present salaries, and use these experienced workers to show new deliverymen how to best work the route For this solution to work well, all parties need to be involved, including deliverymen, labor, management, safety, medical, and engineering, so that the best interests of the deliverymen and the company are served

The current computerized billing system used by the deliverymen needs improvement. A more advanced system 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 out. Including the beverage deliveryman in the decision-making process will help all concerned. Also, customer orders can more efficiently be handled with telecommunication capabilities where sales, orders, and inventory are transmitted back to the plant.

Finally, the lessons learned from this study should be considered for other plants involved in beverage delivery. Beverage handling risk factors are well established and the availability of ergonomic and safety controls used here should reduce musculoskeletal stress and fatigue. The effectiveness of these interventions may be evaluated through lowered morbidity, at present, severity rates appear to be increasing in this industry every year. This is a very competitive and dynamic industry. New technology, such as time-dating products (which means more manual rotation of products), divergence of beverage products, and industry restructuring (downsizing), brings new challenges and opportunities. Making ergonomics an integral component of the health and safety system will serve this industry well. Investing in the beverage deliveryman is money well spent since there will always be a need to get the product delivered to the customer.

CONCLUSIONS

NIOSH researchers have concluded that several of the ergonomic and safety interventions used in this study and improved work practices will reduce musculoskeletal stress and morbidity among deliverymen Modifications to the beverage delivery truck, handtrucks, beverage packages and contents, used in combination with improved work practices will significantly reduce fatigue, the amount of beverage handled per day, awkward postures during beverage handling, and will improve work efficiency Recommendations in this report should be applied to meet the metabolic and biomechanical abilities of deliverymen and the goals of the company Favorable reports from the deliverymen in the study about the effectiveness of these controls helped convince management that all new trucks should have them 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 deliverymen The following summarizes the major findings of this study

The risk of a musculoskeletal injury during beverage delivery was 100 percent among the deliverymen in this study Musculoskeletal hazards and metabolic demands were quantified 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 worker's compensation data, it is theorized that the beverage deliveryman has a high probability of suffering a job-related musculoskeletal injury. Statistically speaking, the probability of such musculoskeletal injuries, in terms of days lost, is twice as high as for those in general manufacturing jobs.

The subjects 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 volunteers may not be typical of the average beverage deliverymen in this industry because of their years on the job.

The Discomfort Assessment Survey showed the key areas where workers experienced discomfort in decreasing order: the lower back, back right shoulder, knees, left elbow, and neck. The physical demands of removing beverages from the truck showed 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 lbs were handled, especially upon removal from the truck.

Beverage handling tasks were divided into high (beverage cases exceeding 51 lbs), medium (39 lbs to 51 lbs), and low (38 lbs and less) handling risks Most tasks performed were high and medium risk for low back injuries The beverage cases with the highest risk included 16-oz glass returnable, 20-oz glass nonreturnable, 8-pack 2-liter bottles, pre- and post-mix tanks, and 5-gallon bag-in-the-box Those with the least amount of risk were the cases of 12-oz cans

Based on heart rate results, the beverage deliveryman's job is classified as physically demanding Indirect measurements of metabolism showed that the energy demands may exceed 5 kcal/min for an 8-hour day during peak delivery periods, especially during the summer, and just before holidays Work exceeding 5 kcal/min (average heart rate of approximately 120 beats per minute) translates to moderate or to heavy work for most healthy workers, and rest periods are recommended to prevent fatigue

Ergonomic evaluations of the truck bays showed that they 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 The good work practice of moving the beverage cases forward to the edge of the bay openings before lifting will 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 handtrucks, (2) pre-planning to minimize handling, (3) using and maintaining material handling equipment, such as handtrucks, 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 In the one-year follow-up evaluation of ergonomic interventions at this plant, feedback from the deliverymen about the ergonomic controls was relayed to plant management and labor, and action was taken If these ergonomic interventions were to be applied to the entire beverage deliveryman work force, a decrease in injury and illness incidence and in severity should occur

RECOMMENDATIONS

Based on this study, recommendations should benefit most of the deliverymen delivering soft drink beverages Such changes should be done through consultation of a trained and experienced ergonomist

ENGINEERING CONTROLS

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-liter, 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 deliverymen the leverage and strength to manually handle the cases of beverage For safety reasons, all glass containers should <u>not</u> be stored above shoulder level Such packages are best kept at waist level and below to avoid head and eye injuries from falling bottles and broken glass

B Drop-down shelves should be used when possible to separate beverages and reduce multiple handling Additional shelving spaced at least 3 feet above and below the adjustable drop shelves should be used as needed, especially when new products are introduced to the market (see Figure 23) Careful shelving placement will reduce multiple handling of beverages

C Tank and Bag-in-the-Box (BIB) delivery should be considered when applying engineering controls Tank cages should be kept in good repair with latches that work and 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 deliverymen should encourage customers to purchase 3-gallon BIBs because they are easier for all concerned to handle

D Development of a fleet of "low boy" tractor-trailers with 14 bays is encouraged Approximately 20-25 more products and packages are introduced to the plant each year Larger trucks with adjustable height shelving will reduce multiple handling of beverages Ergonomic features which will facilitate beverage handling and reduce musculoskeletal stress include the following

1 External grab handles between all bay doors are needed

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 reported as needed by the deliveryman

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 deliveryman 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 deliveryman determines that shelves are not properly aligned or that product is wedged between shelves, then shelves should be aligned before the truck leaves the plant

4 Additional foot wells or pullout step bars with bar 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 bases 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 x 6 in) The pullout step should be portable so that it can be moved to any bay of the deliveryman's choosing Rather than welding the step in place, lock pins similar to the drop-down shelves could be used

6 A dual handtruck holder with high back should be installed One 2-wheel and one 4-wheel handtruck should be offered to each deliveryman so that they have more beverage transportation options with the handtrucks Slot openings on the handtruck holders should be wide enough for the handtruck 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 deliveryman

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

9 Installation of adjustable height cush-n-air^{R} ride seats with lumbar support is recommended to reduce whole body vibration from the road

10 The current computerized beverage billing and printing system on the trucks should be scrapped The deliverymen said it is slow, inefficient, and stressful The printer is bulky and is located at the back of the cab, which requires the worker to get into 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 from the truck battery to keep the printing mechanism warm A light-weight, field-ruggedized, portable, hand-held computer unit which meets the needs of the deliveryman 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 the left and right front bays, and 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 Telecommunications devices should be considered for the hand-held field units so that information can automatically be transmitted back to the plant and inventory prepared for the next delivery

Safety Features

A Five-inch spot mirrors on the right and left door, five-inch spot mirror mounted on the right side of the hood, and heated and motorized mirrors are recommended because they improve visibility for the deliveryman, especially in the city deliveries where other motorized vehicles can pass the truck on both sides

B The 3-point seat belt is useful for driving longer distances, but drivers-salesworkers seldom used them in the city because they do not "buckle up" for just a few blocks Driver input is recommended so that such systems are used more effectively and do not incumber the deliveryman

C The motion back-up alarm system used during this study was faulty and is not recommended The deliverymen did not receive training on proper use of this device It was not clear to either the deliveryman 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 better Deliveryman feedback is encouraged 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 taillight package, wide-turn signal, and reflective safety tape around the trailer are recommended This safety package should make the truck easier to see by motorists and pedestrians, and reduce the potential for accidents

HANDTRUCKS

Two handtrucks should be available for each deliveryman one 2-wheel handtruck and one 4-wheel handtruck Balloon tires for the 2-wheel handtruck are optional If rough terrain is encountered or it snows, the 4-wheel handtruck can be used in the upright position as a 2-wheel handtruck 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 pressure hose (located next to the deliveryman's handtruck storage area) should be available for these workers to use L-shaped tire stems should be avoided and straight stems used, as they are easier to access when inflating tires All moving parts on the handtrucks should be lubricated as needed Additional handtrucks should be available for deliverymen to use when their own handtruck is being repaired The ergonomically designed 2-wheel handtruck showed promise in reducing biomechanical stress to one of the workers during beverage delivery Unfortunately, this ergonomically designed handtruck was not used enough for its performance to be judged If such handtrucks are purchased, operators need training and practice before using them on a full-time basis Feedback from the deliverymen about performance is important in that slight modifications to the unit 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

