RESULTS

Description of Beverage Driver-Salesworkers

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

Questionnaire: Demographics, Past Work Experience, and Medical History

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

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

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

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

Table 3

Descriptive Characteristics of Driver-Salesworkers at the Beginning of Study

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

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

Discomfort Assessment Survey (DAS)

Location of Discomfort

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

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

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

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

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

Table 4

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

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

(N = 8)

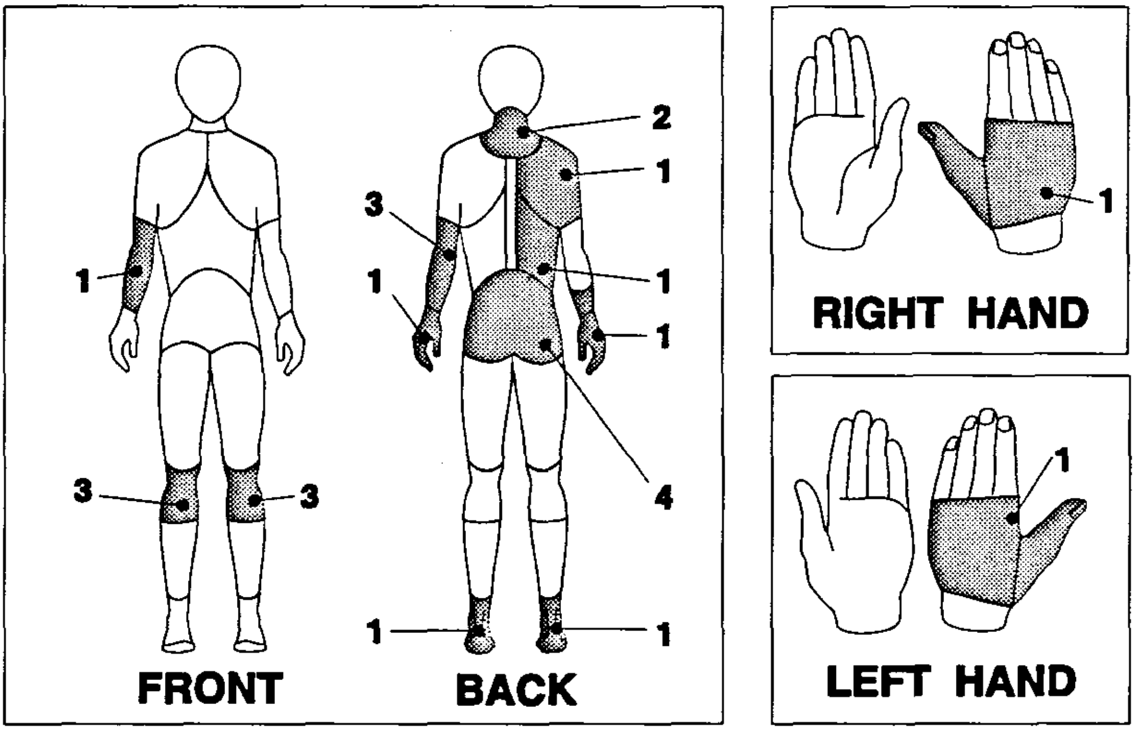

Figure 4. First survey results from Discomfort Assessment Survey (DAS).

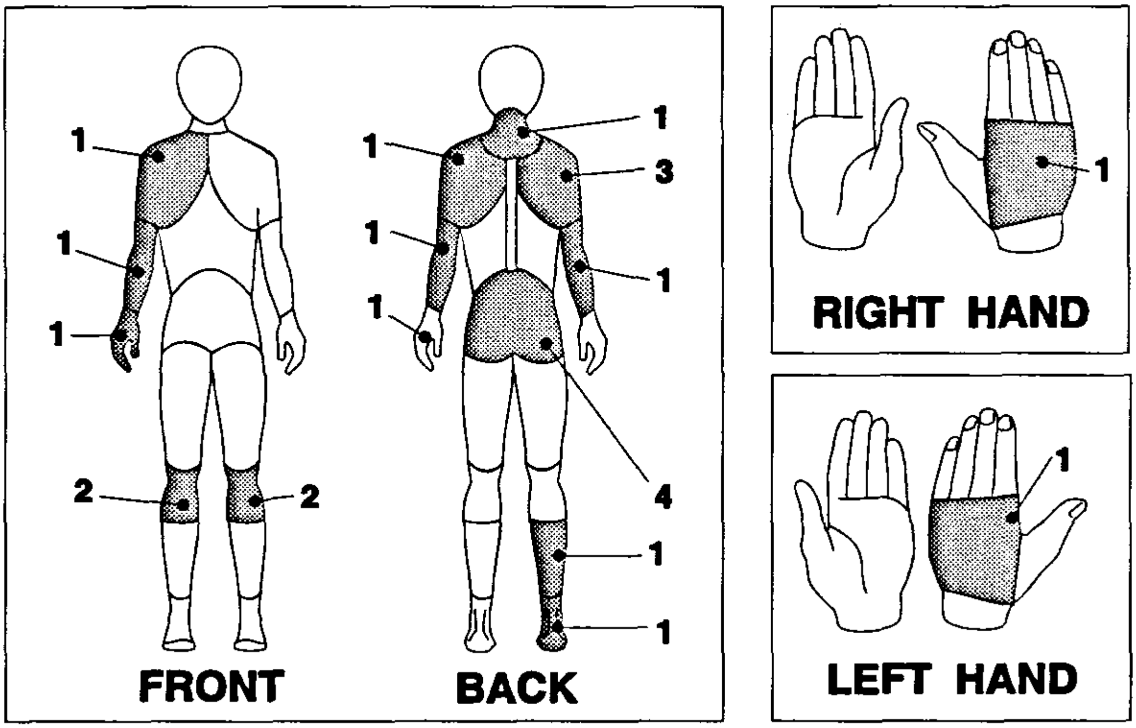

Figure 5. Second survey DAS results—approximately 3 weeks after first DAS.

