WALK-THROUGH SURVEY REPORT:

ERGONOMIC INTERVENTIONS FOR THE BEVERAGE DELIVERY INDUSTRY

AT

Coca-Cola Enterprises Incorporated
Cincinnati, Ohio

REPORT WRITTEN BY:
James D. McGlothlin, M.P.H., Ph.D.
Tracey M. Bernard, M.S.

REPORT DATE:
November 1992

REPORT NO.:
ECTB 181-11a

U.S. Department of Health and Human Services
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
4676 Columbia Parkway - R5
Cincinnati, Ohio 45226

PLANT SURVEYED:	Coca-Cola Enterprises Incorporated 5100 Duck Creek Road Cincinnati, Ohio 45227
SIC CODE:	2086
SURVEY DATE:	April 17-19, 1991
SURVEY CONDUCTED BY:	James D. McGlothlin, M.P.H., Ph.D.
EMPLOYER REPRESENTATIVES CONTACTED:	Jan Cipollone Coca-Cola Enterprises Incorporated Division Manager - Human Resources 5100 Duck Creek Road Cincinnati, Ohio 45227 John Rains Coca-Cola Corporate Manager - Human Resources Coca-Cola Plaza, Northwest P.O. Box 1778 Atlanta, Georgia 30301 Dr. William B. Hope Coca-Cola USA P.O. Drawer 1734 Atlanta, Georgia 30301
EMPLOYEE REPRESENTATIVES CONTACTED:	None - no union
ANALYTICAL WORK PERFORMED BY:	None performed

I. 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), 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 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.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the database of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

The Engineering Control Technology Branch of NIOSH is conducting a study of controls to prevent musculoskeletal injuries in the soft drink beverage delivery industry. In 1990, the soft drink industry had an injury and illness incidence rate of 21.5 cases per 100 full-time employees, and 12 lost workday cases per 100 full-time employees. This compares to general industry illness and injury rates of 8.8 cases and 4.1 cases, respectively, for private industry. Moreover, nearly three-fifths of the injury and illness cases in this industry were serious enough to require workers to take time off from their jobs or be assigned duties restricted to light work or a shortened schedule.[1]

The soft drink beverage industry will be the focus of this study because of its size, manual material handling (MMH) problems, and documented MMH risk factors. Much of the information and technology developed in the study of the soft drink industry can be transferred to the other beverage delivery industries, when such technology has been proven effective.

Based on the information gathered by NIOSH researchers to date, several risk factors for musculoskeletal disease and injury have been associated with beverage delivery. It is concluded that engineering controls, design modifications, and improved work practices are needed in this industry to reduce musculoskeletal disease and injury. However, there is very little information in the literature which evaluates the effectiveness of such controls.

On April 17-19, 1991, researchers from NIOSH conducted a site visit at Coca-Cola Enterprises Incorporated in Cincinnati, Ohio. The purpose of the site visit was to: (1) identify job tasks with potential to cause or aggravate musculoskeletal injuries, (2) determine the feasibility of ergonomic controls to decrease the potential of such injuries, and (3) use this information to help develop a study protocol to evaluate, reduce, and prevent musculoskeletal problems in the soft drink beverage delivery industry.

The evaluation of musculoskeletal risk factors during beverage delivery included an informal interview of the deliverymen and videotaping of three delivery processes including: a rural route (April 17, 1991), a tank and box route (April 18, 1991), and a city route (April 19, 1991). The videotapes were used to perform an ergonomic assessment of the three jobs.

II. JOB DESCRIPTION

The Cincinnati-based Coca-Cola Enterprises Incorporated company bottles and distributes approximately 13 million cases of soft drink per year. They have 120 full-time beverage deliverymen. Deliverymen at this plant usually work 5 to 6 days per week, 10 to 12 hours per day. A typical day's delivery averages 16,000 to 17,000 lb; this amount may increase to 23,000 to 24,000 lb during peak beverage consumption seasons.

A deliveryman's responsibilities involve getting products from a truck prestocked at the warehouse to the customers' shelves. Customers include: grocery and convenience stores, hospitals, schools, etc. A typical delivery consists of: (1) manually lifting piece-by-piece boxes, cases, or tanks from the truck and placing them on a hand truck; (2) wheeling the hand truck to point of delivery specified by customer; and (3) manually unloading the hand truck and store products on display shelves or in storage areas. In the process, each item is manually handled a minimum of two times; often three to four times when sorting and pricing are required. Products delivered range from cases of cans, 2-L bottles, premix tanks, and 16-oz returnable bottles with weights of 22, 40, 52, and 60 lb, respectively. Total weights delivered daily per truck average 16,000 to 17,000 lb, but totals may increase to 23,000 to 24,000 lb during peak consumption seasons. A list of soft drink delivery products for this company, case weight and beverage, and case dimensions is shown in Table 1 below.

Table 1. Soft Drink Product List, Case and Product Weight, and Case Dimensions

PRODUCT	CASE WEIGHT (lb)		CASE DIMENSION (in)
	EMPTY	FULL	
NONRETURNABLES:			length x width x height
10-oz	9	25	16 x 11 x 6
16-oz	12	40	18 x 12½ x 7½
20-oz	15	52	18 x 12½ x 8½
CANS, 24-CASE PACK		22	16 x 10½ x 5
CASE OF 2-L (8-pack)		40	18 x 9 x 12
RETURNABLE BOTTLES		60	18½ x 12 x 12
CASE OF 1-L (12-pack)		30	14 x 10½ x 11
JUICES, 24 CANS (12-oz)		19	14½ x 10 x 5
BOTTLES (6½-oz)		31	15 x 10 x 8
ROOT BEER BOTTLE		39	15 x 10 x 10
BAG-IN-BOX		44	15 x 11 x 8
PREMIX TANK	9	52	------

III. HEALTH EFFECTS

Recently, there has been a dramatic increase in the occurrence of work-related musculoskeletal injuries and disorders. Some of this increase may be attributed to increased awareness by industry, labor, and government, as well as better reporting of these disorders. However, many of these injuries and disorders may be caused by changes in technology, and in production demands which expose employees to increased repetitive motion and other ergonomic risk factors such as awkward posture, force, temperature, static exertions, and reduced recovery time. Injuries and disorders of the musculoskeletal system occur when workers' jobs require repetitive, awkward, and/or forceful exertions. This category of soft tissue disorders may occur in the upper and lower limbs, and the back. Some disorders of the upper limbs, known collectively as Cumulative Trauma Disorders (CTDs), are diagnosed as tendinitis, synovitis, tenosynovitis, bursitis, ganglionic cysts, and carpal tunnel syndrome, and DeQuervain's disease. CTDs affect the tendons, tendon sheaths, and nerves of the involved area. Studies have shown that these disorders can be caused by activities associated with repetitive exertion, particularly if the tasks that require application of force in a awkward posture. Musculoskeletal injuries and disorders of the low back are associated with manual materials handling. Some risk factors of low back pain include: heavy manual handling, lifting, carrying, forward flexion of trunk, rotation of trunk, pushing/pulling, vibration, and slips and falls. Control of musculoskeletal injuries and disorders may be through engineering, work practice, personal protective equipment, and training. Additional information and references about the cause and control of CTDs, and musculoskeletal injuries and disorders, are shown in Appendix A of this report.

Throughout the workday, soft drink beverage deliverymen constantly encounter situations which place them at potential risk for developing musculoskeletal injuries. Typical risk factors that can result in musculoskeletal injuries include: heavy manual handling, frequent lifting, carrying, rotation of trunk, pushing/pulling, and truck vibration. Such risk factors may be exacerbated by individual risk factors such as: age, weight, muscle strength, job experience, fatigue, and smoking. Potential risk is further increased by consumers' demand for more products (i.e., increased material handling) and by improvements in the packaging, warehousing, and loading of products (i.e., more beverage volume handled). Development and use of plastic bottles and aluminum cans in place of returnable glass bottles has increased the amount of product which can be delivered by each truck. Instead of saving space to load a customer's returnable bottles, this space can be loaded with products for delivery; thus increasing the amount delivered. Improvements in the trucks such as an increased number or size of bays also allows for the delivery of a larger amount of products. Each of these improvements allow for larger deliveries for each truck; however, there is still only one driver per truck who must unload and deliver an increased amount.

IV. METHODS

In order to evaluate potential job risks to deliverymen, NIOSH researchers performed an ergonomic assessment of their jobs. This assessment consisted of: (1) discussions with the three deliverymen about risk factors associated with their route delivery, (2) observations of the delivery process and noting potential risk factors associated with beverage delivery, (3) videotaping delivery of three routes, (4) biomechanical evaluation of musculoskeletal stress during manual material handling activities, and (5) recording working dimensions of delivery equipment including truck cabs, bays, and two-wheel hand trucks. Discussions, observation, videotaping, biomechanical modeling, and recording the physical dimensions of the truck and two-wheel hand trucks provided a better picture of potential risk factors, and it helped to formulate a plan for ergonomic interventions to reduce musculoskeletal injuries. For more information on the health effects of manual material handling, a summary is shown in Appendix A of this report.

Biomechanical evaluation of musculoskeletal forces on the upper limbs, back, and lower limbs was performed using the University of Michigan 2D Static Strength Prediction Program Version 4.0™.[2] The biomechanical evaluation showed that certain tasks exceed a worker's biomechanical and static strength capabilities, putting workers at risk for developing musculoskeletal disorders. The Work Practices Guide for Manual Lifting provides a comprehensive explanation of NIOSH allowable limits and maximum permissible limits for lifting tasks.[3] When the allowable limits are exceeded by certain job tasks, the implementation of engineering or administrative controls is recommended.

For the biomechanical evaluation, anthropometric data was adjusted to the dimensions, size, and weight of a 50th percentile American male population. Posture and link angles were determined from stop action analysis of the videotapes filmed during actual deliveries. The evaluation criteria used to evaluate material handling risk factors in this study are explained below.

Evaluation Criteria for Risk of Back Injury

The NIOSH Work Practices Guide for Manual Lifting,[4] was developed using medical, scientific, and engineering resources to develop quantitative recommendations regarding the safe load weight, size, location, and frequency of a lifting task. The recommendations assume that:

a. the lift is smooth;

b. the lift is two-handed and symmetric in the sagittal plane (directly in front of the body with no twisting during the lift);

c. the load is of moderate width, e.g., 30 in or less;

d. the lift is unrestricted;

e. the load has good couplings (handles, shoes, floor surface); and

f. the ambient environment is favorable.

It is further assumed that other material handling activities such as holding, carrying, pushing, and pulling are minimal; that the individual performing the lifting activities is at rest when not lifting; and those involved in lifting are physically fit and accustomed to labor.

The formula used to analyze the various tasks is as follows:

Action Limit (AL) (lb) = 90 (6/H) (1-.01|V-30|) (.7+ 3/D) (1-F/Fmax); (Maximum Permissible Limit (MPL) = 3 AL); where:

H = horizontal location forward of midpoint between ankles at origin of lift
V = vertical location at origin of lift
D = vertical travel distance between origin and destination of lift
F = average frequency of lift (lifts/minute)

Fmax = maximum frequency which can be sustained (table of values provided in Work Practices Guide)

Tasks analyzed in this manner are divided into three categories:

1. those above the Maximum Permissible Limit (MPL) which are considered unacceptable and which require engineering controls;

2. those between the AL and MPL which are unacceptable without administrative or engineering controls; and

3. those below the AL which are believed to represent nominal risk to most industrial work forces.

The Work Practices Guide indicates that corrective action is needed for jobs which exceed the Action Limit. The incidence and severity rates of musculoskeletal injury have been found to increase in populations "exposed to lifting conditions" described by the Action Limit. It has been determined that over 75 percent of women and over 99 percent of men could (safely) lift loads described by the Action Limit. A study used a simple percentage capable index based upon psychophysical strength concluded from a study of 191 cases of low back pain that the proper design of manual handling tasks can reduce up to one-third of industrial back injuries.[5]

Recently, NIOSH released evaluation criteria for evaluating risk of back injury which included additional risk factors and hand/container coupling. Like the 1981 guide, the 1992 version, called the "Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks,"[6] was developed using medical, scientific, and engineering resources to develop guidelines for manual materials handling. However, the 1992 version includes asymmetric lifting and hand/container coupling guidelines. The new guide has one weight limit which is called the recommended weight limit (RWL). The formula and tables are shown in Appendix B. This formula was not available during the evaluation of this survey, and was not used to analyze data in this report. However, the revised NIOSH equation may show that there is an increased risk in soft drink beverage container handling when twisting (asymmetric) and containers with no handles are used. Future studies should use the revised NIOSH equation to evaluate manual material handling jobs.

V. RESULTS - ERGONOMIC EVALUATION AND ANALYSIS

A. WORK CONTENT

A summary of the steps followed in a delivery includes: drive to location of delivery, park, unpack hand truck, scan order form, lift appropriate bay doors, load required products from truck to hand truck, wheel loaded hand truck to customer storage, unload hand truck contents onto shelves, and continue the same process until delivery is complete.

1. Rural Route

A total of 423 boxes and tanks were delivered totaling 9500 lb. Each item was lifted a minimum of two times: off the truck onto the hand truck and then off the hand truck onto the customer's shelves. An estimated 50 percent of the items were rehandled a third or fourth time when the driver sorted beverage cartons to find a specific item to fill an order. Through handling and rehandling, approximately 23,750 lb were lifted and handled by the rural driver.

2. Tank and Box Delivery

A total of 145 boxes and tanks were delivered including: 56 tanks, 75 boxes, and 10 tanks of carbon dioxide with weights of 52, 44, and 10 lb, respectively. Approximately 6400 lb were delivered; however, it is estimated that the driver lifted a total of 16,000 lb through rehandling and sorting.

3. City Route

Delivery of 654 boxes and tanks including cans, 2-L plastic bottles, nonreturnable glass bottles, bag-in-box, and tanks of carbon dioxide totaled 16,890 lb. By including the second handling for delivery and the rehandling during sorting, it is estimated that this driver lifted a total weight of 42,200 lb.

B. BIOMECHANICAL EVALUATION

Described below is the biomechanical evaluation of musculoskeletal forces on the upper limbs, back, and lower limbs performed for rural, tank and box, and city drivers. The evaluation was done using the University of Michigan 2D Static Strength Prediction Program Version 4.0™ and the NIOSH Work Practices Guide for Manual Lifting.