Beverage packages should be redesigned so that they weigh less than 51 lbs Beverage handling should be analyzed using the revised NIOSH lifting equation to identify highly stressful tasks and to determine alternative material handling options Such options include repackaging beverages in smaller units, such as the 5-gallon Bag-in-the-Box to the 3-gallon Bag-in-the-Box, elimination of some beverage packages, such as the 16-oz glass returnable bottles, substitution of glass containers for 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 material that is handled and is 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) is optimized Based on task analysis, heavy loads should be stored in the trailer bays to capitalize on the best posture and location 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 deliverymen

B Plastic shells such as the 2-liter 8-pack, should be redesigned to a lighter 6-pack package or designed to better contain the 2-liter beverages and make handling easier The bottom of the 8-pack plastic shells should be redesigned so that the deliveryman 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 However, the new shell should be evaluated by an ergonomist and through deliveryman feedback

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

WORK PRACTICES

A Deliverymen should park the truck as close to the delivery point as possible to reduce manual transportation distance

B Deliverymen should take the time to turn the truck around if large orders are removed from both sides of the truck

C Deliverymen should preplan the most efficient way to unload the truck and minimize trips to and from the truck without overloading the handtruck

D Beverage loads should not be double-stacked on handtrucks or go over the handtruck support bar, especially when loads are transported up or down hills, ramps, or stairs

E Handtrucks and tractor trailers must be in good repair When inspecting the truck for beverage inventory in the morning, deliverymen 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 handtrucks, as well as make sure the tires are pressurized and in good repair Problems should be fixed before the truck leaves the plant

F Seasonal trends should be kept in mind for self-pacing in avoidance of heat-related illnesses, such as heat cramps and heat exhaustion In the summer workers should drink plenty of water, allow rest breaks when needed, and use air conditioning in the cab if available They should request 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

G To make the job safer and easier to perform, personal protective equipment is recommended Such equipment includes gloves, safety shoes (light weight), and knee pads (for kneeling on floors to load vending machines or individual merchandising units) Other items to consider include a utility knife to cut shrinkwrap 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 handtrucks are used to transport large orders over door thresholds

ORGANIZATIONAL

A Coordination between beverage loader workers, who load beverages on the delivery trucks, and deliverymen should be done on a weekly basis Problems with loads, shortage of product, and suggested modifications to loading of the truck to improve 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 return to work and to gradually integrate them back to full-time work This can be done through a buddy system on the route or assignment of 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 deliverymen A standardized load may vary between deliverymen, the type of route they have, seasonal demands, and new products offered Analysis of the load sheets over time should narrow down choices to the core load (what is taken to the customers on a consistent basis), and be expanded out from there

D Development of career progression jobs should be considered for the deliveryman Currently there are few jobs available, other than management, that are as attractive to the deliveryman 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 grind of manually handling between 25,000 to 50,000 pounds of beverages, driving a truck, maintaining a professional and pleasant disposition under all circumstances, and dealing with myriad other annoyances take their toll As the deliveryman ages, the job demands do not get easier The nature of this business is that the more successful the deliveryman is, the more beverage they sell One suggestion is to create a pre-sale position as the next career level move The pre-sale position would be available to experienced deliverymen who have established rapport with customers and know how to sell their product The experienced deliverymen could transition off the jobs by training new employees on the delivery business and phasing them in over time

E Overloading the beverage trucks with product that does not get sold should be avoided On average, 25 percent of the product loaded on the truck is 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 deliverymen and save on fuel costs If a customer is in need of extra beverage product, then another deliveryman 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 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 deliveryman

F When an ergonomic or safety control is installed on a beverage vehicle, handtruck, or at a customer's service which benefits the deliveryman and company, the control should be documented and 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 that such controls are the standard and available for all trucks used in the company fleet

ROBBERIES

Suggestions for Decreasing the Chances of Being Robbed

1 Form a task force of experienced deliverymen, safety specialists, immediate supervisors, labor, and management to discuss methods to avoid robbery and bodily harm of deliverymen

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 deliverymen during periodic safety and/or sales meetings The types of interventions which could be included for discussion or publication during the strategy sessions include

Scheduling routes to occur during the daylight hours wherever possible,

Posting conspicuous signs on the truck indicating that drivers do not carry more than a certain amount,

Training on conflict resolution and nonviolent response to robbery attempts, and

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 deliverymen 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, another time, or other 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

6 Other suggestions which may benefit the beverage deliveryman include

Installation of safes on all trucks,

A credit-only transaction system,

Refusal of delivery to accounts where robberies have taken place, and

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

Care must be taken as to the efficacy to these intervention strategies The implementation of multiple interventions is usually indicated

The first two suggestions of forming a task force, and an emergency preparedness plan of action should be developed as soon as possible The remaining suggestions are not based on scientific fact but should facilitate discussions to establish a plan of action For example, careful attention should be given to the first item in number 6 above Delaying a robber by opening a safe or not having keys to the safe may irritate the robber and result in serious bodily harm to the deliveryman

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APPENDIX A

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 percent 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 close to one out of every three hospital stays paid for through workers' compensation, with nearly 30 percent 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 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

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 deliveryman 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 outlines what is known about container packaging and handles

Soft drink beverage products are sold in the following breakdown of beverage containers cans (52 percent), plastic bottles (30 1 percent), and glass (17 9 percent) accounting for respectively, 53 3, 32 0, and 20 5 billion of the total [14] Secondary packaging consists of placing the beverage containers in paperboard or plastic, or leaving them loose In 1990, 36 5 percent of cans were sold in paperboard, 56 7 percent in plastic, and 6 8 percent were loose PET (plastic bottles) were packaged as 6 percent paperboard, 84 percent plastic, and 10 percent loose Returnable glass was 95 percent paperboard and 5 percent loose [15]

Improving the operator/container coupling by providing handles has been a consistently recommended practice Handles can increase the maximum force exerted on the container and reduce task energy expenditure [16] Drury, Law, and Pawenski studied more than 2000 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 percent of the containers contained handles [17]

Box handling is a task consisting of five stages pregrasp, pickup, move/carry, put down, and adjust Factors, such as handle position and handle angle, have a large effect on body angles, 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 [17] Since 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 percent of lifts are free from twisting at the start of the task

Drury and Deeb studied two-handed dynamic lifting tasks to determine 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 recommendations have 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 a curved handle showed no significant differences when compared to a straight handle [16]

PUSH VERSUS PULL

Cart or handtruck 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 his 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 had 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 demonstrated was the fact 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 percent 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 greatest strengths occurred at the lowest handle height, followed by the medium, then 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 handtruck 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 deliverymen 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, major structural resonances occurring in the 1 to 20 Hertz (Hz) frequency region, is transmitted to the body as a whole, 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, cannot be ruled out in considering 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 time on their job 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 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 percent) as compared to the control group of skilled working men (47 percent), however, no statistical difference occurred when compared to unskilled workers (52 percent) The forklift truck drivers had a significantly higher rate (22 percent) of absence from work due to low back trouble than both control groups (7 and 9 percent) It was concluded that forklift driving can be a contributing cause of low back trouble

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APPENDIX B 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 Pepsi-Cola™ Facility, Dayton, Ohio

SUBJECT ID ______________________

____
LAST NAME

____
FIRST NAME

____
SOCIAL SECURITY NUMBER

SUBJECT ID ______________________

____	____	____	____
AGE	HEIGHT	FORWARD REACH	WEIGHT

MAXIMUM HAND GRIP STRENGTH LEFT HAND ____ ____ ____
RIGHT HAND ____ ____ ____

WORK HISTORY

When did you begin working with Pepsi-Cola™? __ __ Month __ __ __ __ YEAR

When did you begin delivering beverages for Pepsi-Cola™? __ __ Month __ __ __ __ YEAR