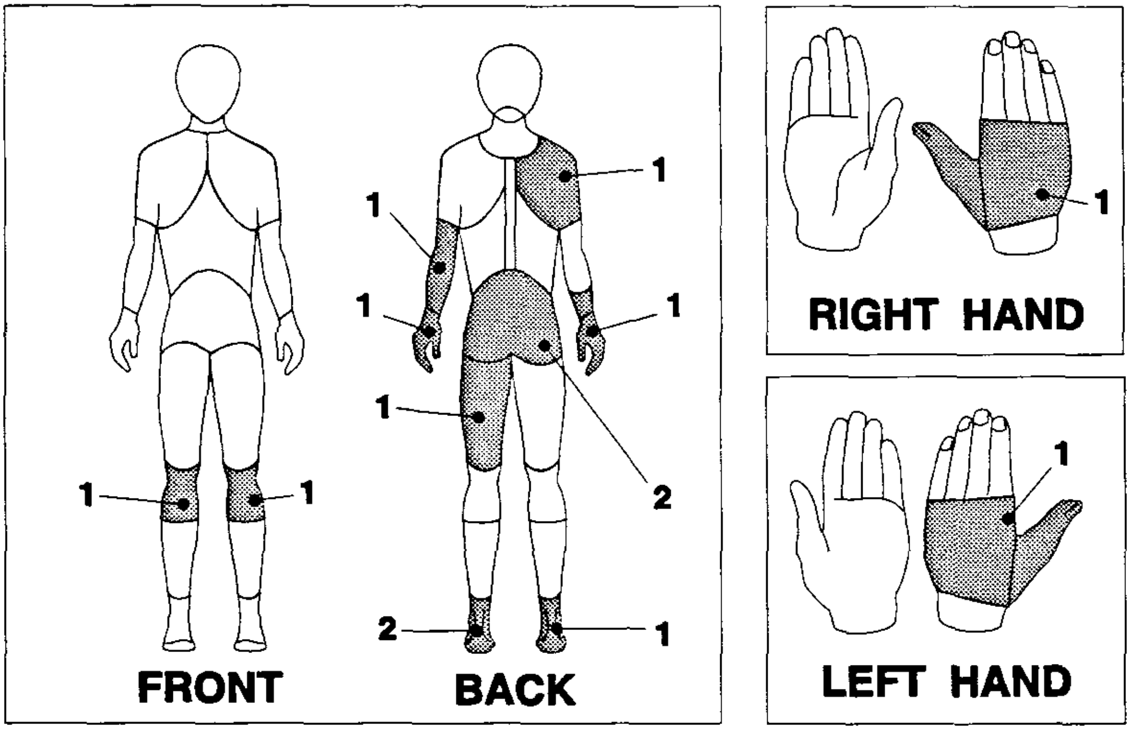

Figure 6. Third survey DAS results—approximately 6 weeks after first DAS.

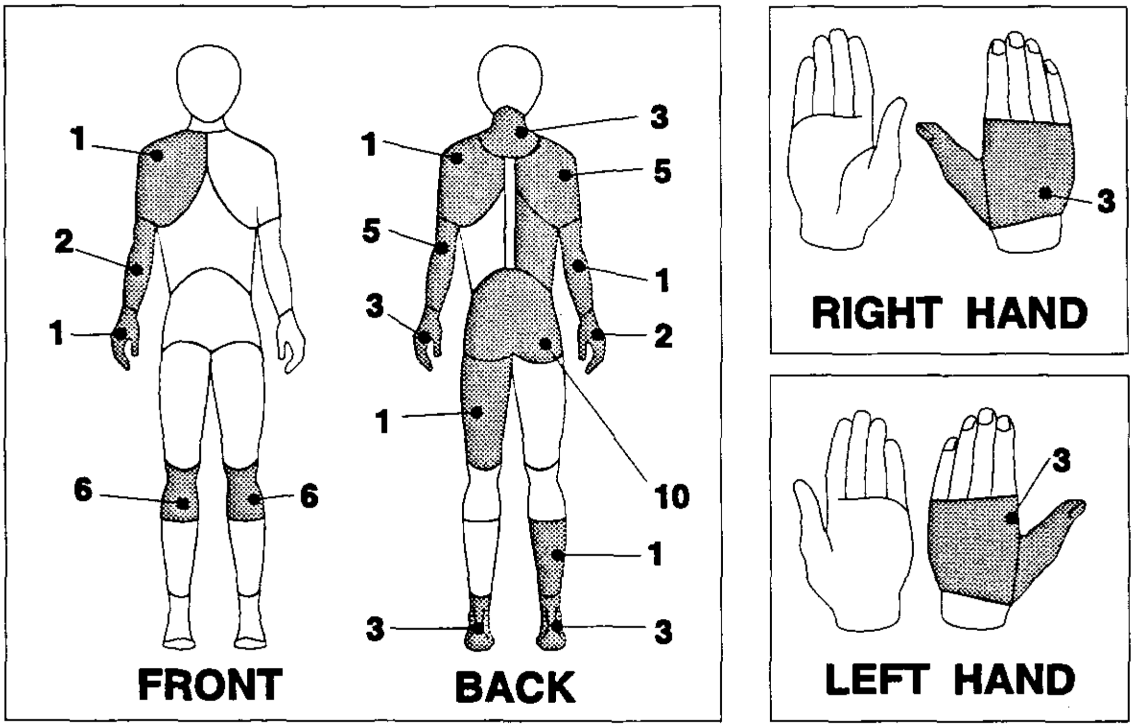

Figure 7. Composite survey DAS results (all three surveys).

Type of Discomfort

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

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

Pain Level

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

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

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

Table 5 summarizes the results of the Discomfort Assessment Survey.