1. Rural Driver

a. Stooping to lift bag-in-box weighing 44 lb from the ground causes 891 lb of compressive force on the back, which exceeds the NIOSH allowable limit (AL) of 770 lb. The strength required to perform this task also exceeds the NIOSH AL for the hip and ankle (Figures 1a, 1b, and 1c).

b. Bending and twisting to put two cases of 2-L (total weight 80 lb) onto a hand truck exceeds the AL and causes 784 lb of compressive force on the back. Elbow and hip AL were also exceeded by this task (Figures 2a, 2b, and 2c).

c. Awkwardly carrying three cases of cans (66 lb) through crowded aisles of limited space exceeds the hip AL and creates 863 lb of compression on the back (Figures 3a, 3b, and 3c).

2. Tank and Box Driver

   a. While delivering a handcart and load (206 lb) down a set of stairs, the force necessary to restrain the load creates 1713 lb of compressive force on the back. This force exceeds the MPL for back compression, elbow, shoulder, L5/S1, and hip joints, thus requiring task redesign (Figures 4a, 4b, and 4c).

   b. The delivery in which a hand truck containing six bag-in-boxes was pushed to a loading dock, and the boxes were manually lifted from the hand truck onto the 2.5-ft high loading dock created excessive stresses in both the initial lifting stage and the final lowering stage. The initial lift created 787 lb of compressive force on the back to exceed the AL for back compression. Hip AL was also exceeded. The lowering stage, performed above the worker's shoulder, exceeded the L5/S1, hip, and ankle ALs (Figures 5a, 5b, and 5c).

3. City Driver

   a. An extended reach, nearly to the roof of the truck while standing on the ground to lower a case of 2-L (40 lb) exceeds the hip and ankle ALs for this worker (Figures 6a, 6b, and 6c).

   b. In the shorter bays, reaching over a stack of products to a deeper stack requires an awkward stooping posture. The necessary posture to lift a 22-lb load causes 825 lb of back compression and also exceeds the allowable hip, knee, ankle, and L5/S1 limits (Figures 7a, 7b, and 7c). Lifting a larger 60-lb product would cause 1310 lb of back compression, almost double the AL (Figures 8a and 8b).

   c. In order to exert the breakaway forces needed to set a four-wheel cart and load (500 lb) into motion, more than 2001 lb of back compression occur. This value greatly exceeds the maximum permissible limit (MPL) of 1430 lb. This task requires job redesign and engineering controls to bring forces within the acceptable limit (Figures 9a, 9b, and 9c).

   d. Once the cart is in motion, the employee exerts a pulling force approximately equal to his body weight to keep the cart moving. When pulling the cart, 793 lb of back compression occur, thus exceeding the AL. ALs are also exceeded at the L5/S1 joint, hip, knee, and the ankle exceeds the MPL (Figures 10a, 10b, and 10c). If the cart is pushed instead of pulled, the back compression reduces to 489 lb; however, the L5/S1 and knee forces exceed the MPL and the forces at the hip joint exceed the AL (Figures 11a and 11b).

VI. DISCUSSION AND CONCLUSIONS

The preliminary assessment of soft drink beverage delivery for this product showed that there was excess musculoskeletal stress placed upon all three employees during the beverage delivery process. Biomechanical analysis of selected material handling tasks during the work cycle provided ample evidence to show that there was cumulative musculoskeletal stress over the work shift. For example, a conservative estimate of total weight lifted for a workday is well above 15,000 lb for each of the three jobs. The amount of weight handled on a daily basis puts these workers in a very exclusive group of individuals who have developed the strength and endurance to sustain such work loads. Each of the jobs had risk factors that were common to all three. Some of the common risk factors were: (1) excessive biomechanical loading of the spine during the delivery process, especially during loading and transport of the two-wheel hand trucks; (2) mechanical trauma on the back of the wrist and forearm caused by the sharp edge of the "U-loop" on the hand truck (the U-loop presses against the back of the wrist and forearm when the hand truck is manually balanced during loading and delivery); and (3) excess search time and musculoskeletal stress for specific beverages by lifting and closing bay doors during delivery. However, there were several risk factors that were characterized by the type of route the worker performed. Examples of these differences are discussed below.

During rural route delivery, it was noted that there was excessive searching for beverages because of the diversity of soft drink products and because of the numerous stops and deliveries. At several of the stops, there was poor access to the stores because of uneven surfaces, gravel surfaces, obstacles and debris, and makeshift delivery ramps. Once inside the store, there was often limited aisle and working space to set up beverage displays. It also was noted that at some stops there was not enough space to pull off the country roads, thus posing a hazard to the worker as he unloaded beverages from the truck as vehicles passed nearby.

During tank delivery, it was noted that this worker was faced with hauling unstable loads (i.e., tanks lying sideways on a two-wheel hand truck) up and down dark stairwells, and around corners of stairs (because of the larger clearances needed for the long tanks). Steep delivery ramps were a problem due to the increased forces required to keep the load in control. In addition, ramps can be a safety problem in the winter because of slip and fall hazards associated with snow and ice. Also, there were more loading docks on this route which required double handling where the tanks were unloaded from the truck onto the dock then loaded on the two-wheel hand truck for delivery to the customer. Another risk factor included the lack of handles for the "bag-in-box" beverages which could result in higher forces on the back during the delivery process. It was also noted that wooden pallets which supported the tanks inside the truck were not designed to keep the tanks from rolling about on the truck during transport.

City route delivery risk factors included very high forces on the back during pulling of loaded pallets of soft drink from the delivery area into the store. It was calculated that a fully loaded four-wheel cart weighed over 650 lb, and that a substantial amount of manual force was required to initiate movement of the cart. The pallets which are loaded outside and weigh much more also require such movement and high forces are needed to initiate movement of the loaded pallet jacks. There are also seasonal demands such as special setup areas for the sale of beverages outside the normal aisle space. The hands were used to manually rip open plastic which encased the 2-L bottles when the shelves were being stocked.

In conclusion, the biomechanical analysis of job tasks showed that frequently compressive back forces exceeded the NIOSH allowable limits (AL) and should be controlled through administrative or engineering controls. In some instances, particularly delivering a loaded hand-truck down a set of stairs, the NIOSH maximum permissible limit (MPL) is exceeded. Tasks in which compressive back forces exceed the MPL require the implementation of engineering controls. The following section contains recommendations for using engineering controls, work practices, and administrative controls to reduce the potential for an overexertion injury during the beverage delivery process.

VII. RECOMMENDATIONS

The purpose of this soft drink beverage delivery assessment was to: (1) collect information on beverage delivery risk factors, (2) devise methods for ergonomic interventions, and (3) use this information to develop a NIOSH scientific study protocol for the soft drink beverage delivery industry. During this field survey, risk factors were observed, and based on an analysis of this information, the following recommendations are presented to reduce the potential for musculoskeletal injuries at this plant. These recommendations, based on the principles of ergonomic controls, may be used to develop the NIOSH project protocol control section. The effectiveness of such controls is yet to be proven.

Based on the information gathered during this preliminary assessment of risk factors for beverage delivery at this plant, it was determined that no single engineering and/or administrative control would sufficiently reduce musculoskeletal disorders for these operations. Instead, a number of controls may be applied to reduce these disorders. The following list describes some of the controls which may, when used together, decrease and prevent musculoskeletal injuries at this plant.

A. ENGINEERING CONTROLS

1. Reduce the amount of handling, rehandling, sorting, and opening of bay doors:

    a. Develop a new product layout form designed in the shape of a map or diagram of the truck. The diagram should detail the contents of each bay. This will help reduce musculoskeletal stress and search time for soft drink beverages by knowing where the beverages are before opening bay doors.

    b. Use a clipboard to hold order forms and product layout map. Magnetize the clipboard so it can be attached to the nearest truck bay and still be visible while driver is unloading. The use of the clipboard will free the driver's hands to unload and will also reduce the chances of lost order forms. An alternate suggestion is to computerize the product inventory and use a computerized clipboard to input/output soft drink delivery information.

   c. Tag empty bays where product has already been unloaded so that driver will not open doors unnecessarily.

   d. Consider purchasing "multi-shelf" storage racks with separate storage compartments to organize and reduce multiple handling of different soft drink brands. The "multi-shelf" storage racks can be engineered to fit into truck bays.

2. Wrap the hand truck "U-loop" with foam or rubberized padding to reduce stress to wrists and lower arms.

3. For large orders (two pallets and larger), pack pallets in warehouse. At the delivery site, use a forklift (electric preferable) to unload full pallets.

4. Provide hand holds on all boxes, including bag-in-boxes. Standardize the size and location of hand holds to be consistent. Hand holds should be designed to fit the 95th percentile male hand width which is 3.8 inches. Providing hand holds of this size will allow easy access for workers ranging from the 5th percentile female to the 95th percentile male.[7]

5. Replace all tanks that do not have "safety collars." The safety collars have built-in handles to reduce mechanical stress during handling.

6. Develop new labeling system on boxes:

   a. Label all sides of existing boxes for easier identification of box contents and to reduce material handling during searches for specific beverages. Consider using an ink roller instead of printed labels to conserve resources.

   b. Use soft drink beverage cardboard boxes with large cutouts in the sides of the box. Contents are easily visible and will reduce search time, material handling, and musculoskeletal stress, as well as provide better hand/container coupling.

7. Change the form of packaging:

   Boxes are typically taped together, and the tape often tears away and drivers must catch the falling boxes. Consider placing the two boxes in a cardboard tray.

8. Consider having two hand trucks per deliveryman; one standard two-wheel hand truck and one three-position hand truck. The three-position hand truck can be used as a four-wheel cart, so that larger deliveries will require less time and fewer trips will be required. This hand truck also can assume a position in which it remains tilted at an angle. The tilted angle is ideal for tank deliveries as it frees both hands for lifting tanks. The three-position hand truck also assumes the two-wheel position consistent with hand trucks in present use.

9. Provide trucks with a flip-down flag, magnetic sign, or flashing light, for use when unloading beverages onto or near a busy street, especially street corners. The flag, sign, or flashing light should be easy to see by other motorists. The flag, sign, or flasher may be attached to the side rear of the truck where the deliveryman is working.

10. Pallets used for tank delivery/return should have thinly spaced wooden slats or should be on plastic skids so that tanks do not tip and create potential hazards during transportation. Lightweight plastic skids with preformed "pods" will allow easy placement and safe storage of tanks during transportation.

11. Provide a knife/blade to remove plastic wrap from beverage cartons secured onto pallets.

12. Drivers should consider carrying wooden or rubber door wedges to prop open doors when doors are located at the top or bottom of stairs. This will reduce the potential for an injury.

13. Work with customers to install small access ramps to curbs and stairs to ease hand truck deliveries.

B. WORK PRACTICES

1. Work with warehouse loading to reduce the amount of sorting required by the driver to fill an order. Place only one type of product in each stack, with like products stacked deeper in the bay.

2. While sorting to fill an order, avoid placing products which will require lifting or reloading onto the ground.

3. Work with the customer to clear delivery and storage areas of obstructions and to widen delivery aisles. Plan ahead and scout area for potential hazards.

4. Avoid overstacking the hand truck. Extra boxes require awkward shoulder support and excess biomechanical loading on the back. Load stability decreases and visibility may be impaired when overstacking occurs.

5. Push hand truck instead of pulling. Pushing is biomechanically advantageous over pulling.

6. Park trucks as near as possible to the point of delivery.

7. Wheel hand truck as close as possible to point of unloading. Less work is required to push the hand truck than to carry loads.

8. When stacking 2-L bottles, lift only one bottle with each hand. When two bottles are lifted, increased stresses are produced on the fingers and hand.

9. Inflate tires on hand trucks to the proper air pressure. Make sure the air pressure is the same for both tires to make loaded hand truck handling easier.

10. Use the "buddy system" to handle large pallet loads. For example, after a pallet is loaded with beverage, ask for assistance to initially move the load.

C. ADMINISTRATIVE CONTROLS

1. Encourage drivers to inform the warehouse of route changes so that the warehouse can perform appropriate changes in loading the truck.

2. Encourage drivers to store their hand truck on the front of the truck. The visibility of the hand truck will reduce the chances of leaving the hand truck at the last stop, and may protect them from traffic mishaps (i.e., rear-end collisions while loading the hand truck on the back of the truck).

3. Encourage customers to pay by check, or other means, rather than by paying the driver in cash. A safe or money vault built into the truck with a money slot, is a possible alternative.

VIII. REFERENCES

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IX. FIGURES

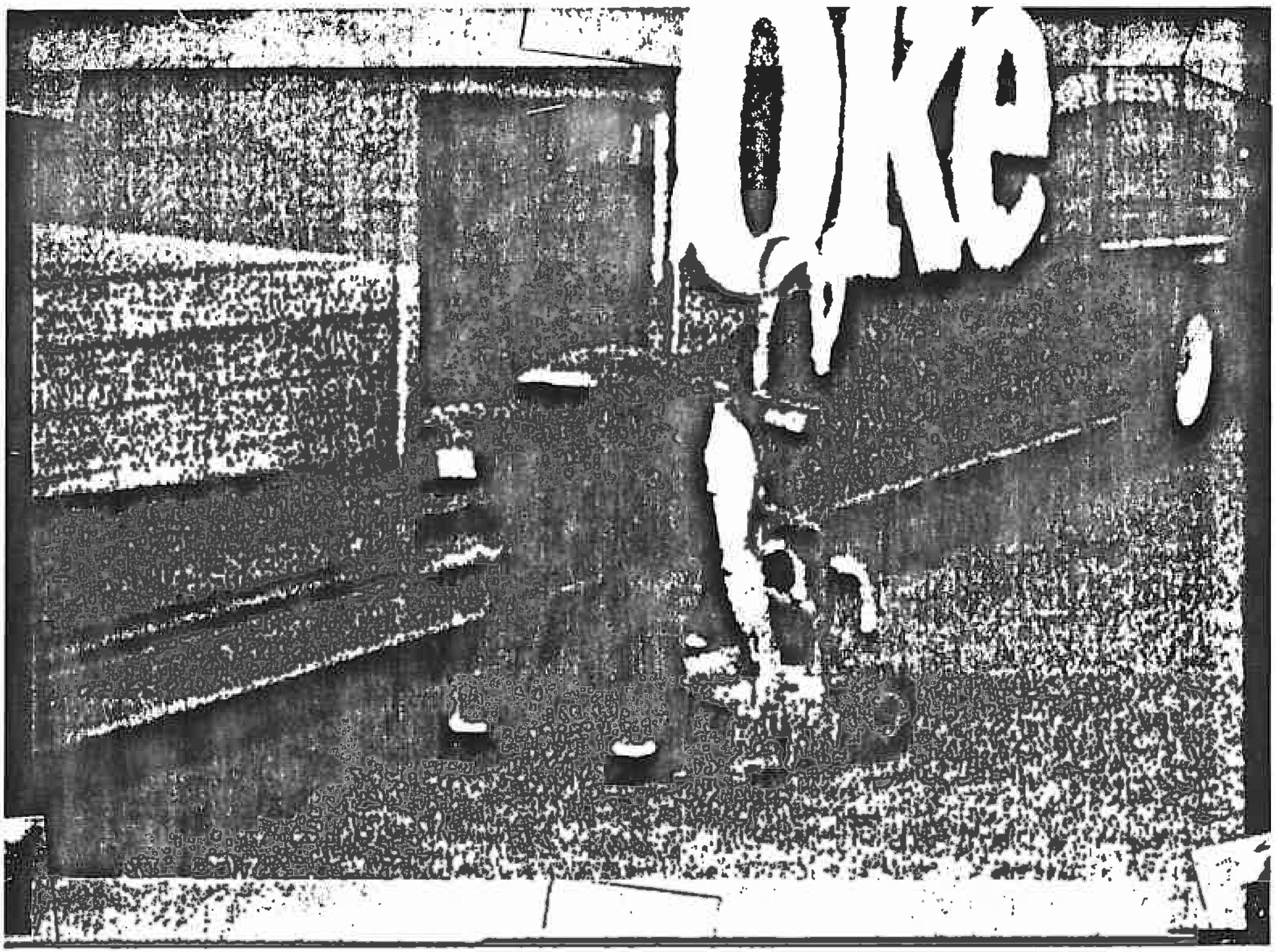

Figure 1a. Deliveryman lifting a bag-in-box weighing 44 lb from ground.