Since working for Pepsi-Cola™ 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 Pepsi-Cola™ facility? ____ (yes) ____ (no)

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

COMPANY AND LOCATION

WORK ACTIVITIES

WHEN STARTED (MONTH, YEAR) HOW LONG AT JOB (MONTHS, YEARS)

COMPANY AND LOCATION

WORK ACTIVITIES

WHEN STARTED (MONTH, YEAR) HOW LONG AT JOB (MONTHS, YEARS)

COMPANY AND LOCATION

WORK ACTIVITIES

WHEN STARTED (MONTH, YEAR) HOW LONG AT JOB (MONTHS, YEARS)

COMPANY AND LOCATION

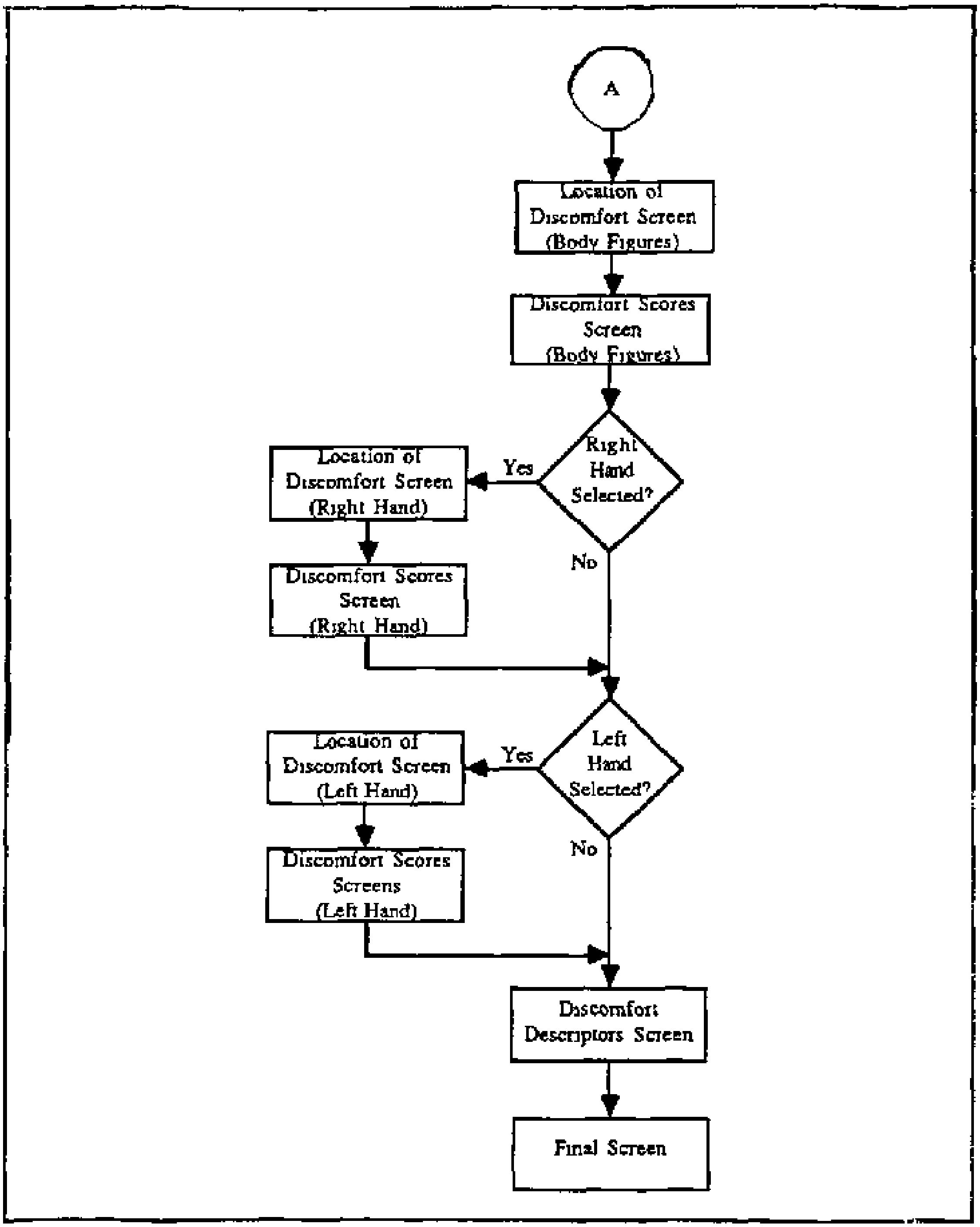
WORK ACTIVITIES

WHEN STARTED (MONTH, YEAR) HOW LONG AT JOB (MONTHS, YEARS)

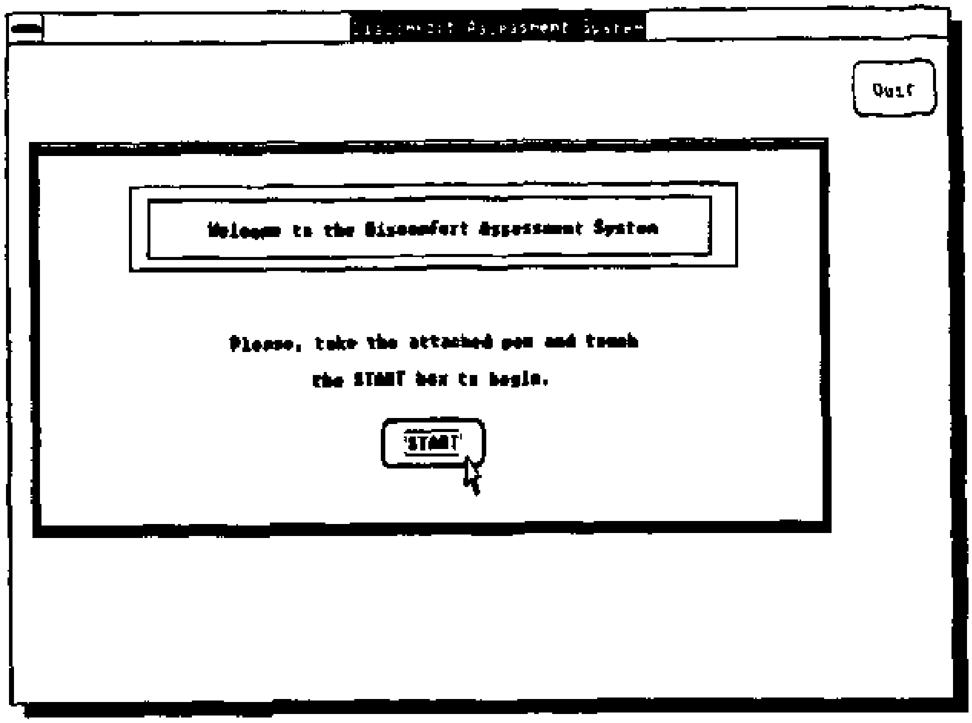
Do you have, or did you ever have, any musculoskeletal disorders while performing your job? If yes, please explain