Metabolic Measures

Heart Rate

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

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

Heart Rate Values Before and After Ergonomic Interventions

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

Table 5

Summary of Discomfort Assessment System Survey

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

Table 6

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

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

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

Table 7

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

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

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

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

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

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

Work Analysis

Work Documentation and Analysis

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

Biomechanical

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

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

Table 8

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

Job Analysis Worksheet

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

STEP 1. Measure and record task variables

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

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

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

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

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

STEP 3. Compute the Lifting Index

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

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

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

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

Table 9

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

Job Analysis Worksheet

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

STEP 1. Measure and record task variables

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

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

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

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

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

STEP 3. Compute the Lifting Index

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

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

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

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

Table 10

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

Job Analysis Worksheet

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

STEP 1. Measure and record task variables

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

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

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

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

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

STEP 3. Compute the Lifting Index

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

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

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

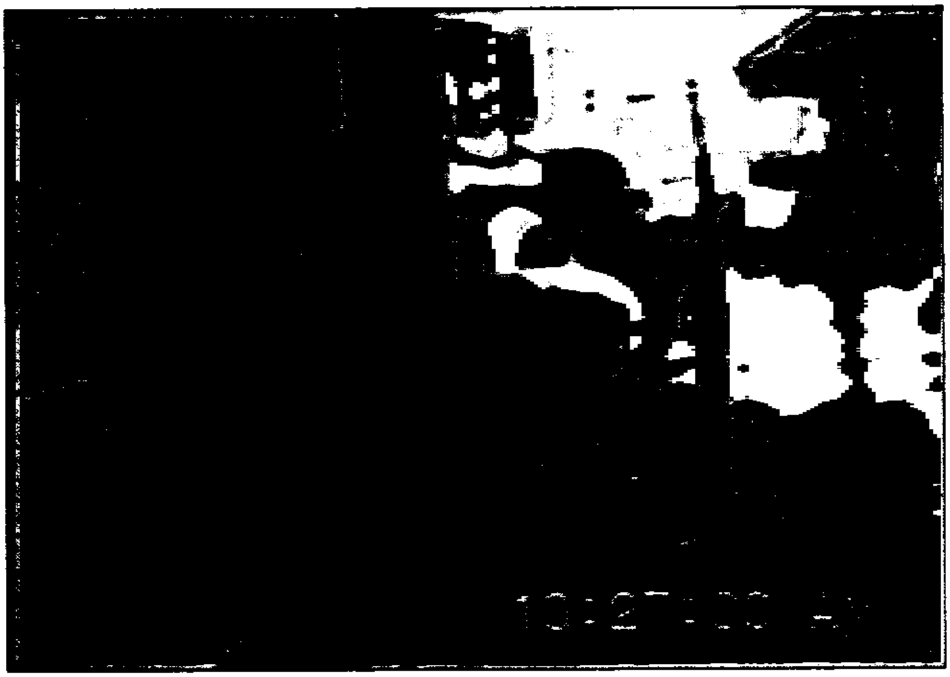

Figure 11. Driver-salesworker placing 8-pack of 2-L soft drink beverages on hand truck.

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

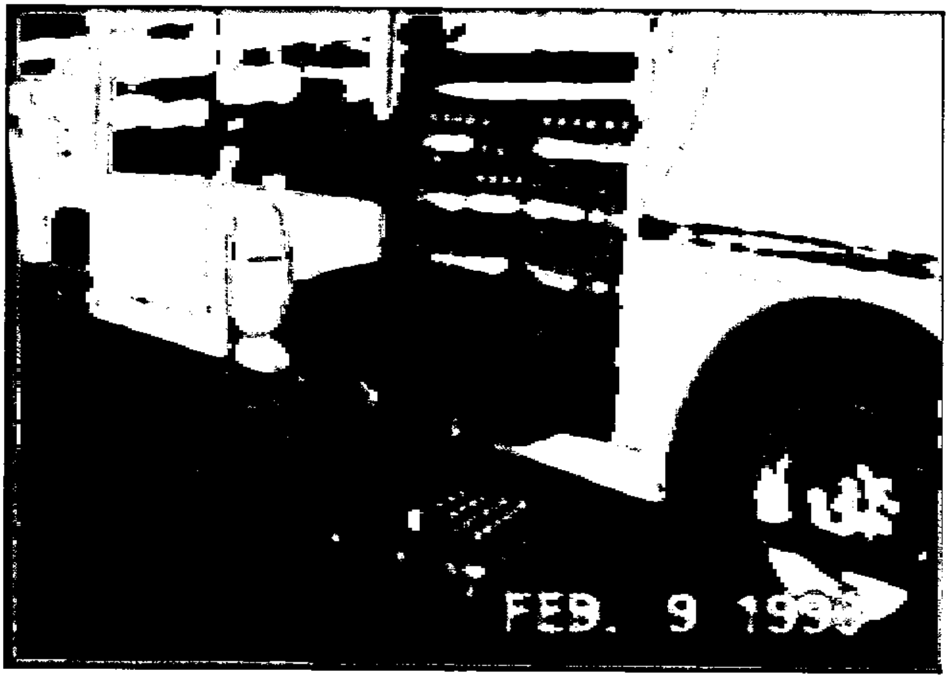

Figure 13. Driver-salesworker placing 24-pack of 20-oz glass bottled soft drink beverages on ground.

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

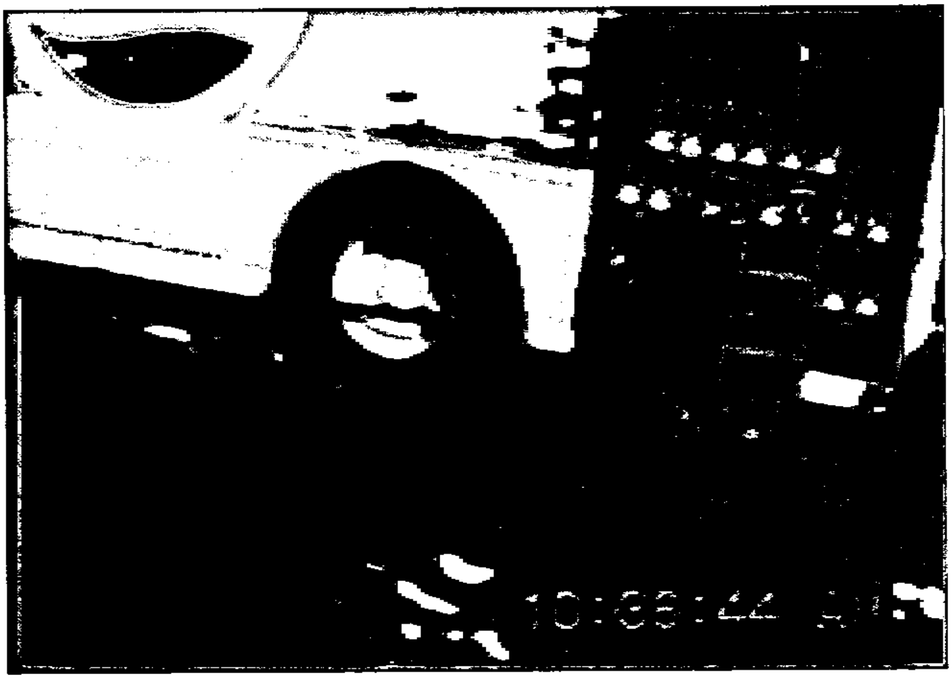

Figure 15. Driver-salesworker placing 24-pack of 16-oz glass bottled soft drink beverages on hand truck.