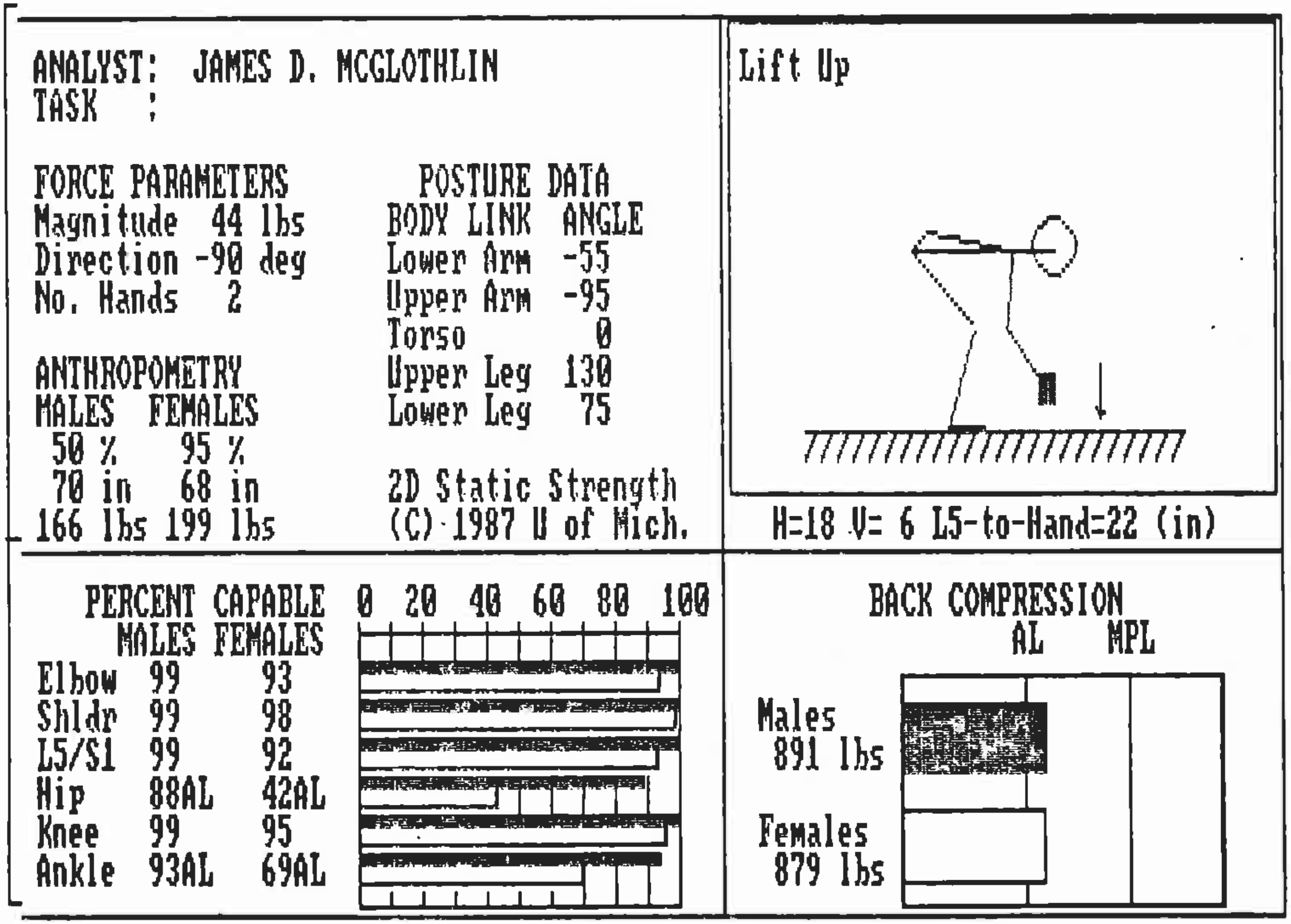

Figure 1b. Biomechanical analysis of deliveryman lifting a bag-in-box weighing 44 lb from ground.

STATIC STRENGTH PROGRAM

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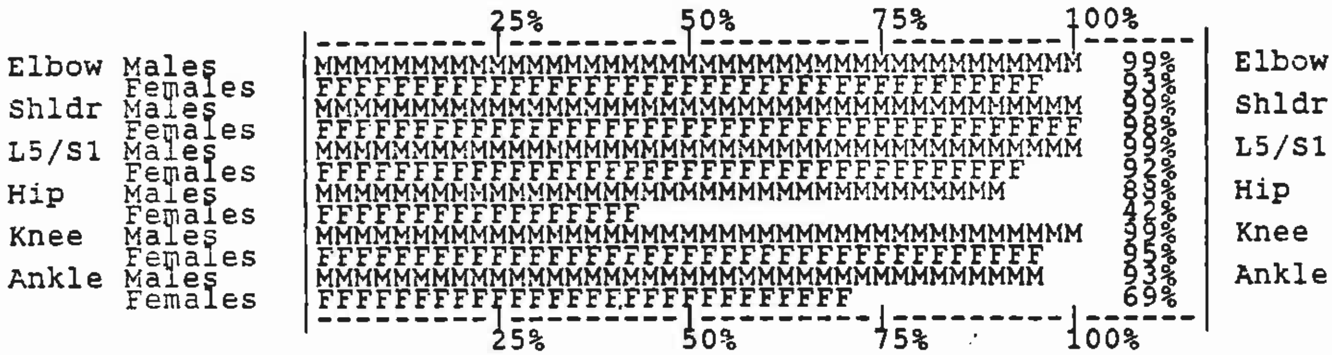
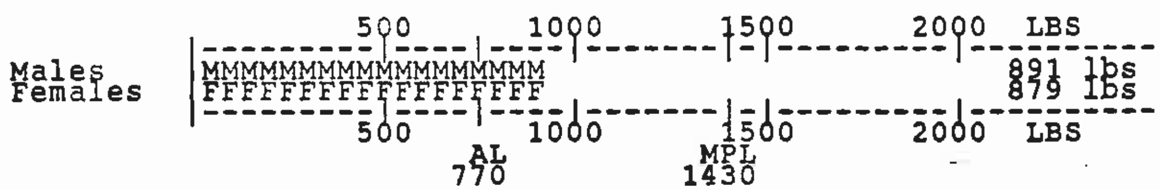
ANALYST:  JAMES D. MCGLOTHLIN                 Mon Jun 17 14:50:02 1991

TASK    :
   FORCE PARAMETERS                         POSTURE DATA
Magnitude    44 lbs                 LINK ANGLES FROM HORIZONTAL
Direction   -90 deg                      Lower Arm   -55 deg
No. Hands     2                          Upper Arm   -95 deg
                                         Torso         0 deg
   ANTHROPOMETRY DATA                    Upper Leg   130 deg
ITEM       MALES   FEMALES               Lower Leg    75 deg
%tile       50 %     95 %
Heigth      70 in     68 in              H =  18 in V =    6 in
Weight     166 lbs   199 lbs             L5/S1-to-Hand =   22 in
---------------------------------------------------------------------
```

PERCENT CAPABLE



BACK COMPRESSION




```
COF:  Males=0.00  Females=0.00          Balance Acceptable
---------------------------------------------------------------------
```

Figure 1c. Biomechanical summary information of deliveryman lifting a bag-in-box weighing 44 lb from ground.

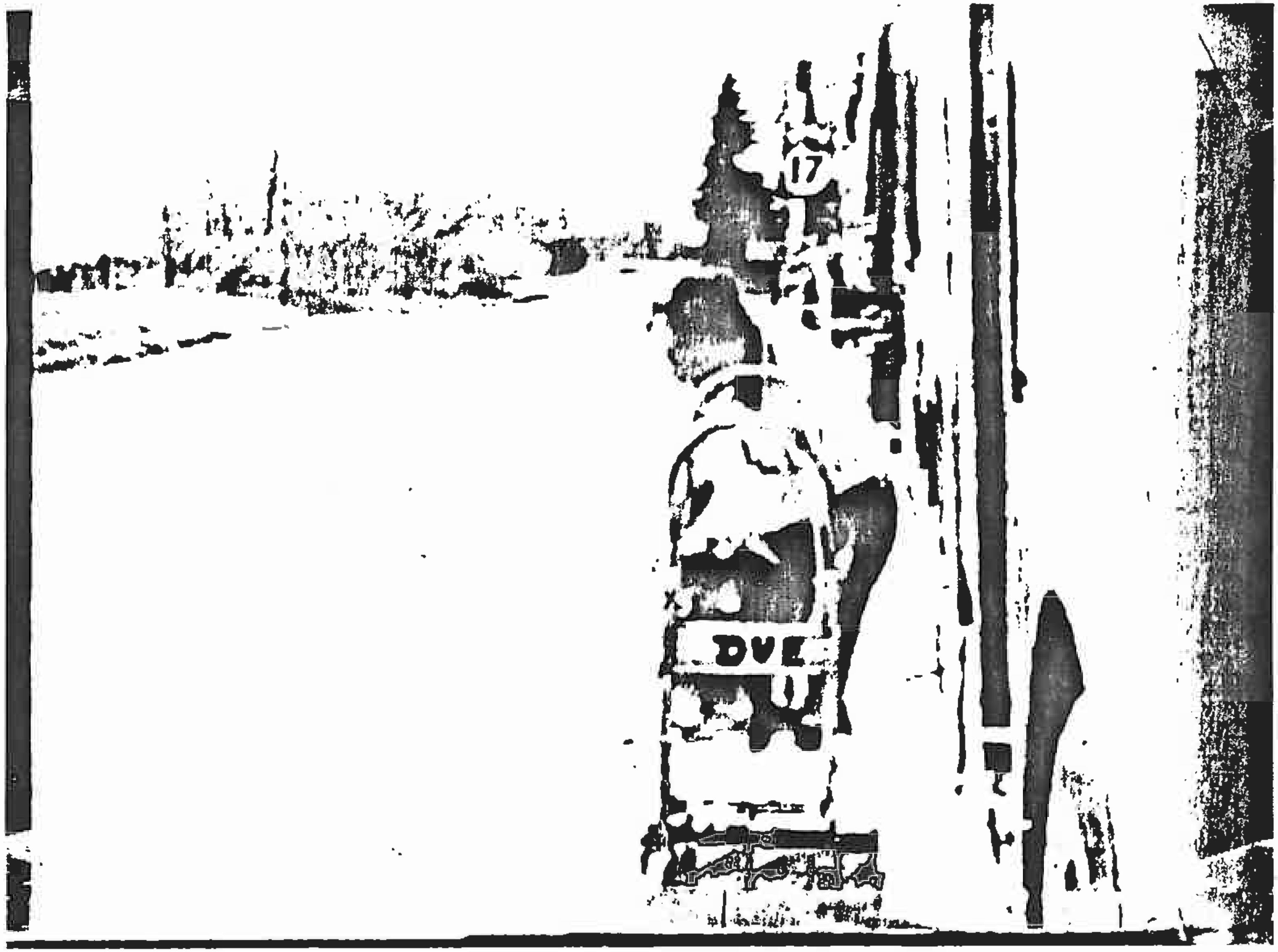


Figure 2a. Deliveryman lifting two cases of 2-L soft drink weighing 80 lb onto a hand truck.

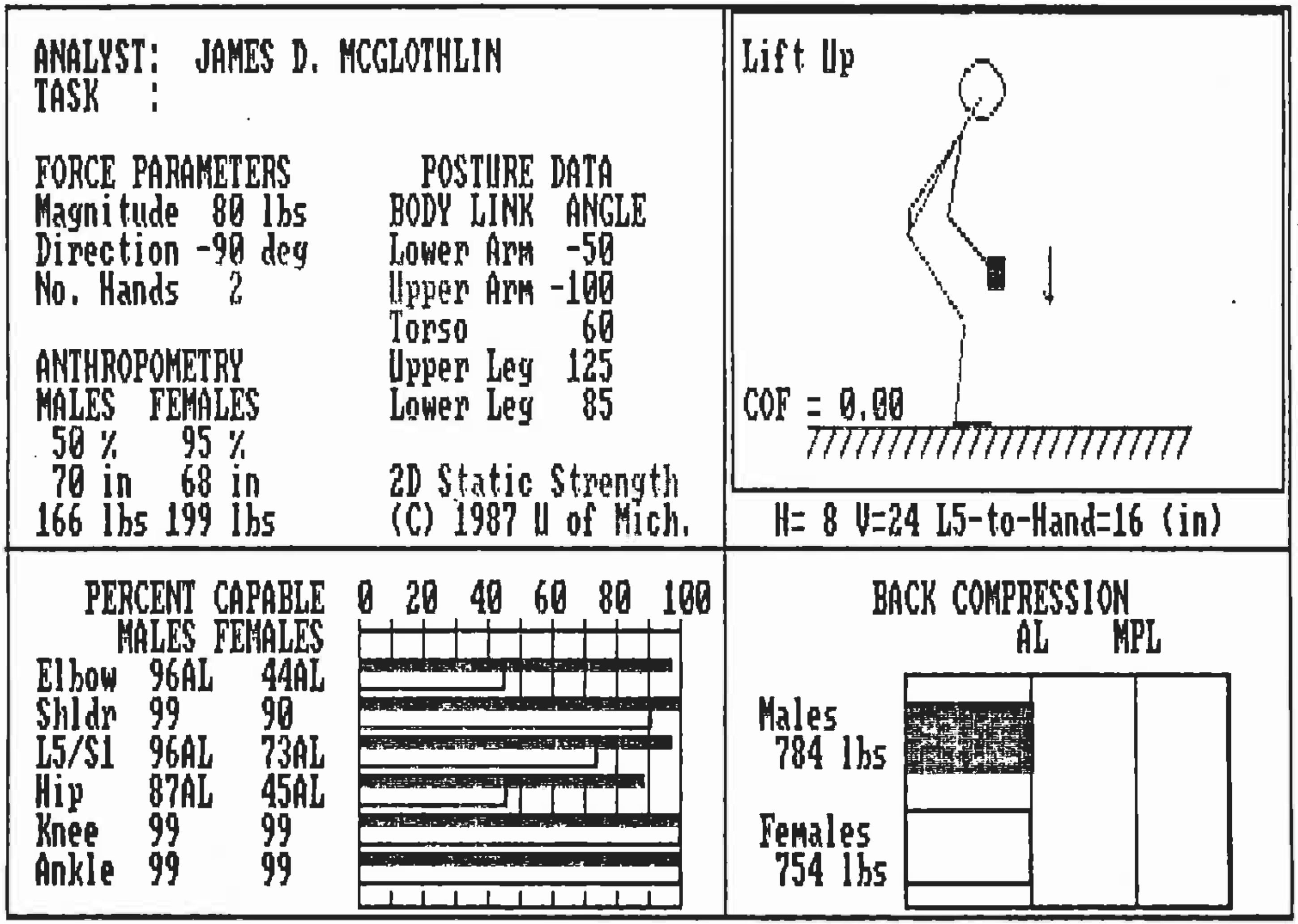


Figure 2b. Biomechanical analysis of deliveryman lifting two cases of 2-L soft drink weighing 80 lb onto a hand truck.