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

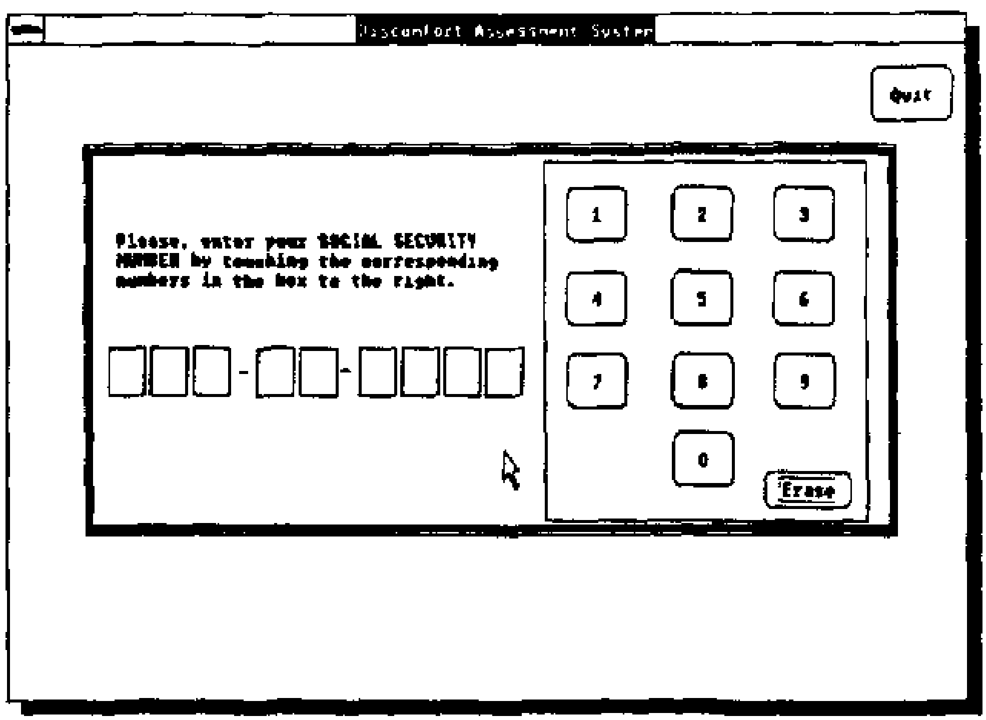
APPENDIX C Figures showing the Different DAS Screens Shown on the Computer



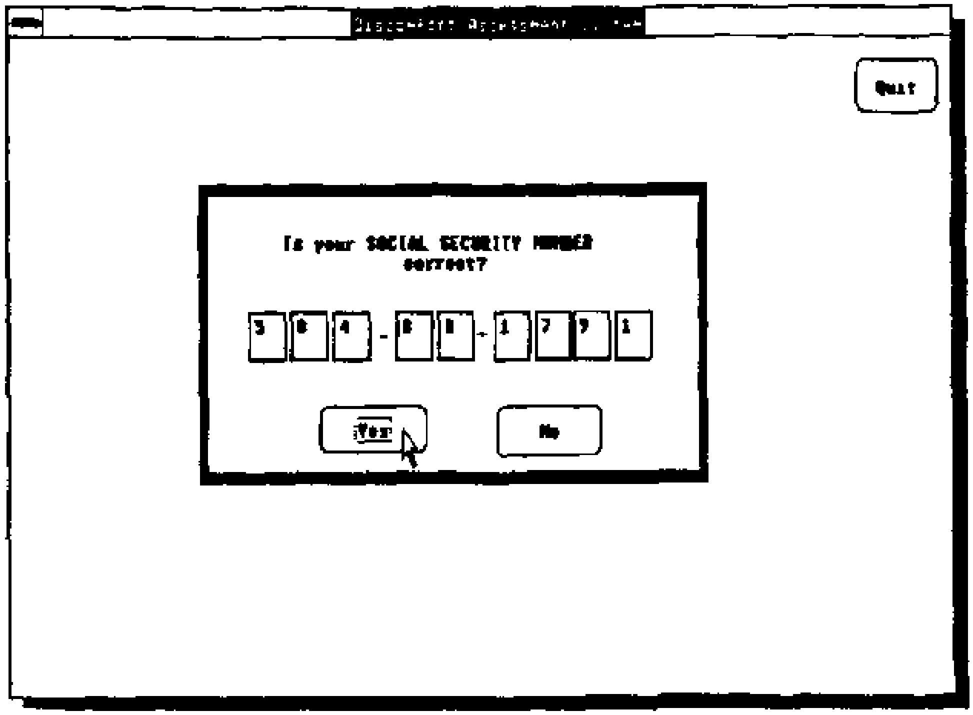
Flowchart of the sequence of screens displayed in DAS