Table 11

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

Job Analysis Worksheet

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

STEP 1. Measure and record task variables

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

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

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

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

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

STEP 3. Compute the Lifting Index

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

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

Hand Grip

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

Table 12

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

Job Analysis Worksheet

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

STEP 1. Measure and record task variables

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

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

RWL = LC × HM × VM × DM × AM × FM × CM
ORIGIN RWL = 51 × .50× .89× .87 × .90 × .75 × .90 = 12.0 lb
DESTINATION RWL = 51 × .67 × .85× .87 × 1.0 × .75 × .90 = 17.0 lb

STEP 3. Compute the Lifting Index

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

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

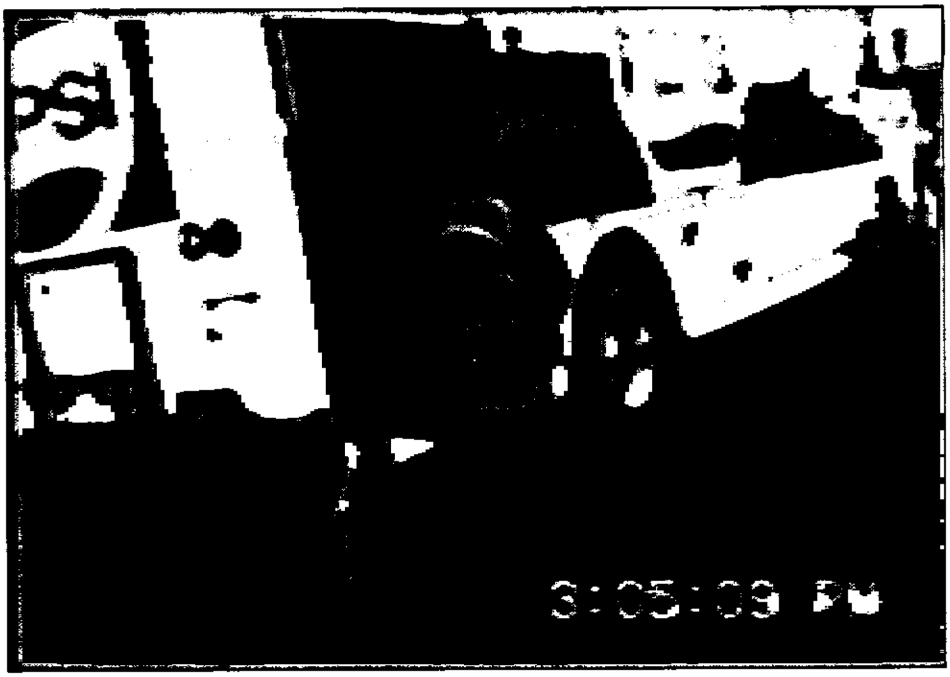

Figure 16. Driver-salesworker lifting bag-in-the-box (BIB) beverage syrup (53 lb) from truck.

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

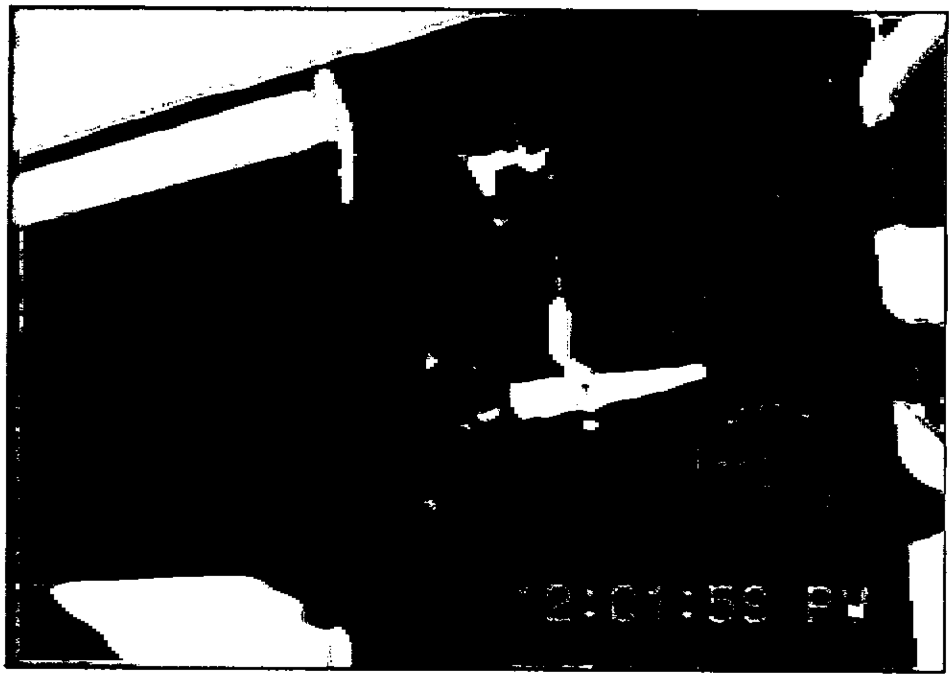

Figure 18. Driver-salesworker lifting aluminum cylinder containing pre-mix soft drink beverage (54.5 lb) from truck.