```
                         STATIC STRENGTH PROGRAM
----------------------------------------------------------------------
ANALYST:  JAMES D. MCGLOTHLIN                 Mon Jun 17 15:42:38 1991

TASK    :
   FORCE PARAMETERS                          POSTURE DATA
Magnitude    80 lbs                  LINK ANGLES FROM HORIZONTAL
Direction   -90 deg                       Lower Arm   -50 deg
No. Hands     2                           Upper Arm  -100 deg
                                          Torso        60 deg
   ANTHROPOMETRY DATA                     Upper Leg   125 deg
ITEM      MALES    FEMALES                Lower Leg    85 deg
%tile      50 %      95 %
Heigth     70 in      68 in               H =    8 in V =   24 in
Weight    166 lbs   199 lbs               L5/S1-to-Hand =   16 in
----------------------------------------------------------------------
                                 PERCENT CAPABLE
                          25%       50%       75%      100%
                |---------|---------|---------|---------|------|
   Elbow Males  |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM    96% |  Elbow
         Females|FFFFFFFFFFFFFFFFFFF                         44% |
   Shldr Males  |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   99% |  Shldr
         Females|FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF        90% |
   L5/S1 Males  |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM    96% |  L5/S1
         Females|FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF              73% |
   Hip   Males  |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM        87% |  Hip
         Females|FFFFFFFFFFFFFFFFFFF                          45% |
   Knee  Males  |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   99% |  Knee
         Females|FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF   99% |
   Ankle Males  |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   99% |  Ankle
         Females|FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF   99% |
                |---------|---------|---------|---------|------|
                          25%       50%       75%      100%
                                 BACK COMPRESSION
                         500      1000      1500      2000   LBS
                |---------|----|----|-------|-|---------|----------|
         Males  |MMMMMMMMMMMMMMMMM                          784 lbs |
         Females|FFFFFFFFFFFFFFFFF                          754 lbs |
                |---------|----|----|-------|-|---------|----------|
                         500      1000      1500      2000   LBS
                               AL          MPL
                              770          1430
COF:  Males=0.00   Females=0.00          Balance Acceptable
----------------------------------------------------------------------
```

Figure 2c. Biomechanical summary information of deliveryman lifting two cases of 2-L soft drink weighing 80 lb onto a hand truck.

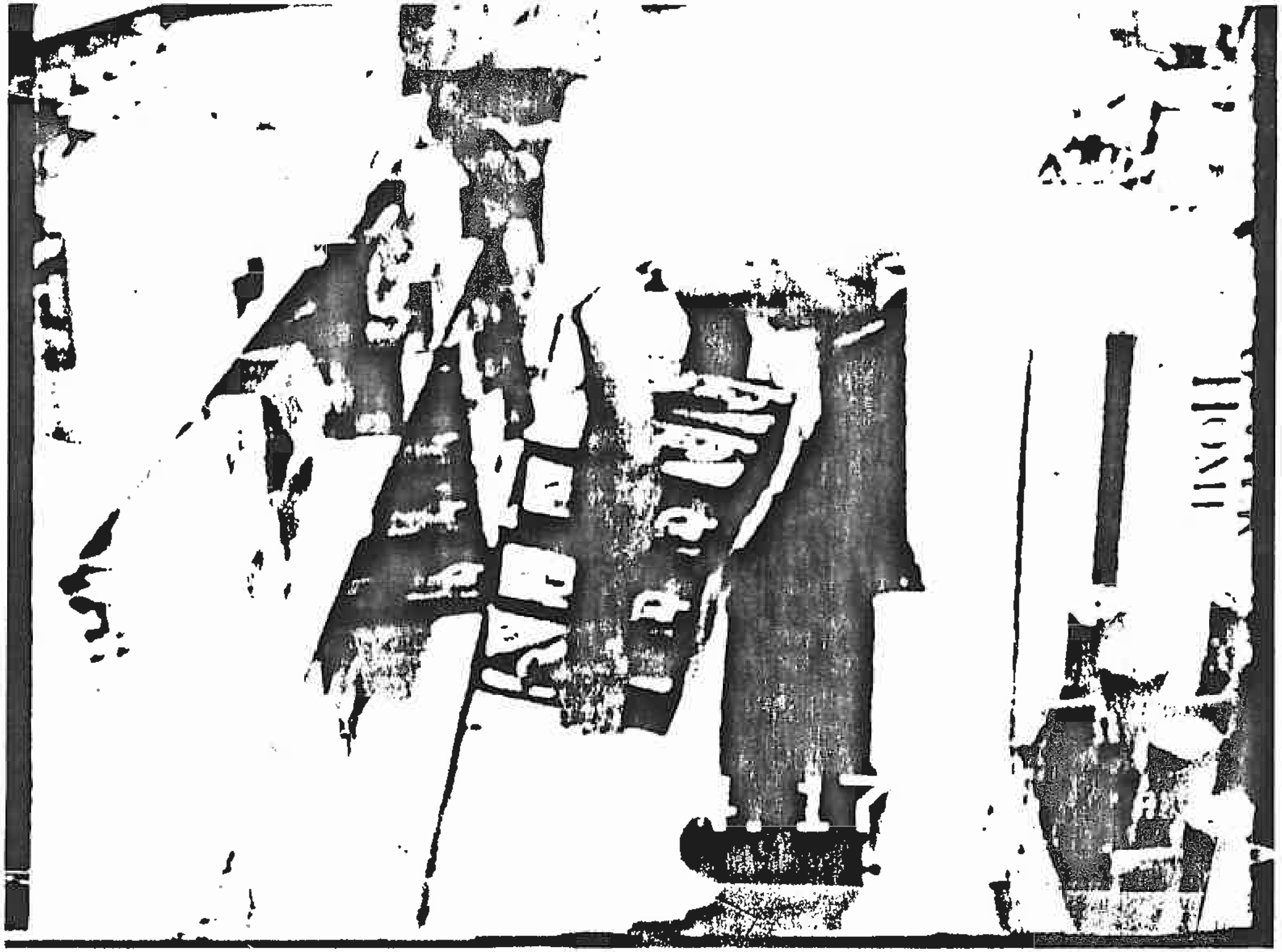


Figure 3a. Deliveryman lifting three 24-can cases of soft drink weighing 66 lb.

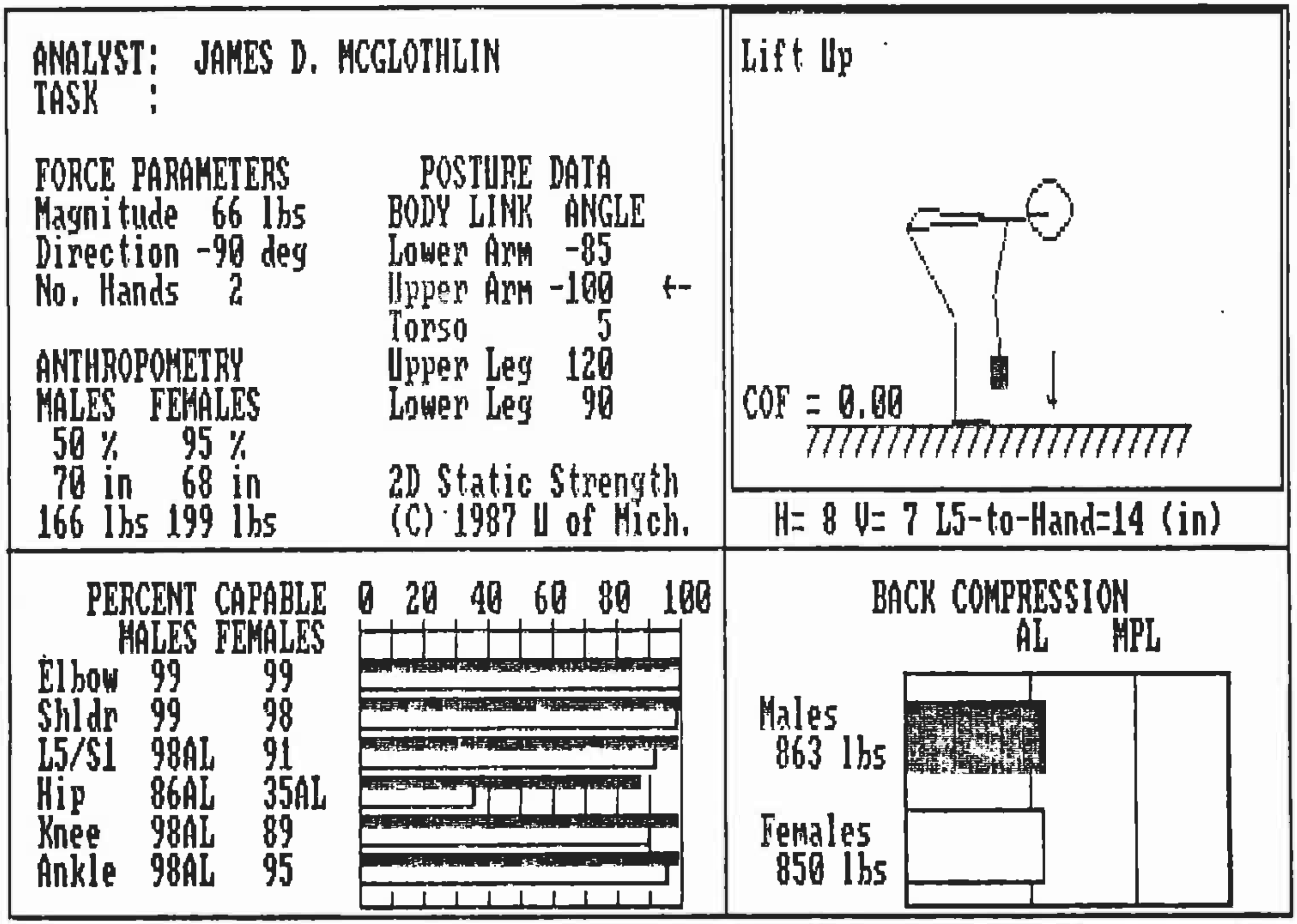


Figure 3b. Biomechanical analysis of deliveryman lifting three cases of 24-can soft drink weighing 66 lb.

STATIC STRENGTH PROGRAM

```
------------------------------------------------------------------------
ANALYST:  JAMES D. MCGLOTHLIN                 Mon Jun 17 15:30:52 1991

TASK   :

     FORCE PARAMETERS                          POSTURE DATA
Magnitude    66 lbs                LINK  ANGLES FROM HORIZONTAL
Direction   -90 deg                      Lower Arm  -85 deg
No. Hands     2                          Upper Arm -100 deg
                                         Torso        5 deg
     ANTHROPOMETRY DATA                  Upper Leg  120 deg
ITEM      MALES    FEMALES               Lower Leg   90 deg
%tile      50 %      95 %
Heigth     70 in      68 in              H =   8 in V =   7 in
Weight    166 lbs   199 lbs              L5/S1-to-Hand =  14 in
------------------------------------------------------------------------
                            PERCENT CAPABLE

                       25%       50%       75%      100%
                 |---------|---------|---------|---------|-----|
Elbow  Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  99% |  Elbow
       Females   |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF  99% |
Shldr  Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  99% |  Shldr
       Females   |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF  98% |
L5/S1  Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  98% |  L5/S1
       Females   |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF      91% |
Hip    Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM       86% |  Hip
       Females   |FFFFFFFFFFFFFF                            35% |
Knee   Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  98% |  Knee
       Females   |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF      89% |
Ankle  Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  98% |  Ankle
       Females   |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF     95% |
                 |---------|---------|---------|---------|-----|
                       25%       50%       75%      100%

                          BACK COMPRESSION
                      500       1000      1500      2000   LBS
                 |---------|----|----|-------|-|---------|---------|
         Males   |MMMMMMMMMMMMMMMMMMMM                  863 lbs |
         Females |FFFFFFFFFFFFFFFFFF                    850 lbs |
                 |---------|----|----|-------|-|---------|---------|
                      500       1000      1500      2000   LBS
                               AL            MPL
                              770           1430