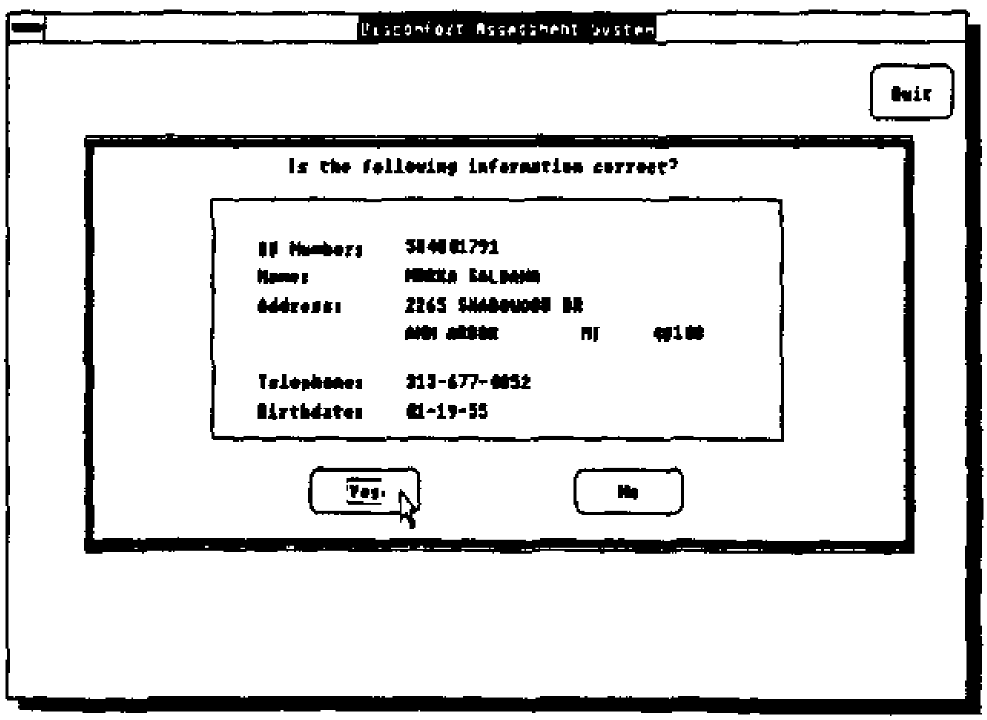
Welcome Screen



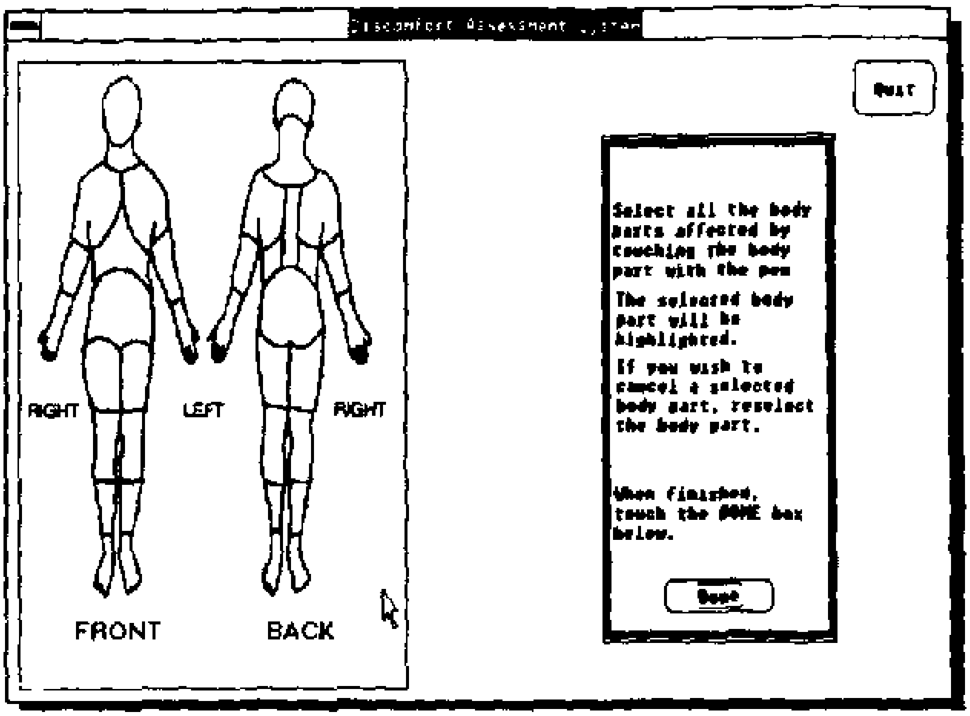
Social Security Number Screen



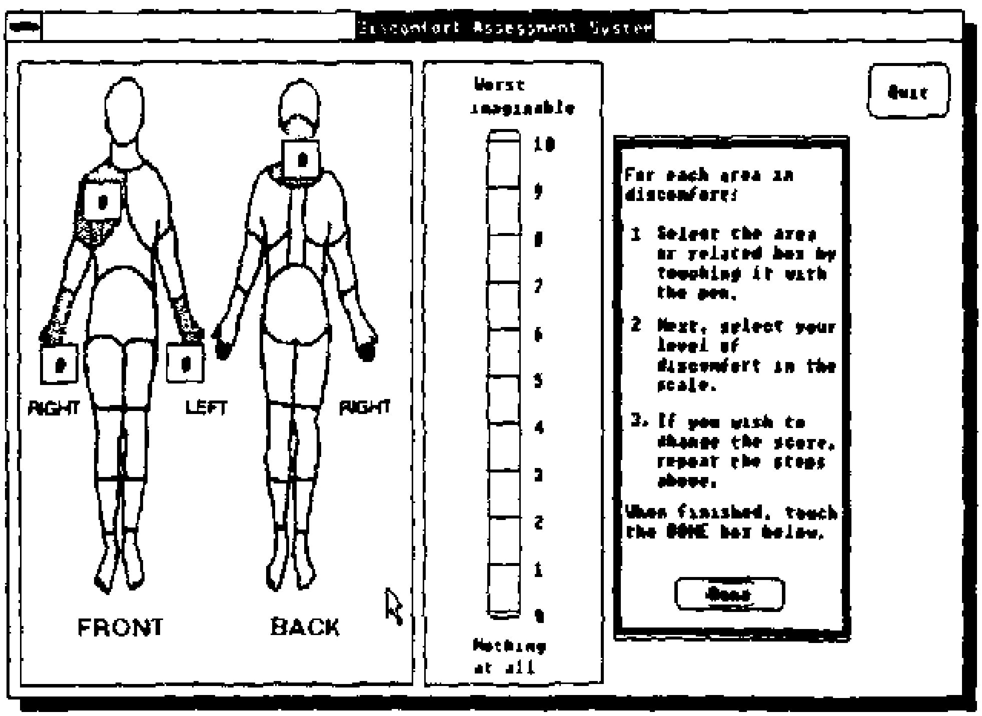
Social Security Number Confirmation Screen



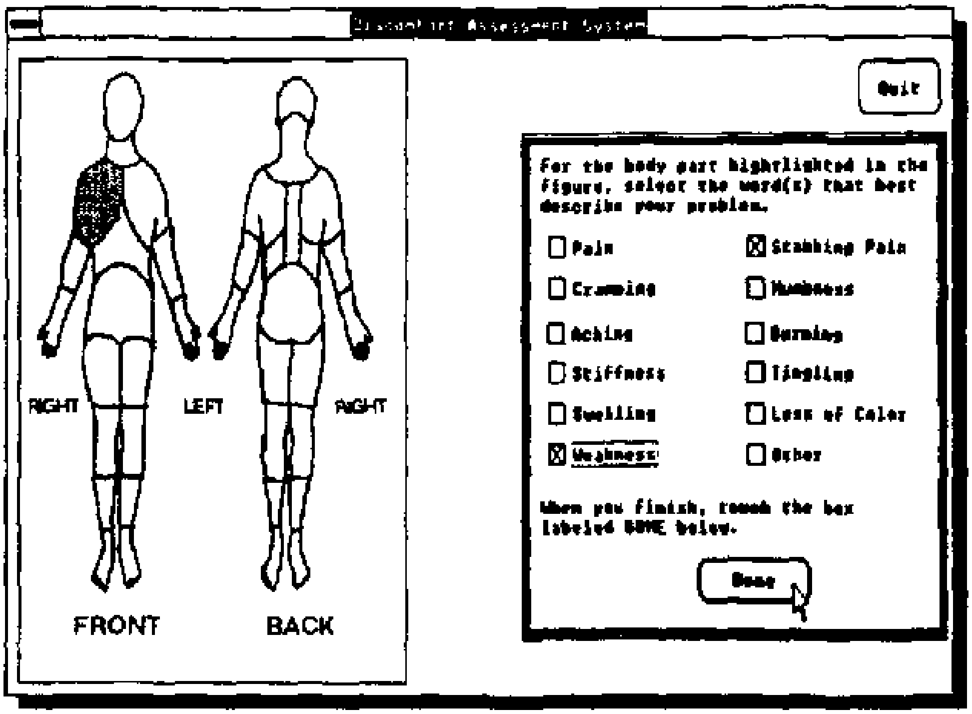
User Information Confirmation Screen



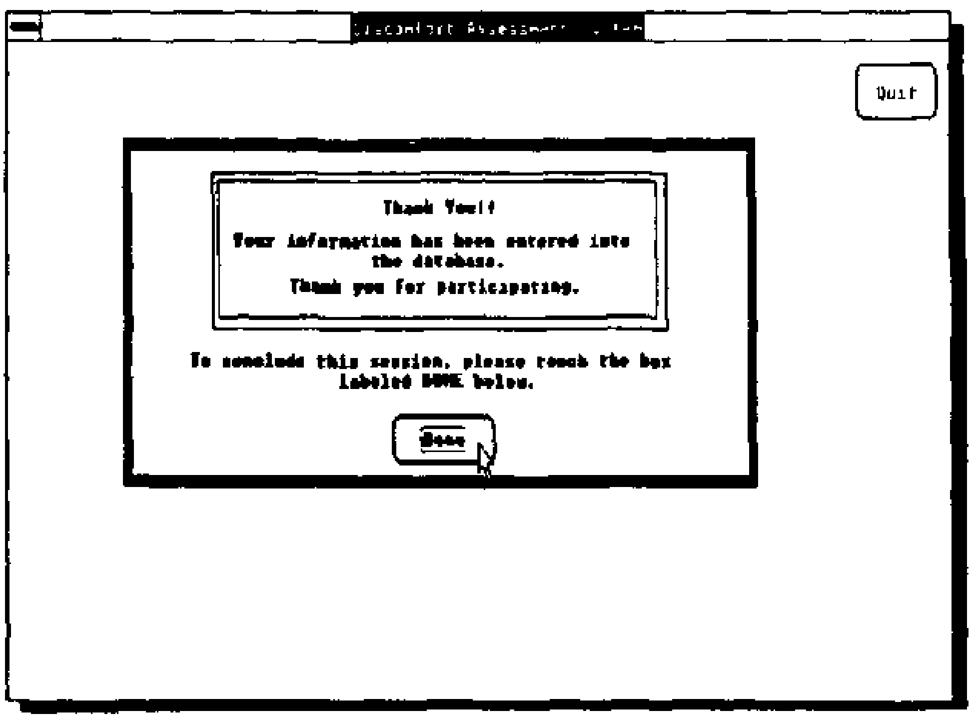
Location of Discomfort Screen (Body Figures)



Discomfort Scores Screen (Body Figures)



Discomfort Descriptors Screen



Final Screen

APPENDIX D Selected Pictures of Activities and Associated Risk Factors for Musculoskeletal Injuries