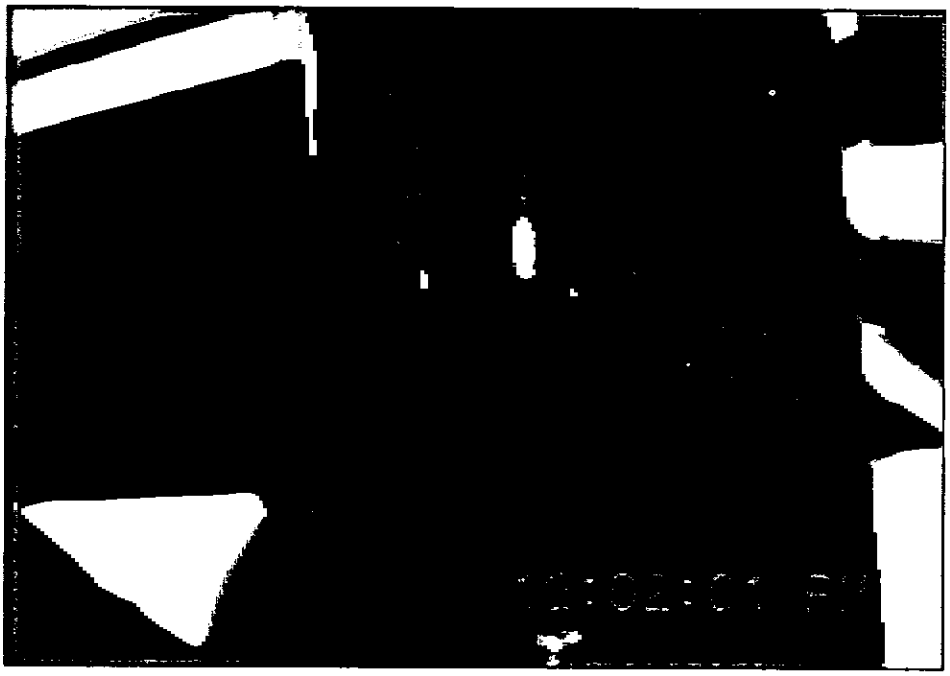

Figure 19. Driver-salesworker placing aluminum cylinder containing pre-mix soft drink beverage on ground.

MATERIAL HANDLING

Beverage Material Loaded and Delivered

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

Beverage Material Handled During Delivery Day

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

Table 13

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

Job Analysis Worksheet

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

STEP 1. Measure and record task variables

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

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

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

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

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

STEP 3. Compute the Lifting Index

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

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

Table 14

Hand Grip Strength—Beginning and End of Workday

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

[1] s.d. = standard deviation

Not statistically significant comparing beginning with end grip strength.

Table 15

Truck Inventory—Beverages Loaded and Sold

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

[1] s.d. = standard deviation

Table 16

Average Amount of Conventional Beverage Material Handled

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

[1] Each beverage package handled two times.

[2] Each beverage package handled three times.

[3] Each beverage package handled four times.

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

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

Beverage and Type of Load

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

Ergonomic Interventions

Beverage Delivery Trucks

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

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

The ergonomic retrofit problems were:

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

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

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

Table 17

Beverage Cases and Loads Handled Comparing Driver-Salesworkers

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

Table 18

Beverage Truck Safety and Ergonomic-Related Intervention Results

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

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

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

Bay Door Forces for Opening and Closing

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

Hand Trucks

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

Table 19

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

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

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

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

Table 20

Tire Pressure from Hand trucks—Tire Pressure (lb)

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

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

DISCUSSION

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

Discomfort Assessment System

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

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

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

Metabolic Measures

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

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

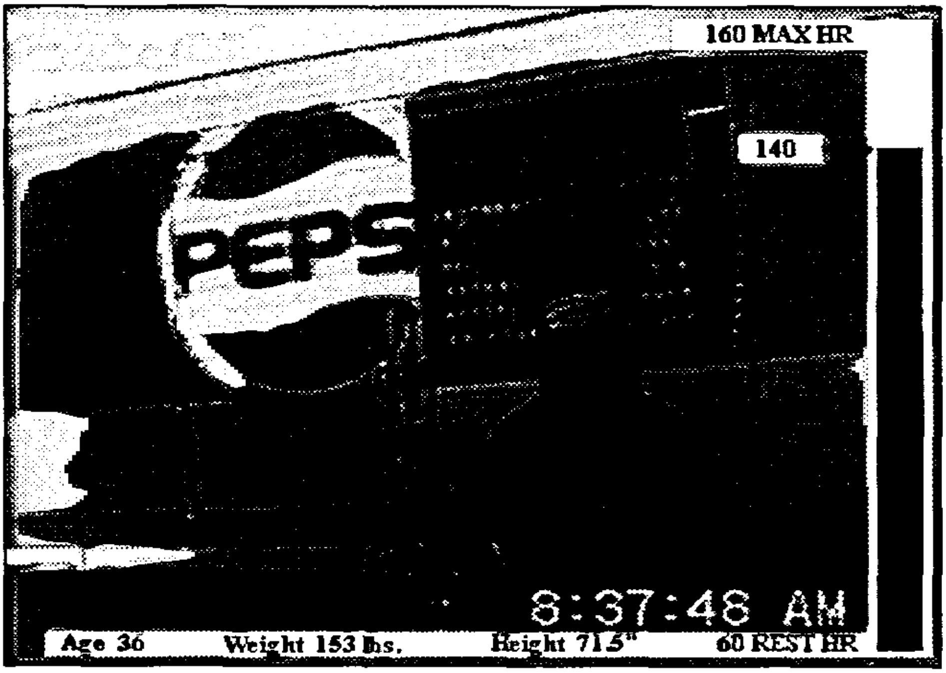

Figure 20. Heart rate overlay (bar graph) on videograph of worker getting soft drinks from top shelf in truck. **[Arrow points to driver-salesworker's current heart rate.]**