COF:  Males=0.00  Females=0.00            Balance Acceptable
------------------------------------------------------------------------
```

Figure 3c. Biomechanical summary information of deliveryman lifting three cases of 24-can soft drink weighing 66 lb.

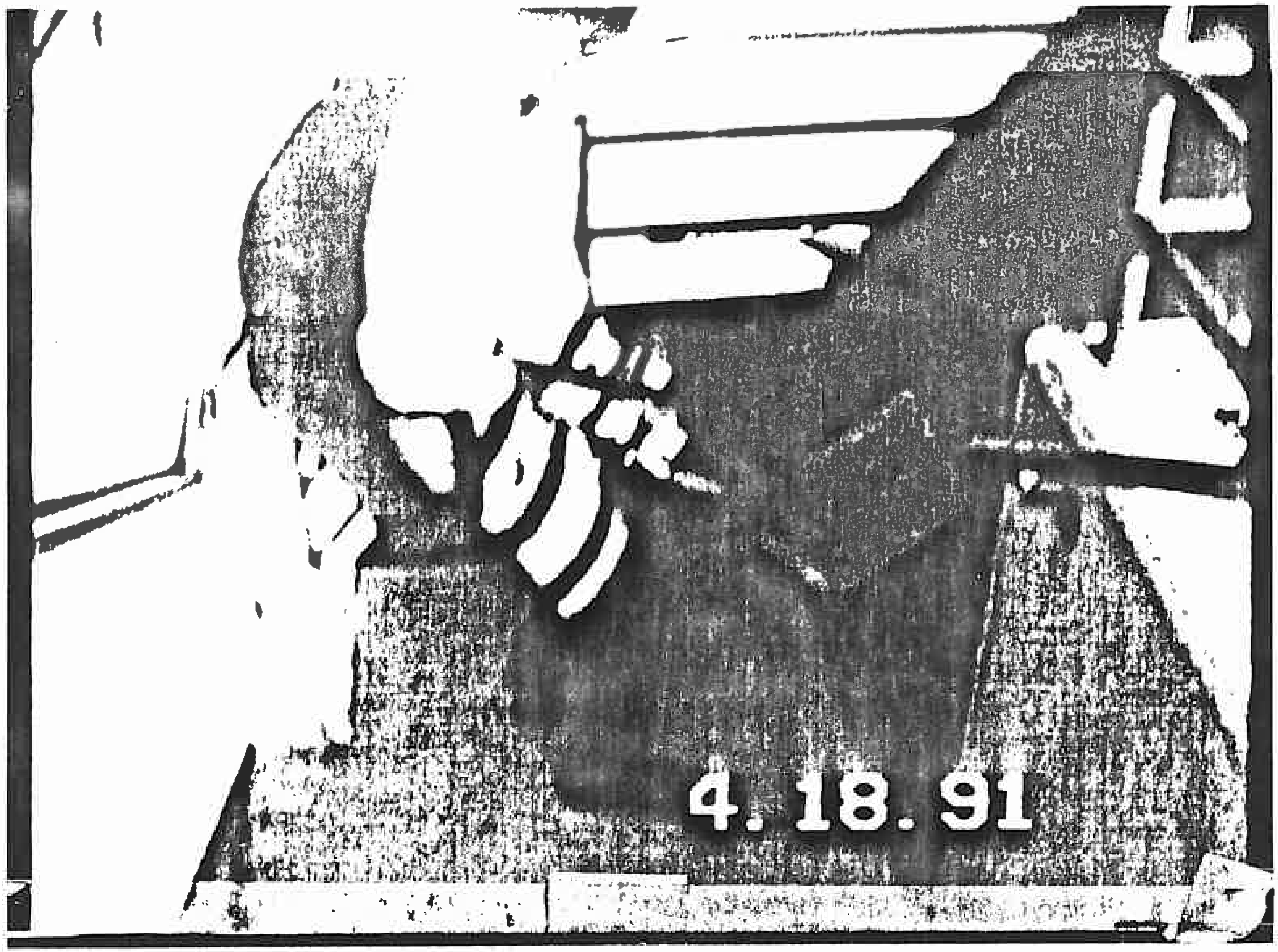


Figure 4a. Deliveryman lowering soft drink-loaded, 2-wheel hand truck weighing 206 lb downstairs.

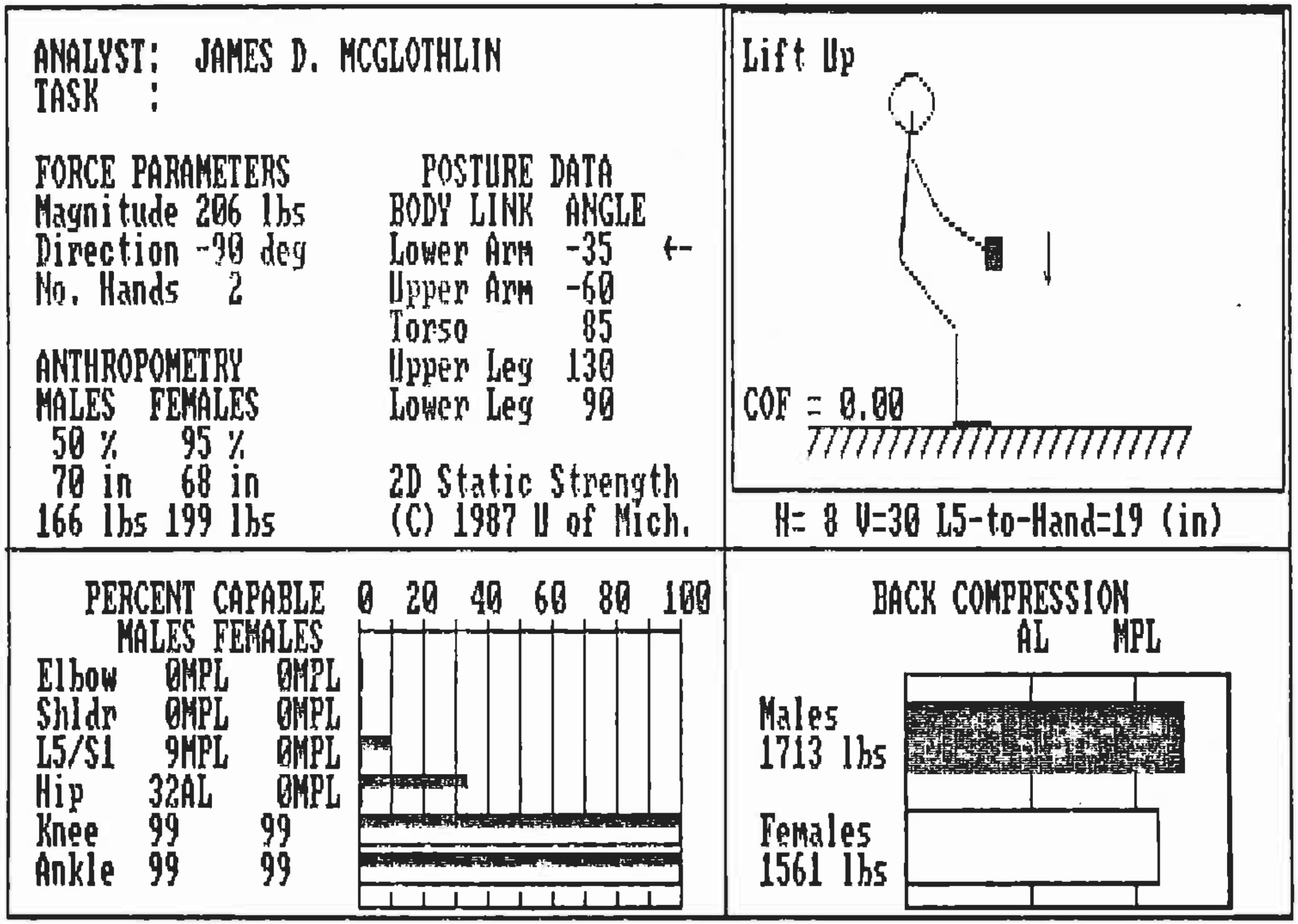


Figure 4b. Biomechanical analysis of deliveryman lowering soft drink-loaded, 2-wheel hand truck weighing 206 lb downstairs.

```
                    STATIC STRENGTH PROGRAM
-------------------------------------------------------------------
ANALYST:   JAMES D. MCGLOTHLIN              Tue Jun 18 09:48:30 1991

TASK    :
   FORCE PARAMETERS                          POSTURE DATA
Magnitude   206 lbs                  LINK ANGLES FROM HORIZONTAL
Direction   -90 deg                       Lower Arm   -35 deg
No. Hands     2                           Upper Arm   -60 deg
                                          Torso        85 deg
   ANTHROPOMETRY DATA                     Upper Leg   130 deg
ITEM      MALES    FEMALES                Lower Leg    90 deg
%tile      50 %      95 %
Heigth     70 in      68 in               H =    8 in V =   30 in
Weight    166 lbs    199 lbs              L5/S1-to-Hand =   19 in
-------------------------------------------------------------------
                          PERCENT CAPABLE
                        25%       50%       75%       100%
                |---------|---------|---------|---------|------|
   Elbow Males  |                                          0%  |  Elbow
         Females|                                          0%  |
   Shldr Males  |                                          0%  |  Shldr
         Females|                                          0%  |
   L5/S1 Males  |MMMM                                      9%  |  L5/S1
         Females|                                          0%  |
   Hip   Males  |MMMMMMMMMMMMM                            32%  |  Hip
         Females|                                          0%  |
   Knee  Males  |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  99%  |  Knee
         Females|FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF  99%  |
   Ankle Males  |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  99%  |  Ankle
         Females|FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF  99%  |
                |---------|---------|---------|---------|------|
                        25%       50%       75%       100%
                          BACK COMPRESSION
                       500      1000      1500      2000   LBS
                |---------|----|----|-----|-|-|---------|----------|
         Males  |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM       1713 lbs |
         Females|FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF           1561 lbs |
                |---------|----|----|-----|-|-|---------|----------|
                       500      1000      1500      2000   LBS
                               AL         MPL
                              770        1430
COF:  Males=0.00  Females=0.00          Balance Acceptable
-------------------------------------------------------------------
```

Figure 4c. Biomechanical summary information of deliveryman lowering soft drink-loaded, 2-wheel hand truck weighing 206 lb downstairs.

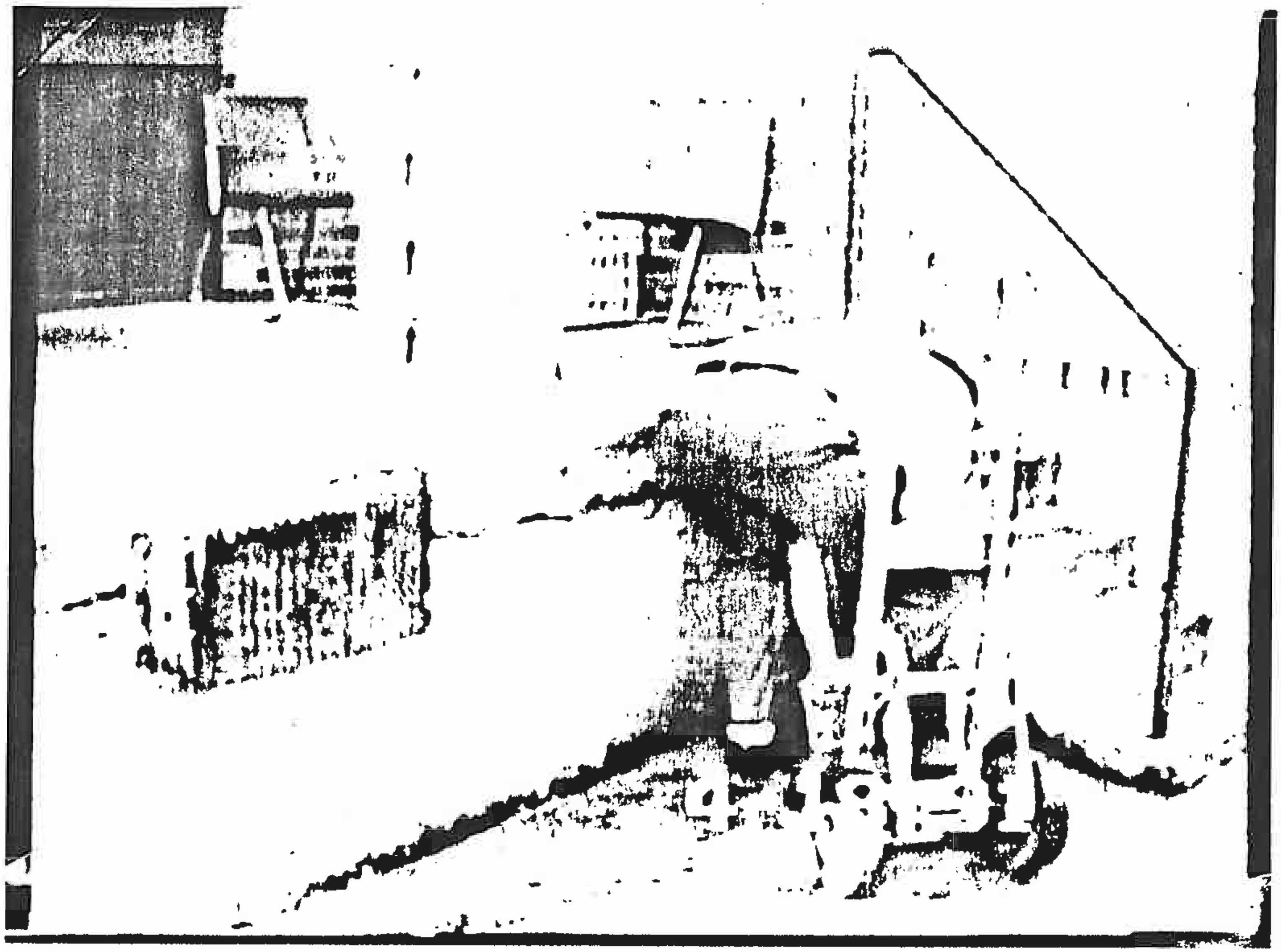


Figure 5a. Deliveryman lifting bag-in-box weighing 44 lb from ground.

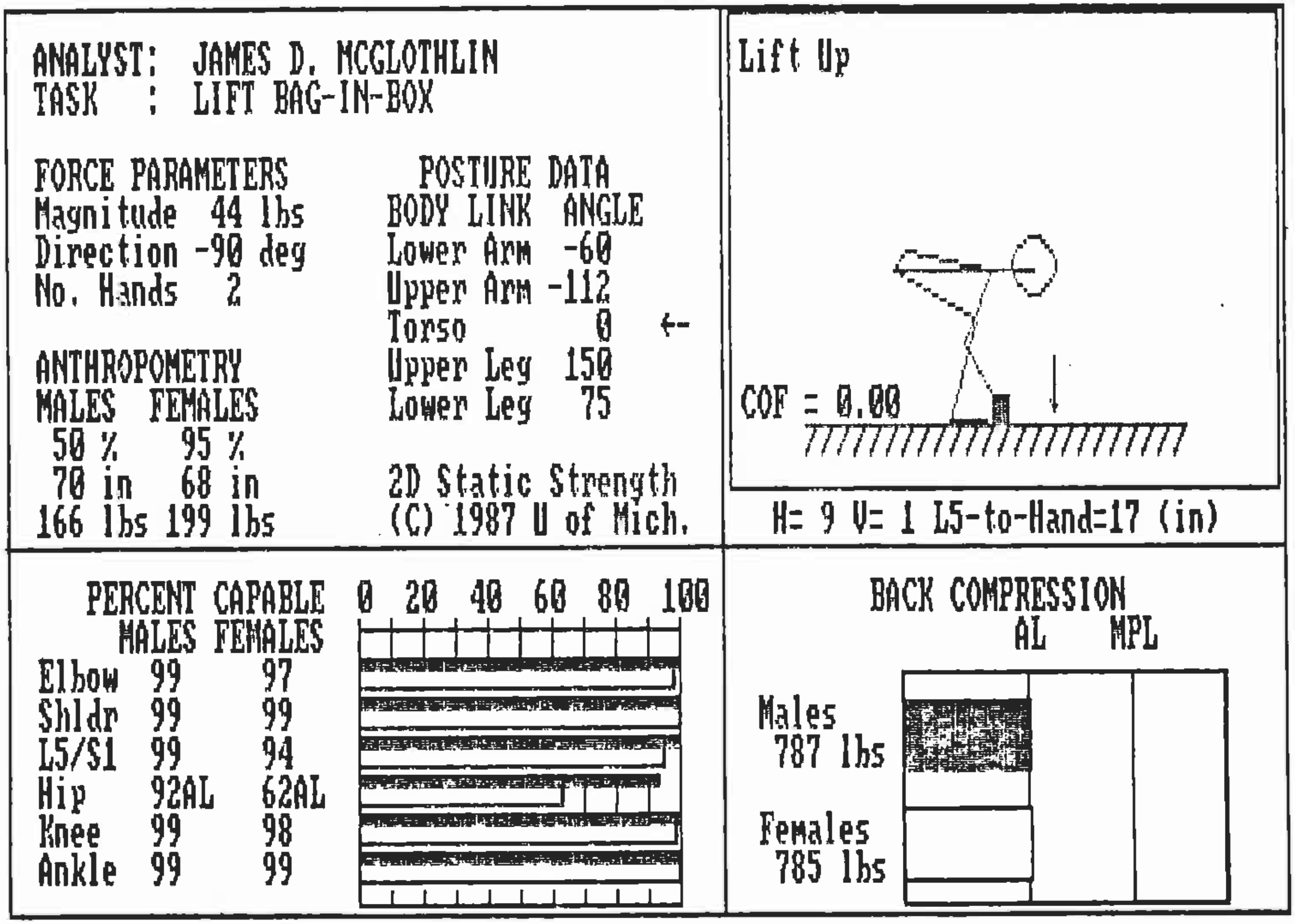


Figure 5b. Biomechanical analysis of deliveryman lifting bag-in-box weighing 44 lb from ground.