Figure A1 Deliveryman lifting 20-oz 24-bottle case of glass softdrink beverage from truck while standing on platform [Comment excessive reach reduced by standing on platform This reduces biomechanical stress on shoulders]

Figure A2   Deliveryman placing 20-oz 24-bottle case of glass softdrink beverage on platform   [Comment Deliveryman does not have to step off truck to place beverage case on ground]

Figure A3 Deliveryman lifting 20-oz 24-bottle case of glass softdrink beverage from truck platform [Comment excessive reach reduced, lower biomechanical stress on shoulders]

Figure A4 Deliveryman placing 20-oz 24-bottle case of glass softdrink beverage from truck platform on hand truck [Comment Figures A1 through A4 show that beverage cases are handled twice by using truck platform However, metabolic costs are less than biomechanical costs when beverages cases are handled once]

Figure A5 Deliveryman lifting 2-liter 8 pack case from truck not using truck platform [Comment extended reach to access 2-liter 8 pack beverage case Deliveryman initially does not use platform but later remembered to use platform (see figure A6)]

Figure A6 Deliveryman using truck handhold to stand on platform to access 2-liter 8 pack beverage cases
[Comment Deliveryman uses truck hand holds to step on platform for easier access to beverages]

Figure A7 Deliveryman lifting 2-liter 8 pack case from truck using truck platform [Comment Deliveryman uses platform to unload beverages from truck]

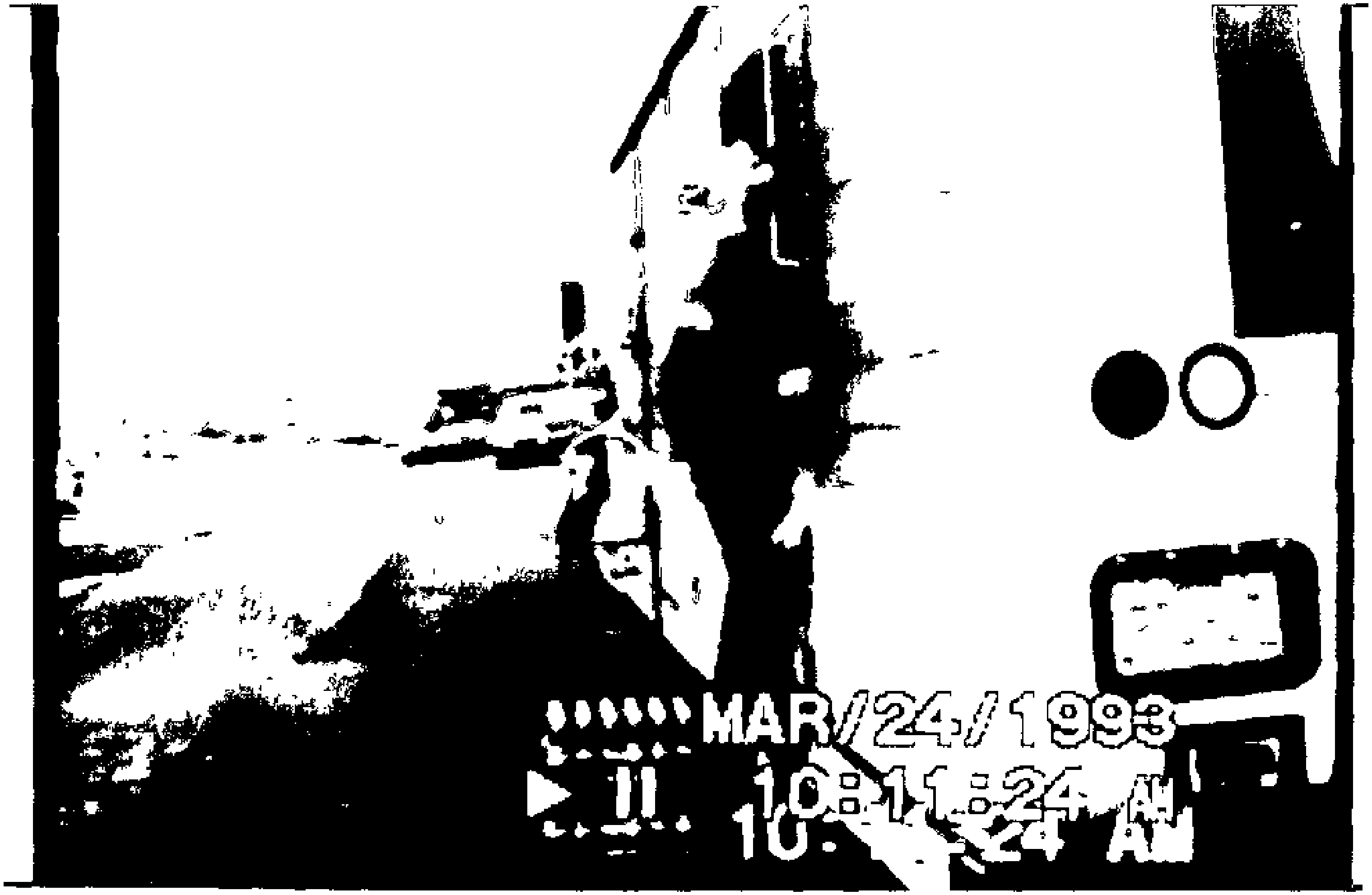


Figure A8 Deliveryman using truck wheel bar and using handhold to improve leverage for lifting 20 oz 24 pack case of softdrink beverage from truck [Comment Deliveryman uses truck handles for leverage while getting 20-oz 24 pack case of beverage crates from truck]