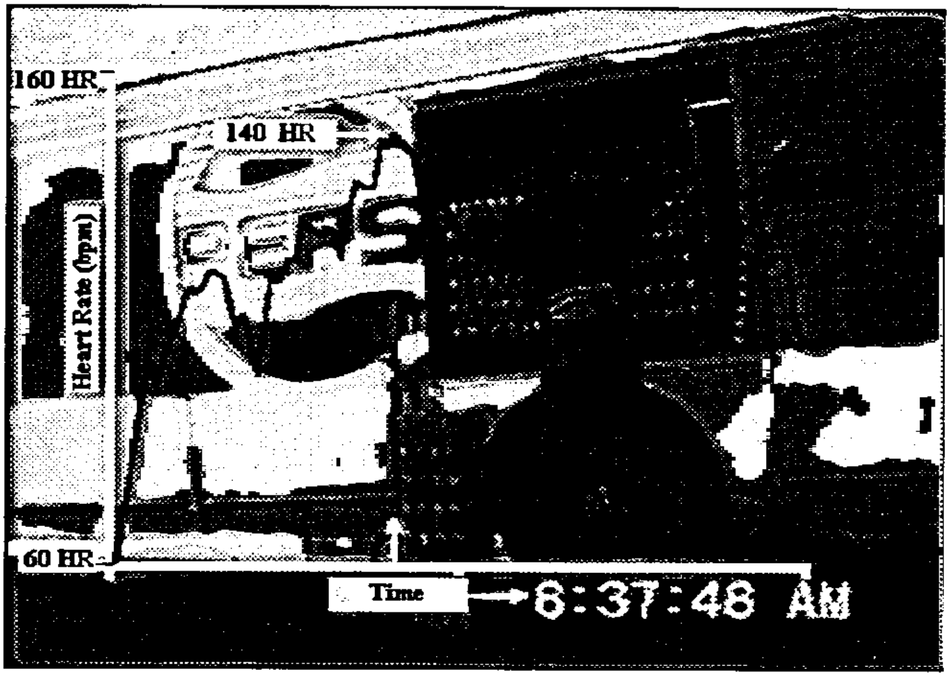

Figure 21. Heart rate overlay (chart) on videograph of worker getting soft drinks from top shelf in truck. **[Arrow points to driver-sales-worker's current heart rate.]**

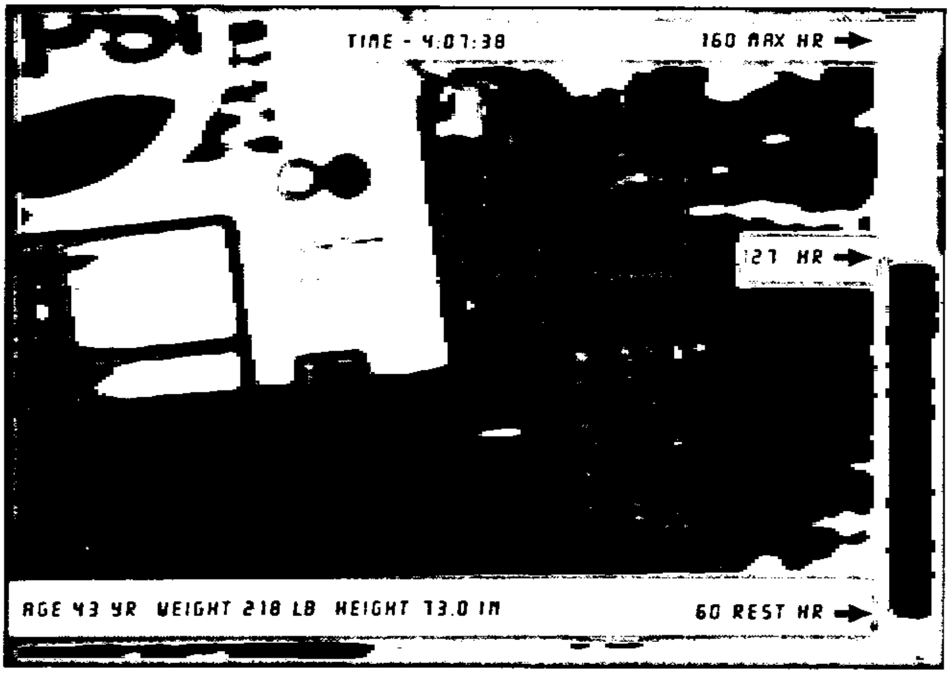

Figure 22. Heart rate overlay (bar graph) on videograph of worker pulling out shelf on beverage delivery truck.

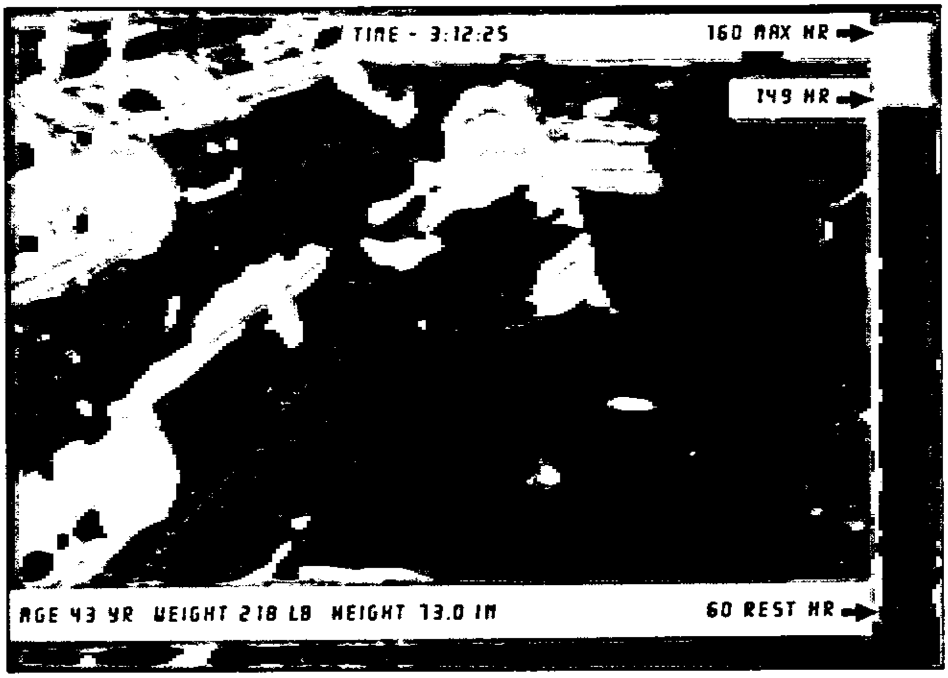

Figure 23. Heart rate overlay (bar graph) on videograph of worker in squatted position putting soft drinks on store shelf.