```
                      STATIC STRENGTH PROGRAM
----------------------------------------------------------------------
ANALYST:  JAMES D. MCGLOTHLIN                Fri Jul  5 13:04:40 1991

TASK    :  LIFT BAG-IN-BOX
   FORCE PARAMETERS                               POSTURE DATA
Magnitude    44 lbs                   LINK ANGLES FROM HORIZONTAL
Direction   -90 deg                        Lower Arm   -60 deg
No. Hands     2                            Upper Arm -112 deg
                                           Torso        0 deg
   ANTHROPOMETRY DATA                      Upper Leg  150 deg
ITEM     MALES    FEMALES                  Lower Leg   75 deg
%tile     50 %     95 %
Heigth    70 in     68 in                  H =    9 in V =    1 in
Weight   166 lbs   199 lbs                 L5/S1-to-Hand =   17 in
----------------------------------------------------------------------
                           PERCENT CAPABLE
                         25%       50%       75%       100%
                    |---------|---------|---------|---------|-----|
   Elbow Males      |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   99% | Elbow
         Females    |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF    97% |
   Shldr Males      |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   99% | Shldr
         Females    |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF   99% |
   L5/S1 Males      |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   99% | L5/S1
         Females    |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF     94% |
   Hip   Males      |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM      92% | Hip
         Females    |FFFFFFFFFFFFFFFFFFFFFFFFFF                  62% |
   Knee  Males      |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   99% | Knee
         Females    |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF   98% |
   Ankle Males      |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   99% | Ankle
         Females    |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF   99% |
                    |---------|---------|---------|---------|-----|
                         25%       50%       75%       100%
                          BACK COMPRESSION
                        500       1000      1500      2000   LBS
                    |---------|----|----|-------|-|---------|---------|
         Males      |MMMMMMMMMMMMMMMMMM                          787 lbs |
         Females    |FFFFFFFFFFFFFFFFF                           785 lbs |
                    |---------|----|----|-------|-|---------|---------|
                        500       1000      1500      2000   LBS
                               AL              MPL
                               770            1430
COF:  Males=0.00  Females=0.00             Balance Acceptable
----------------------------------------------------------------------
```

Figure 5c. Biomechanical summary information of deliveryman lifting bag-in-box weighing 44 lb from ground.

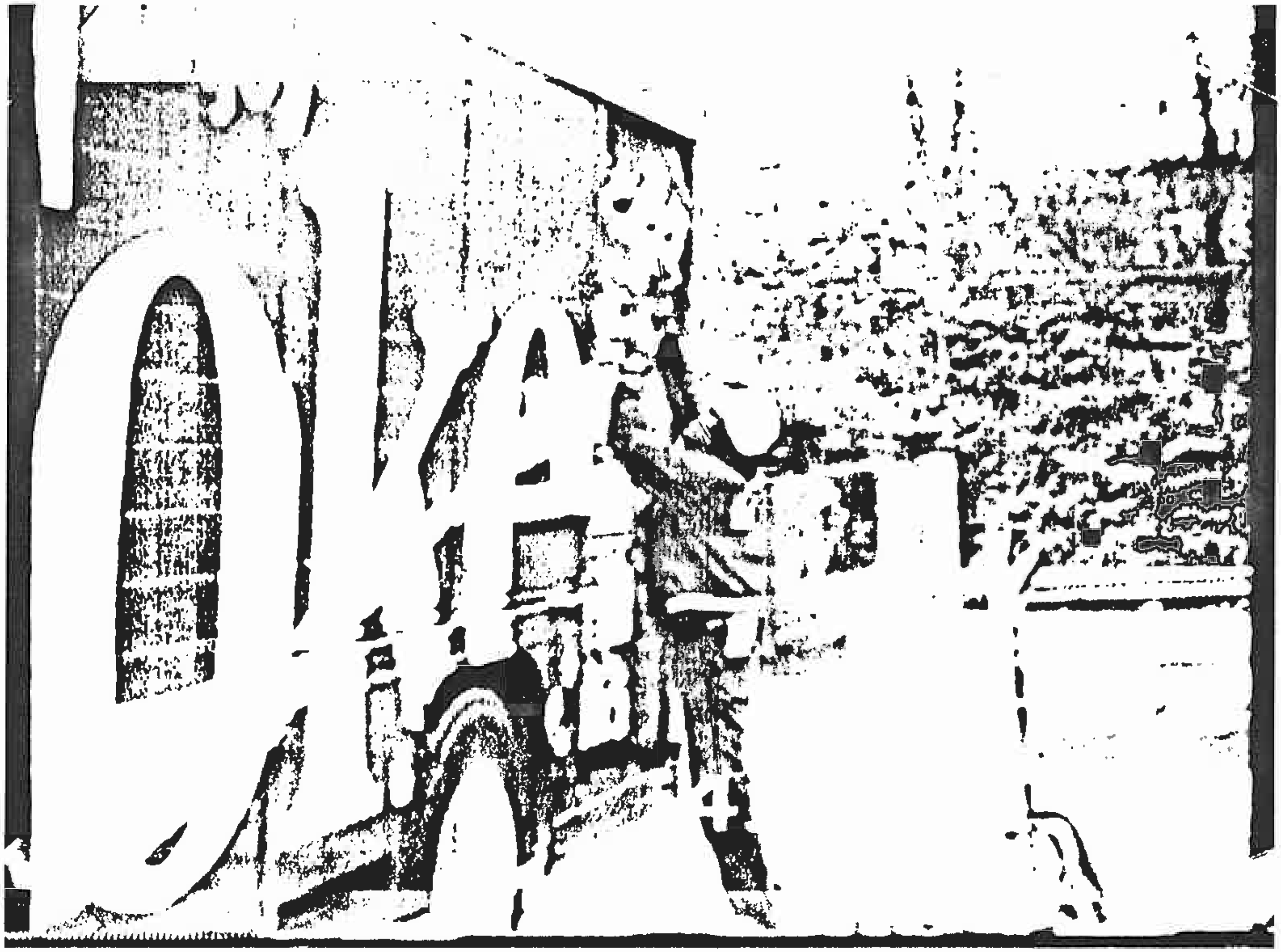


Figure 6a. Deliveryman lifting crate of 2-L soft drink beverages weighing 40 lb into truck bay.

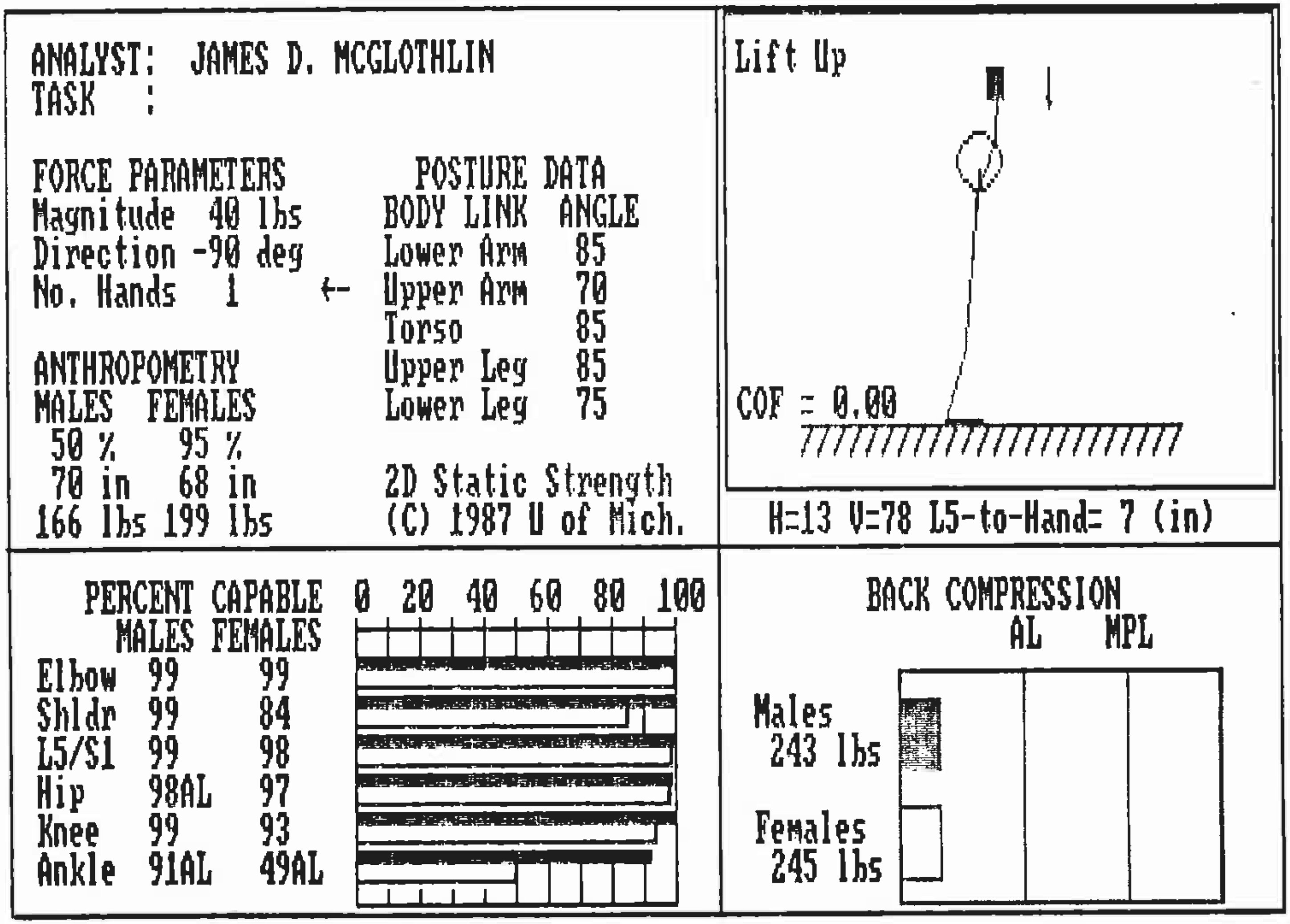


Figure 6b. Biomechanical analysis of deliveryman lifting crate of 2-L soft drink beverages weighing 40 lb into truck bay.