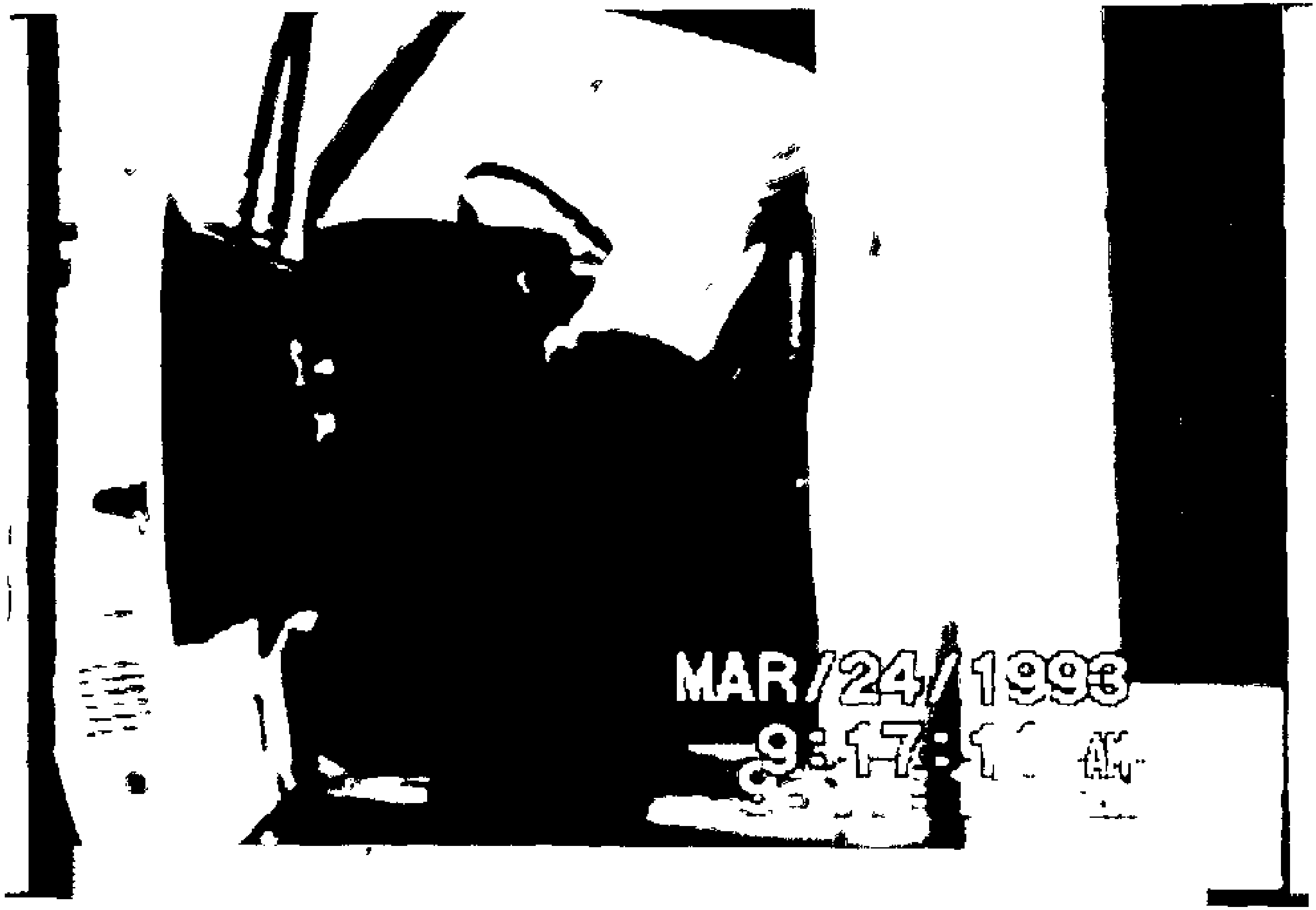


Figure A9 Deliveryman getting printed receipt from printer located in middle, back wall of truck cab [Comment [Deliveryman is in an awkward posture to access the printer to get receipt This may increase stress to the back Excessive twisting was also observed when the driver operated the printer from the driver's seat]

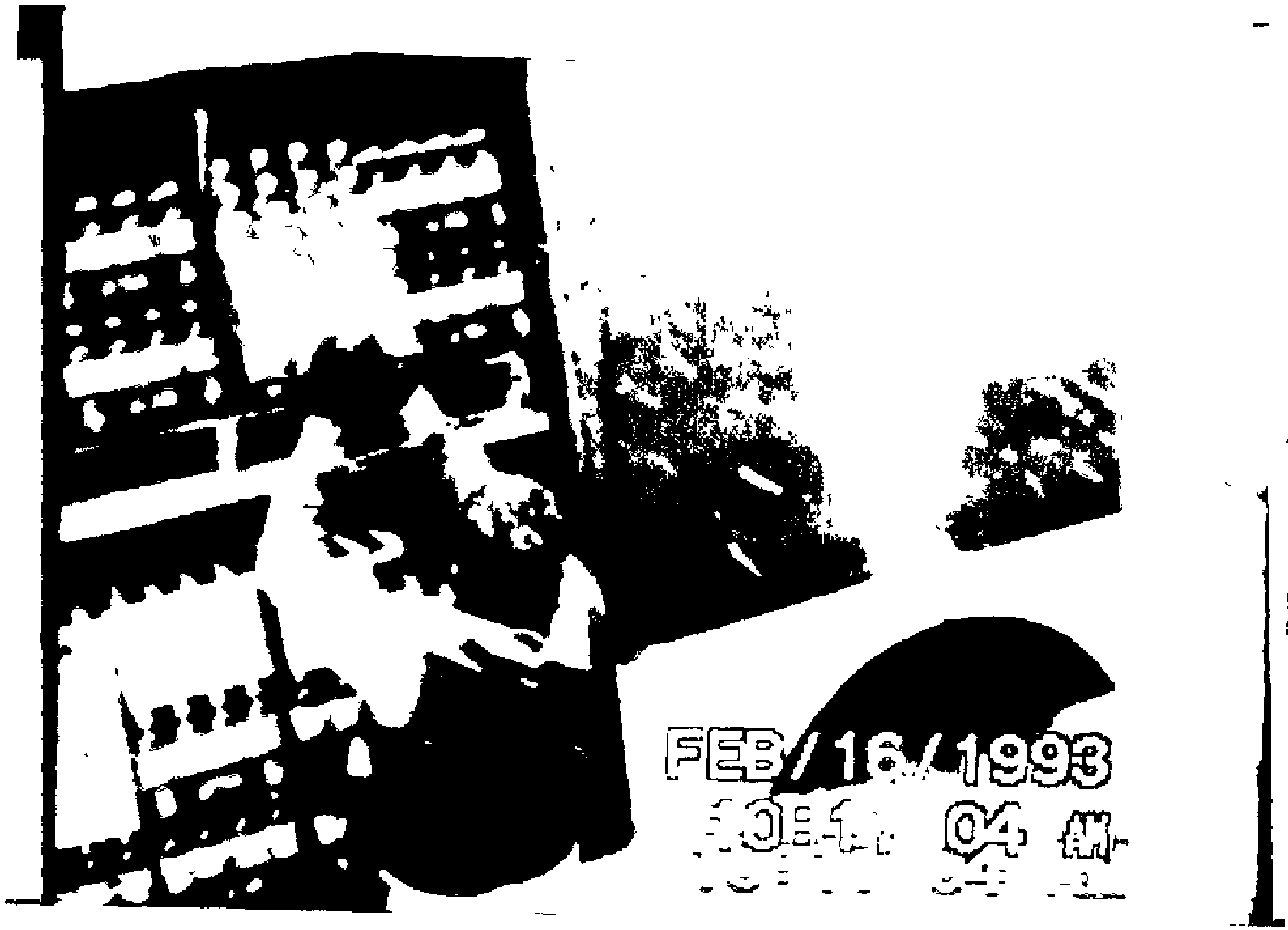


Figure A10 Deliveryman unloading 20-oz 24 pack case of softdrink beverages from truck during snow storm [Comment Poor weather conditions add stress to job Snow and ice may increase chances for beverages to slip out of hands and fall on deliverymen]

Figure A11 Deliveryman loading 2-liter 8 pack softdrink beverages on hand truck on high dock during snow storm [Comment Beverages 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]