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

Biomechanical Analysis of Videotapes

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

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

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

Table 21

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

Job Analysis Worksheet

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

STEP 1. Measure and record task variables

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

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

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

ORIGIN RWL = 51 × 1.0 × .85 × .88 × .95 × .75 × 1.0 = 27.2 lb

DESTINATION RWL = 51 × .1.0 × .94 × .88 × .1.0 × .75 × 1.0 = 31.6 lb

STEP 3. Compute the Lifting Index

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

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

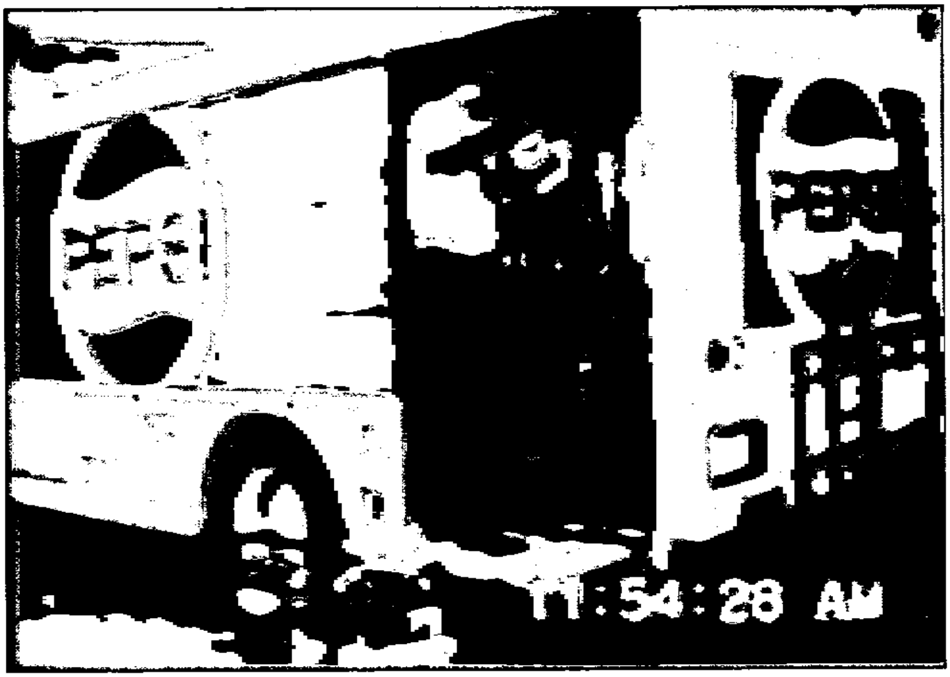

Figure 24. Driver-salesworker lifting aluminum cylinder containing pre-mix soft drink beverage (54.5 lb) from truck while standing on pullout platform.

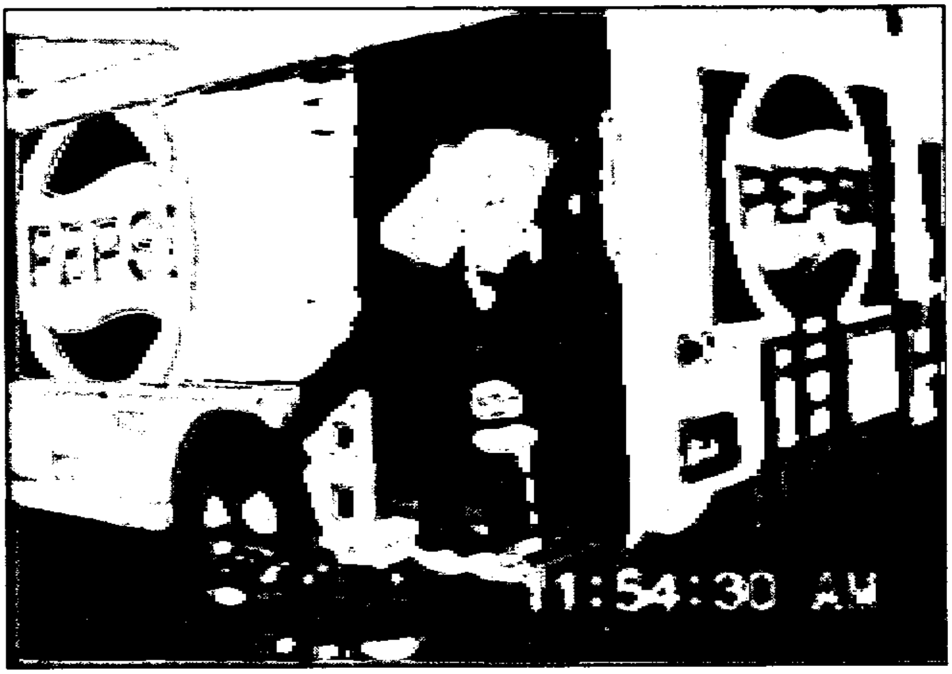

Figure 25. Driver-salesworker placing aluminum cylinder containing pre-mix soft drink beverage on pullout platform.