```
                        STATIC STRENGTH PROGRAM
----------------------------------------------------------------------
ANALYST:  JAMES D. MCGLOTHLIN                Mon Jun 17 16:03:26 1991

TASK    :
   FORCE PARAMETERS                          POSTURE DATA
Magnitude    40 lbs                 LINK ANGLES FROM HORIZONTAL
Direction   -90 deg                      Lower Arm    85 deg
No. Hands     1                          Upper Arm    70 deg
                                         Torso        85 deg
   ANTHROPOMETRY DATA                    Upper Leg    85 deg
ITEM      MALES    FEMALES               Lower Leg    75 deg
%tile      50 %      95 %
Heigth     70 in      68 in              H =  13 in V =  78 in
Weight    166 lbs   199 lbs              L5/S1-to-Hand =    7 in
----------------------------------------------------------------------
                                PERCENT CAPABLE
                         25%       50%       75%       100%
                 |---------|---------|---------|---------|------|
   Elbow Males   MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   99%  |  Elbow
         Females FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF   99%
   Shldr Males   MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   99%  |  Shldr
         Females FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF         84%
   L5/S1 Males   MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   99%  |  L5/S1
         Females FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF   98%
   Hip   Males   MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   98%  |  Hip
         Females FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF    97%
   Knee  Males   MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   99%  |  Knee
         Females FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF     93%
   Ankle Males   MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM      91%  |  Ankle
         Females FFFFFFFFFFFFFFFFFFFF                       49%
                 |---------|---------|---------|---------|------|
                          25%       50%       75%       100%
                                BACK COMPRESSION
                         500     1000      1500       2000  LBS
                 |---------|----|----|-------|-|---------|----------|
         Males   MMMMM                                      243 lbs
         Females FFFFF                                      245 lbs
                 |---------|----|----|-------|-|---------|----------|
                         500     1000      1500       2000  LBS
                              AL           MPL
                             770          1430
COF:  Males=0.00  Females=0.00         Balance Acceptable
----------------------------------------------------------------------
```

Figure 6c. Biomechanical summary information of deliveryman lifting crate of 2-L soft drink beverages weighing 40 lb into truck bay.

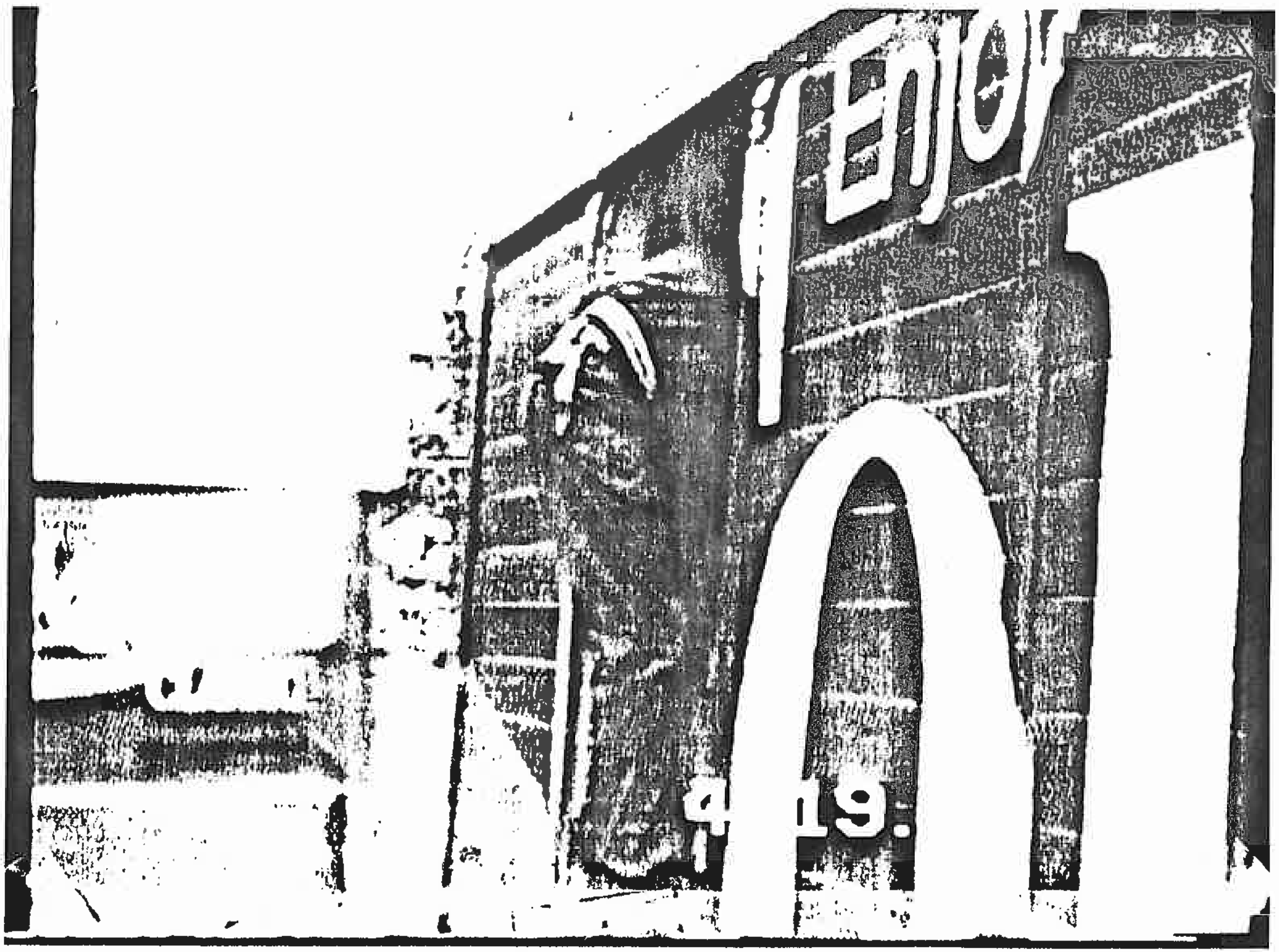


Figure 7a. Deliveryman lifting one 24-can case of soft drink weighing 22 lb.

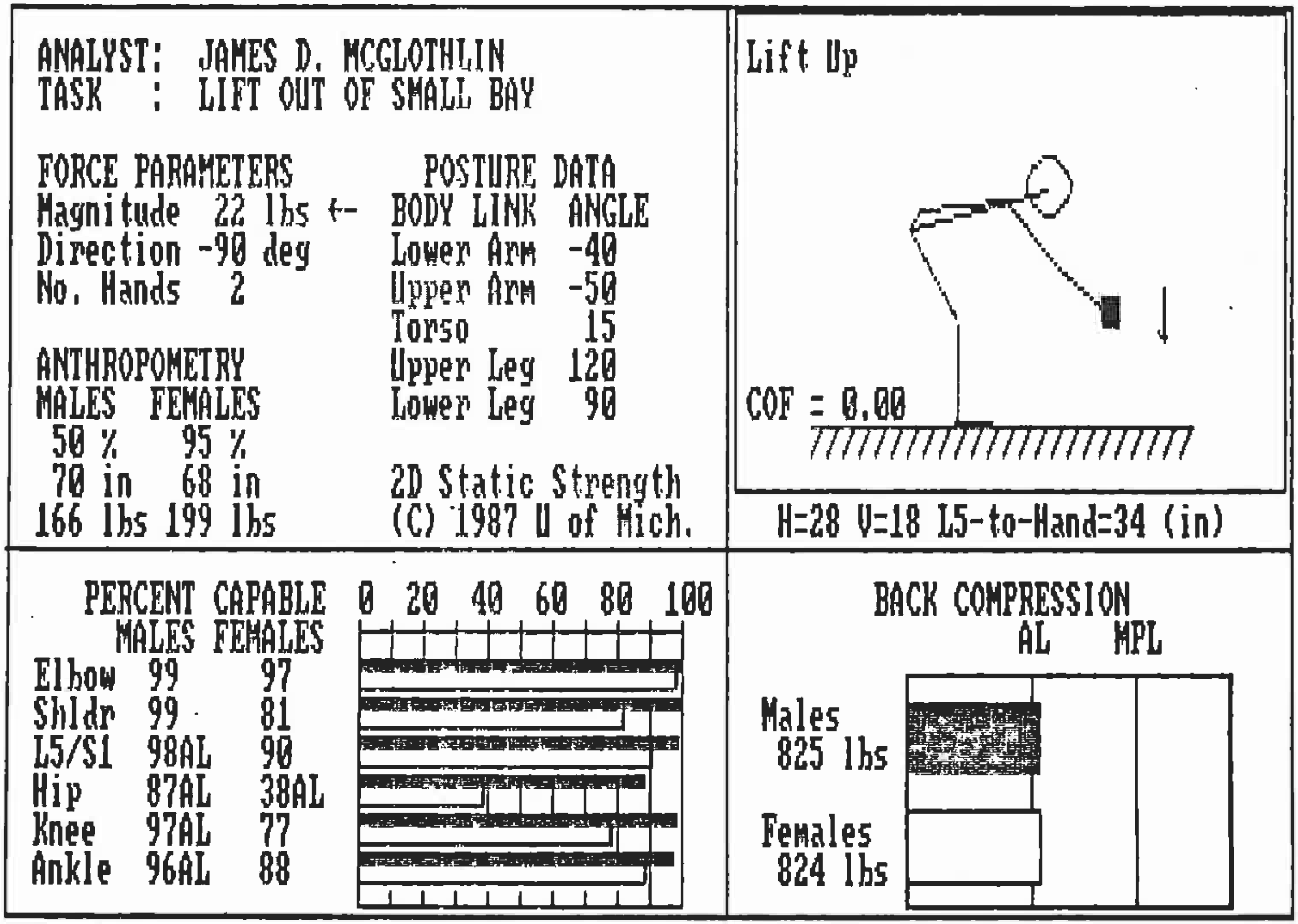


Figure 7b. Biomechanical analysis of deliveryman lifting one case of 24-can soft drink weighing 22 lb.

STATIC STRENGTH PROGRAM

ANALYST: JAMES D. MCGLOTHLIN   Fri Jul 5 12:45:18 1991

TASK : LIFT OUT OF SMALL BAY

FORCE PARAMETERS		
Magnitude	22 lbs	
Direction	-90 deg	
No. Hands	2	

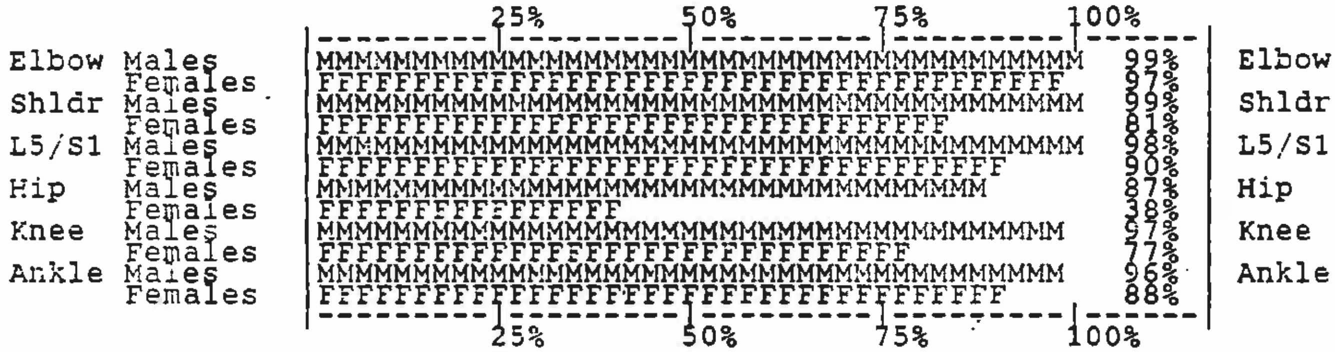
ANTHROPOMETRY DATA ITEM	MALES	FEMALES
%tile	50 %	95 %
Heigth	70 in	68 in
Weight	166 lbs	199 lbs

POSTURE DATA

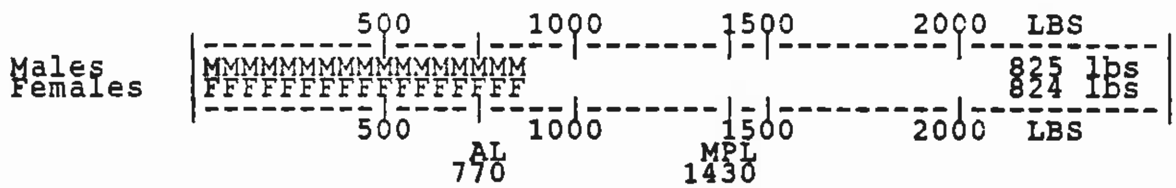
LINK ANGLES FROM HORIZONTAL	
Lower Arm	-40 deg
Upper Arm	-50 deg
Torso	15 deg
Upper Leg	120 deg
Lower Leg	90 deg

H = 28 in V = 18 in
L5/S1-to-Hand = 34 in

PERCENT CAPABLE



BACK COMPRESSION



COF: Males=0.00 Females=0.00   Balance Acceptable

Figure 7c. Biomechanical summary information of deliveryman lifting one case of 24-can soft drink weighing 22 lb.

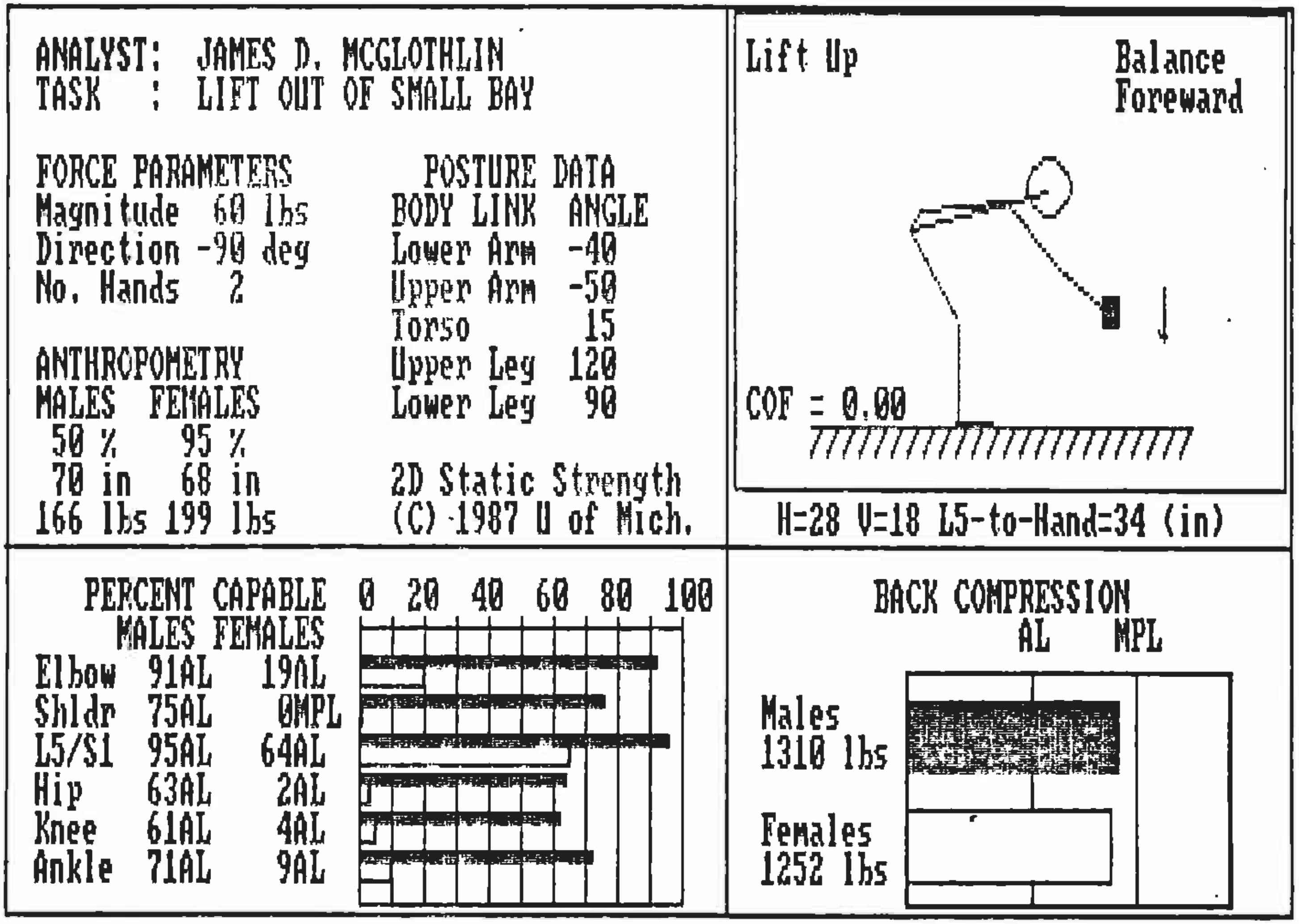


Figure 8a. Biomechanical analysis of deliveryman hypothetically lifting 60 lb of soft drink beverage.