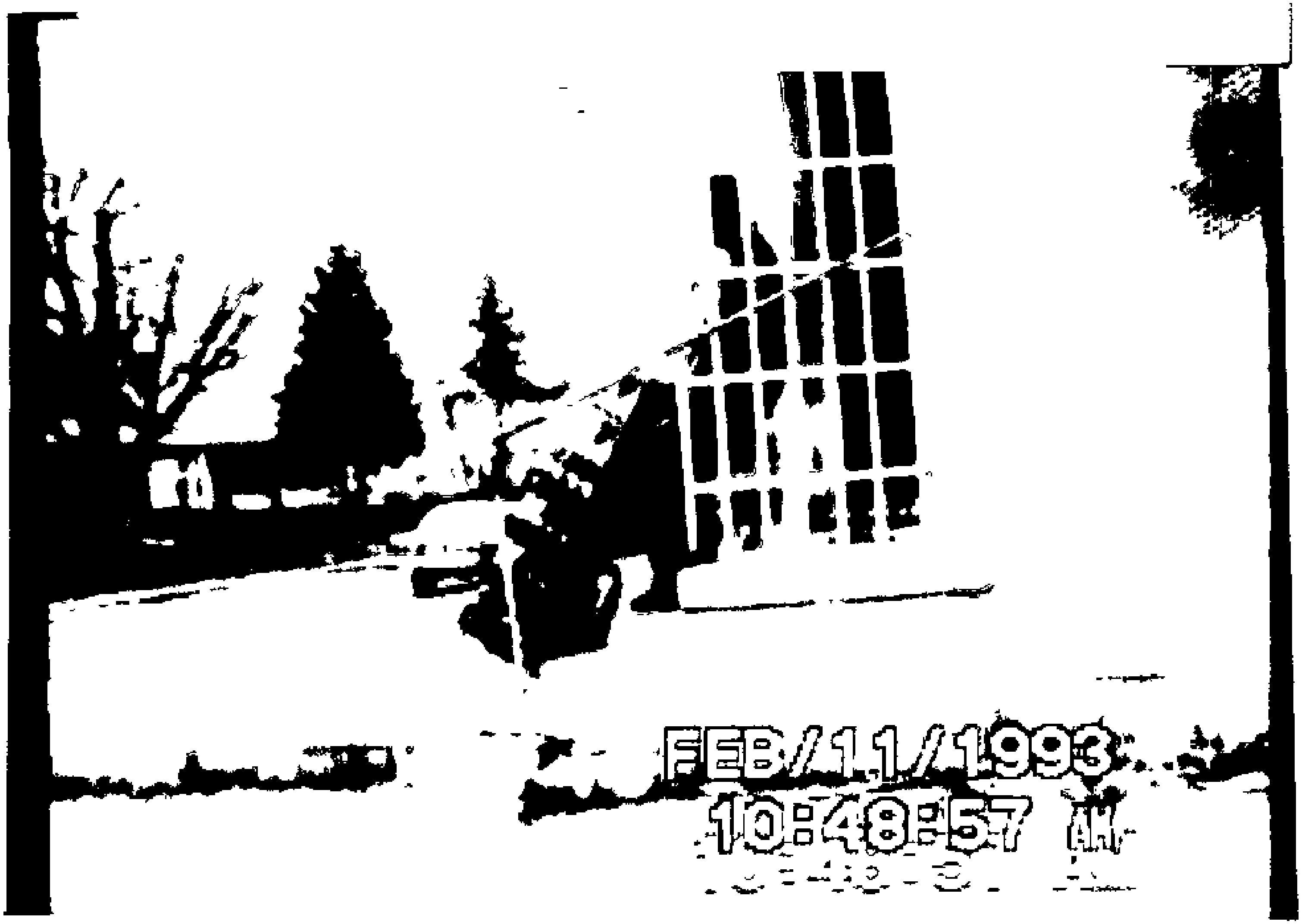


Figure A12 Deliveryman lifting loaded hand truck (350 lbs - includes weight of hand truck) up steps to store [Comment The combination of a heavy load, control of load, posture, and pulling load up steps, create significant biomechanical loads on the back]

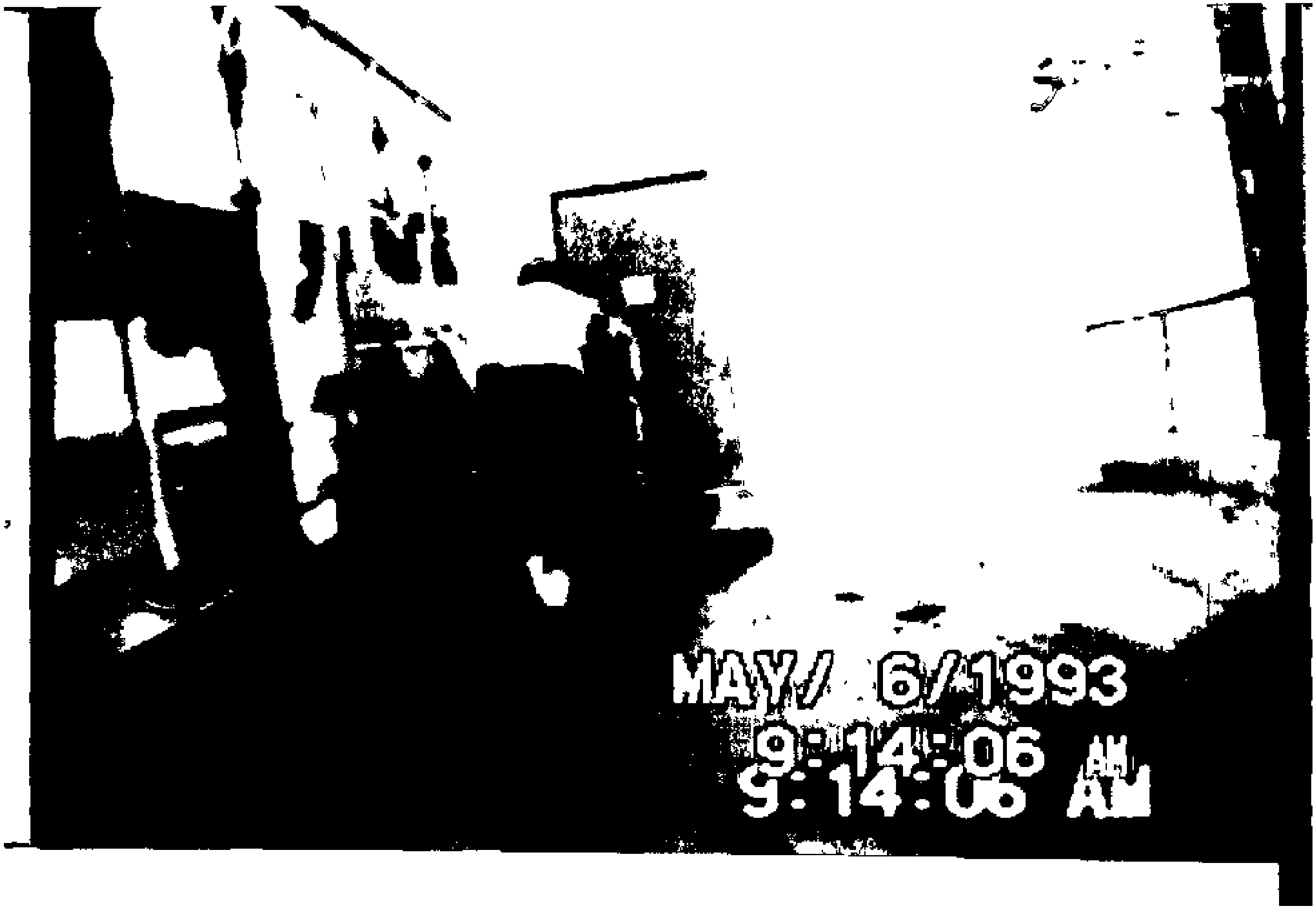


Figure A13 Deliveryman pushing loaded 4-wheel hand truck (approximately 680 lbs - includes weight of hand truck) up low grade hill to store service entrance [Comment Pushing or pulling loads up hill cause significant stress to the back, and increase chances for slip and fall injuries if the foot and ground contact is not good]

Figure A14 Deliveryman pushing loaded 4-wheel hand truck (approximately 680 lbs - includes weight of hand truck) up 6 degree rank 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 A15 Deliveryman stooped over while loading beverage cooler with individual servings of 20-oz softdrink [Comment Stooped over posture increases stress to the back even though materials handled are low in weight It is recommended that deliverymen kneel on one knee, and keep back more erect, to perform this task]

Figure A16   Deliveryman stocking shelves with 12-oz 24-can cases of softdrink [Comment Stooped over static postures with heavy loads significantly increases stress to the back   It is recommended that deliverymen kneel on one knee, handle one case at a time, and keep back more erect to perform this task]

Figure A17 Deliveryman loading beverage cooler with individual servings of 20-oz softdrink [Comment Deliveryman loading beverages in cooler while kneeling This work practice reduces stress to back However, knee pads may help reduce stress to knees]

Figure A16 Deliveryman loading 53 pound Bag-in-the-Box (BIB) under the counter [Comment Deliveryman 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 A19 Deliveryman lifting 2-liter 8 pack of beverages from truck [Comment Slip and fall hazard from standing on narrow ledge while removing beverages Pull out platform may reduce slip and fall hazards]

Figure A20 Deliveryman stepping off truck with 2-liter 8 pack load [Comment Deliveryman stepping off truck with load Load is unstable and 2-liter containers may fall from the 8 pack shell causing injury to the deliveryman Also, unloading the beverage cases in this manner causes significant strain on the back and legs when contacting the ground Pull out platform should help reduce strain to back and legs]