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

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

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

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

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

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

Material Handling

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

Beverage Material Handled

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

Beverage and Type of Load

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

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

Ergonomic Interventions

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

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

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

Hand Trucks

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

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

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

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

One-Year Follow-up

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

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

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

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

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

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

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

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

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

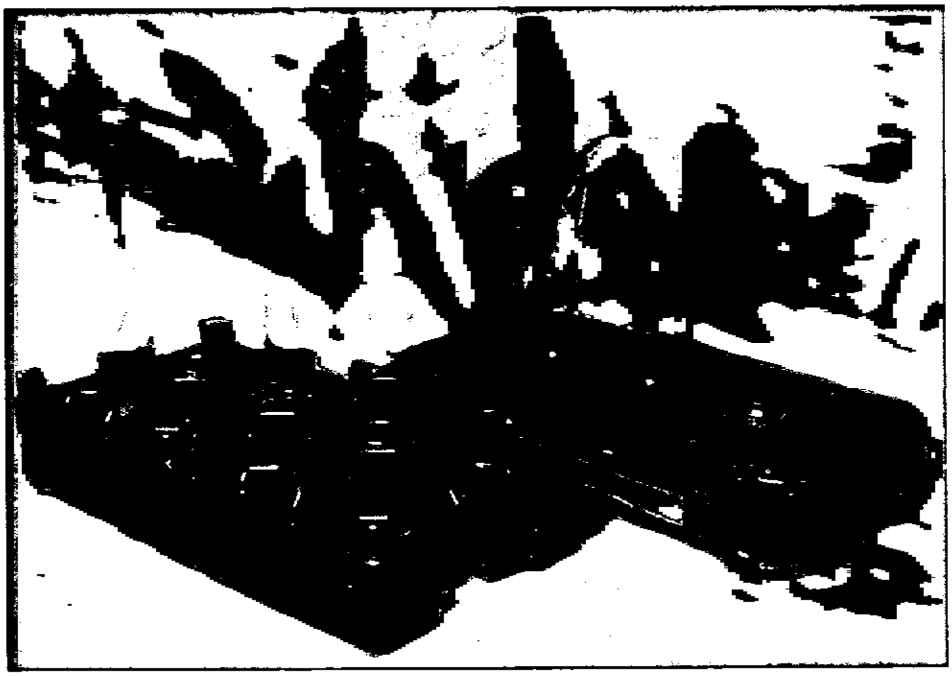

Figure 28. New plastic shells (left) and original plastic shells (right) for 8 pack, 2-L beverage containers.

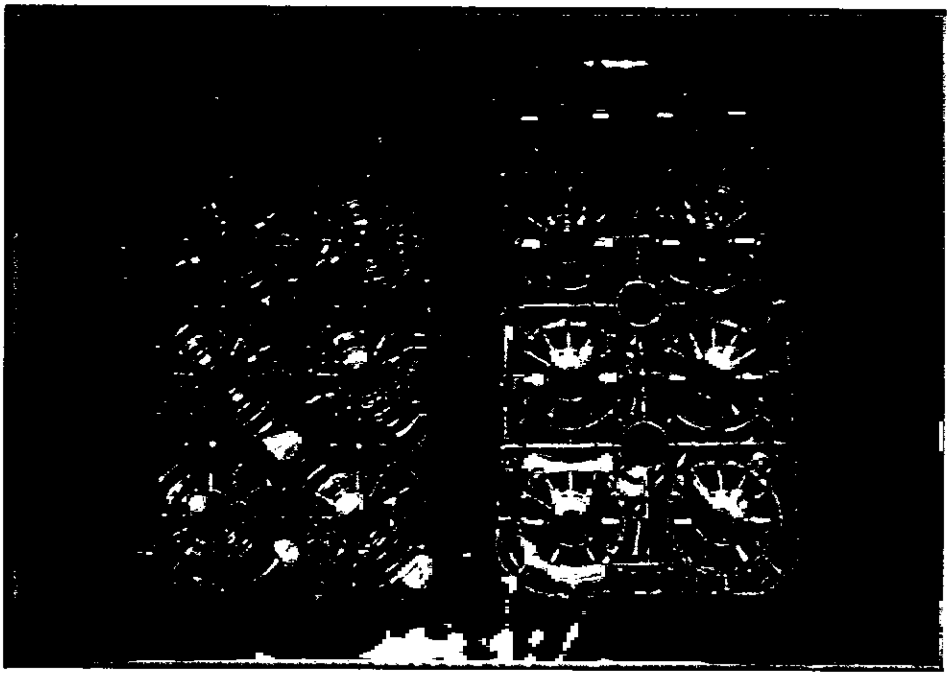

Figure 29. Bottom view of new (left) and original plastic shells (right) for 8-pack, 2-L beverage containers. **[Note: Fewer sharp edges on the bottom of the new shell made it easier to manually slide them when unstacking beverages.]**

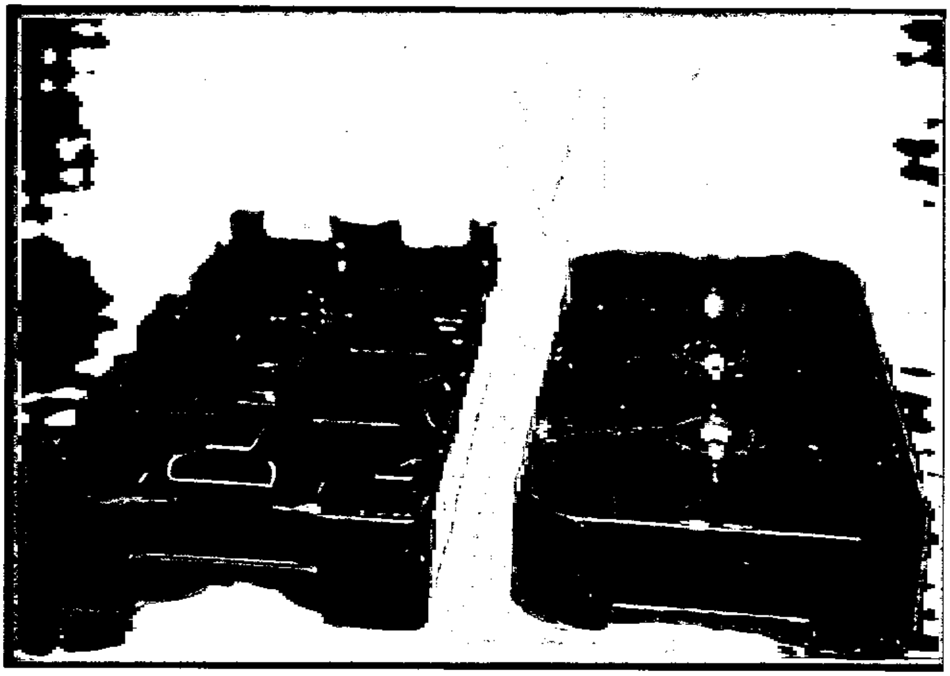

Figure 30. Profile of new (top left) and original plastic shells for 8-pack, 2-L beverage containers. **[Note: "Towers" along the shell perimeter and in the center to stabilize individual 2-L beverages and make the package easier to transport.]**

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

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

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

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