```
                        STATIC STRENGTH PROGRAM
----------------------------------------------------------------------
ANALYST:  JAMES D. MCGLOTHLIN                 Fri Jul  5 12:48:14 1991

TASK    :  LIFT OUT OF SMALL BAY
   FORCE PARAMETERS                          POSTURE DATA
Magnitude    60 lbs                 LINK ANGLES FROM HORIZONTAL
Direction   -90 deg                      Lower Arm   -40 deg
No. Hands     2                          Upper Arm   -50 deg
                                         Torso        15 deg
   ANTHROPOMETRY DATA                    Upper Leg   120 deg
ITEM     MALES   FEMALES                 Lower Leg    90 deg
%tile     50 %     95 %
Heigth    70 in     68 in                H =  28 in V =  18 in
Weight   166 lbs   199 lbs               L5/S1-to-Hand =  34 in
----------------------------------------------------------------------
                               PERCENT CAPABLE
                          25%       50%       75%       100%
                        |---------|---------|---------|---------|------ |
   Elbow Males          |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   91% |  Elbow
         Females        |FFFFFFFFF                                      19% |
   Shldr Males          |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM            75% |  Shldr
         Females        |                                                0% |
   L5/S1 Males          |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  95% |  L5/S1
         Females        |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFF                 64% |
   Hip   Males          |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMM                 53% |  Hip
         Females        |F                                               2% |
   Knee  Males          |MMMMMMMMMMMMMMMMMMMMMMMMMMMMM                  61% |  Knee
         Females        |FF                                              4% |
   Ankle Males          |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM             71% |  Ankle
         Females        |FFFF                                            9% |
                        |---------|---------|---------|---------|------ |
                          25%       50%       75%       100%
                             BACK COMPRESSION
                          500      1000      1500      2000   LBS
                        |---------|----|----|-------|-|---------|----------|
         Males          |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM           1310 lbs |
         Females        |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF            1252 lbs |
                        |---------|----|----|-------|-|---------|----------|
                          500      1000      1500      2000   LBS
                                AL            MPL
                               770            1430
COF:  Males=0.00  Females=0.00           Balance Foreward
----------------------------------------------------------------------
```

Figure 8b. Biomechanical summary information of deliveryman hypothetically lifting 60 lb of soft drink beverage.

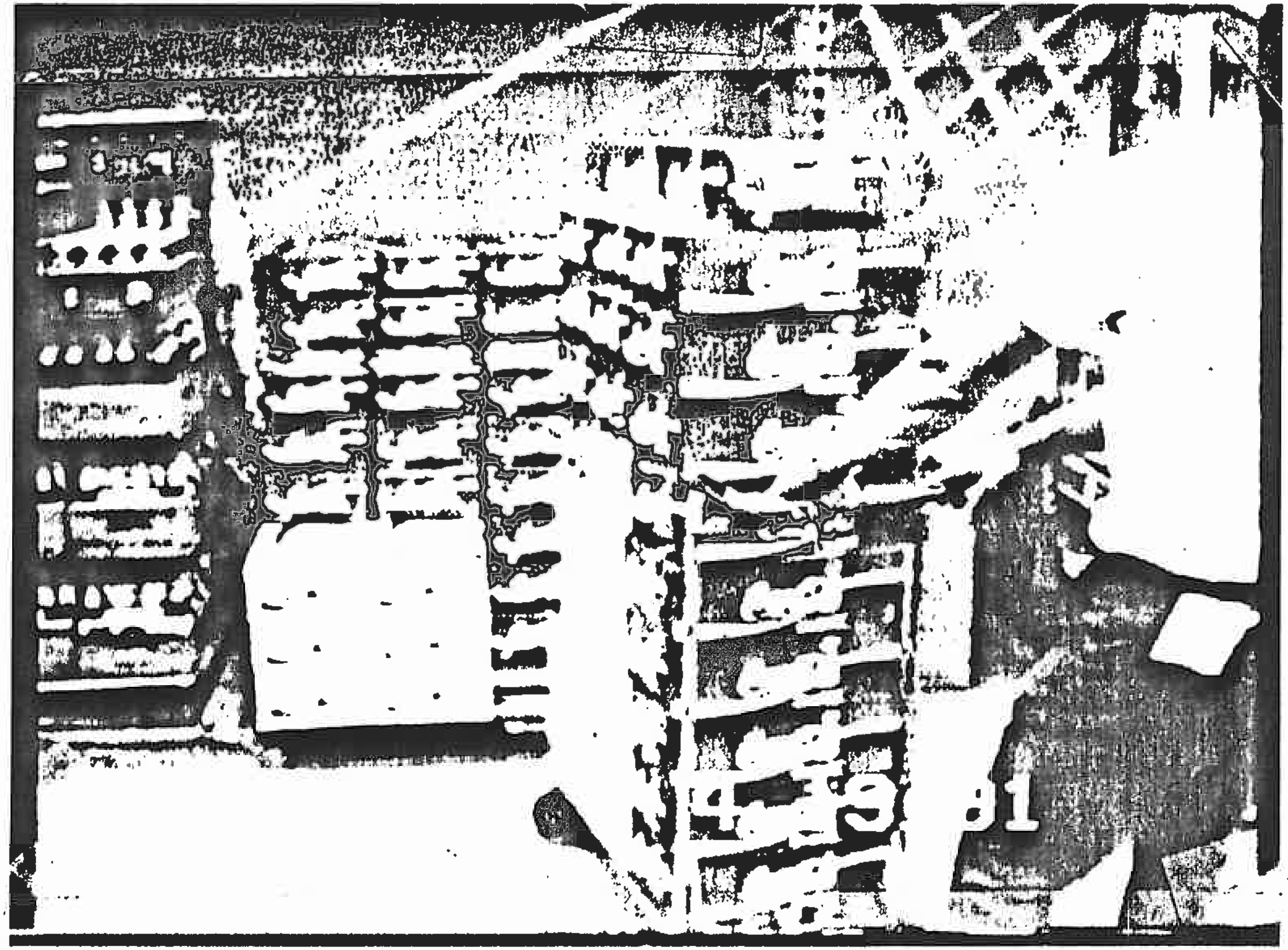


Figure 9a. Deliveryman beginning to pull a soft drink-loaded, 4-wheel hand truck weighing 500 lb.

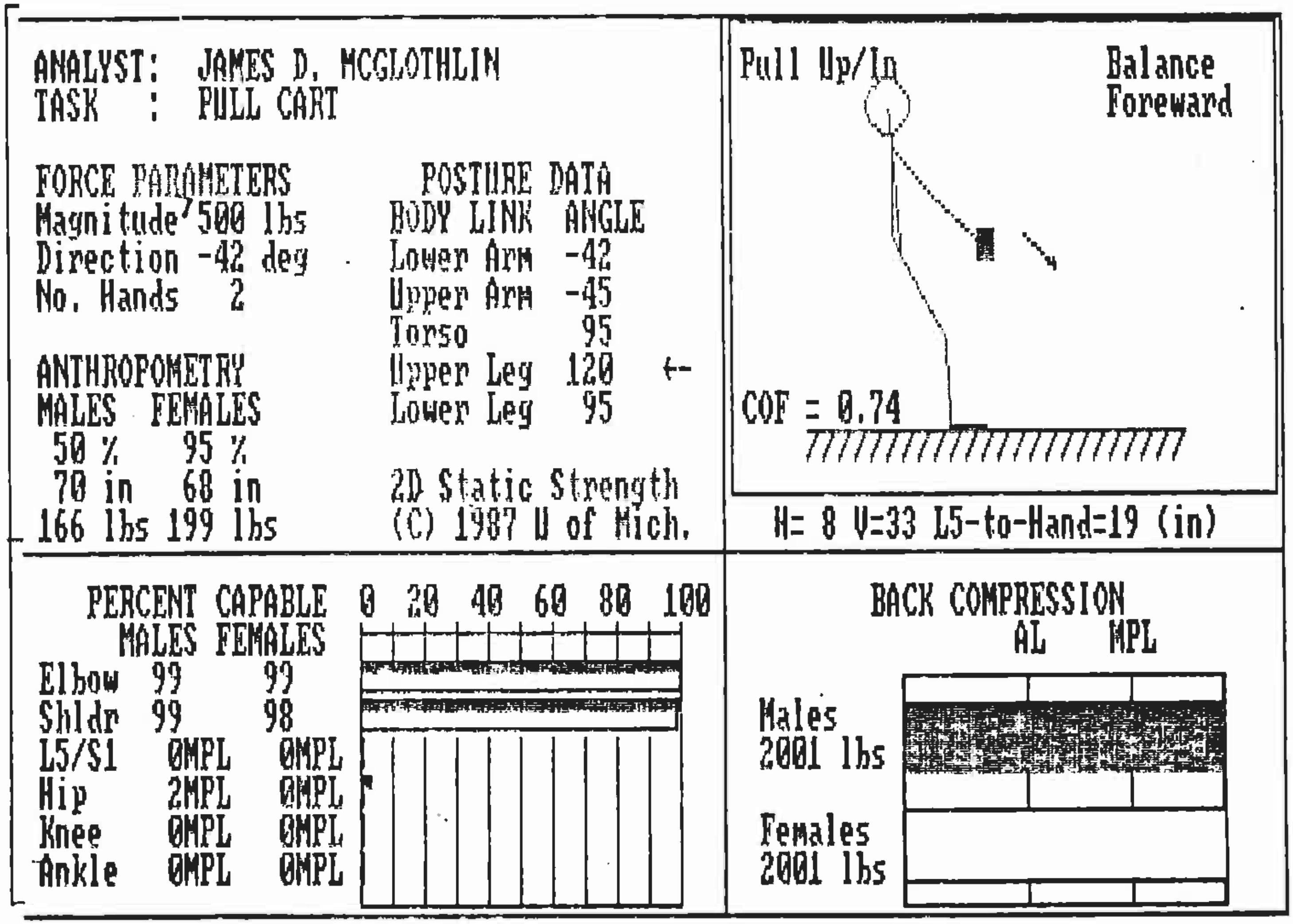


Figure 9b. Biomechanical analysis of deliveryman beginning to pull a soft drink-loaded, 4-wheel hand truck weighing 500 lb.

```
                         STATIC STRENGTH PROGRAM
-----------------------------------------------------------------------
ANALYST:   JAMES D. MCGLOTHLIN                 Mon Jul  8 09:04:24 1991

TASK    :  PULL CART
   FORCE PARAMETERS                               POSTURE DATA
Magnitude   500 lbs                  LINK  ANGLES FROM HORIZONTAL
Direction   -42 deg                        Lower Arm   -42 deg
No. Hands     2                            Upper Arm   -45 deg
                                           Torso        95 deg
   ANTHROPOMETRY DATA                      Upper Leg   120 deg
ITEM     MALES    FEMALES                  Lower Leg    95 deg
%tile     50 %      95 %
Heigth    70 in     68 in                  H =   8 in V =  33 in
Weight   166 lbs   199 lbs                 L5/S1-to-Hand =   19 in
-----------------------------------------------------------------------
                              PERCENT CAPABLE
                         25%       50%       75%      100%
                  |---------|---------|---------|---------|------|
 Elbow Males      |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  99% | Elbow
       Females    |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF  99% |
 Shldr Males      |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  99% | Shldr
       Females    |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF  98% |
 L5/S1 Males      |                                             0% | L5/S1
       Females    |                                             0% |
 Hip   Males      |M                                            2% | Hip
       Females    |                                             0% |
 Knee  Males      |                                             0% | Knee
       Females    |                                             0% |
 Ankle Males      |                                             0% | Ankle
       Females    |                                             0% |
                  |---------|---------|---------|---------|------|
                         25%       50%       75%      100%
                              BACK COMPRESSION
                        500      1000      1500      2000    LBS
                  |---------|----|----|---------|---------|---------|
        Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  2001 lbs |
        Females   |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF  2001 lbs |
                  |---------|----|----|---------|---------|---------|
                        500      1000      1500      2000    LBS
                               AL           MPL
                              770          1430
COF:   Males=0.74   Females=0.70            Balance Foreward
-----------------------------------------------------------------------
```

Figure 9c. Biomechanical summary information of deliveryman beginning to pull a soft drink-loaded, 4-wheel hand truck weighing 500 lb.

Figure 10a. Deliveryman pulling a soft drink-loaded, 4-wheel hand truck weighing 166 lb.

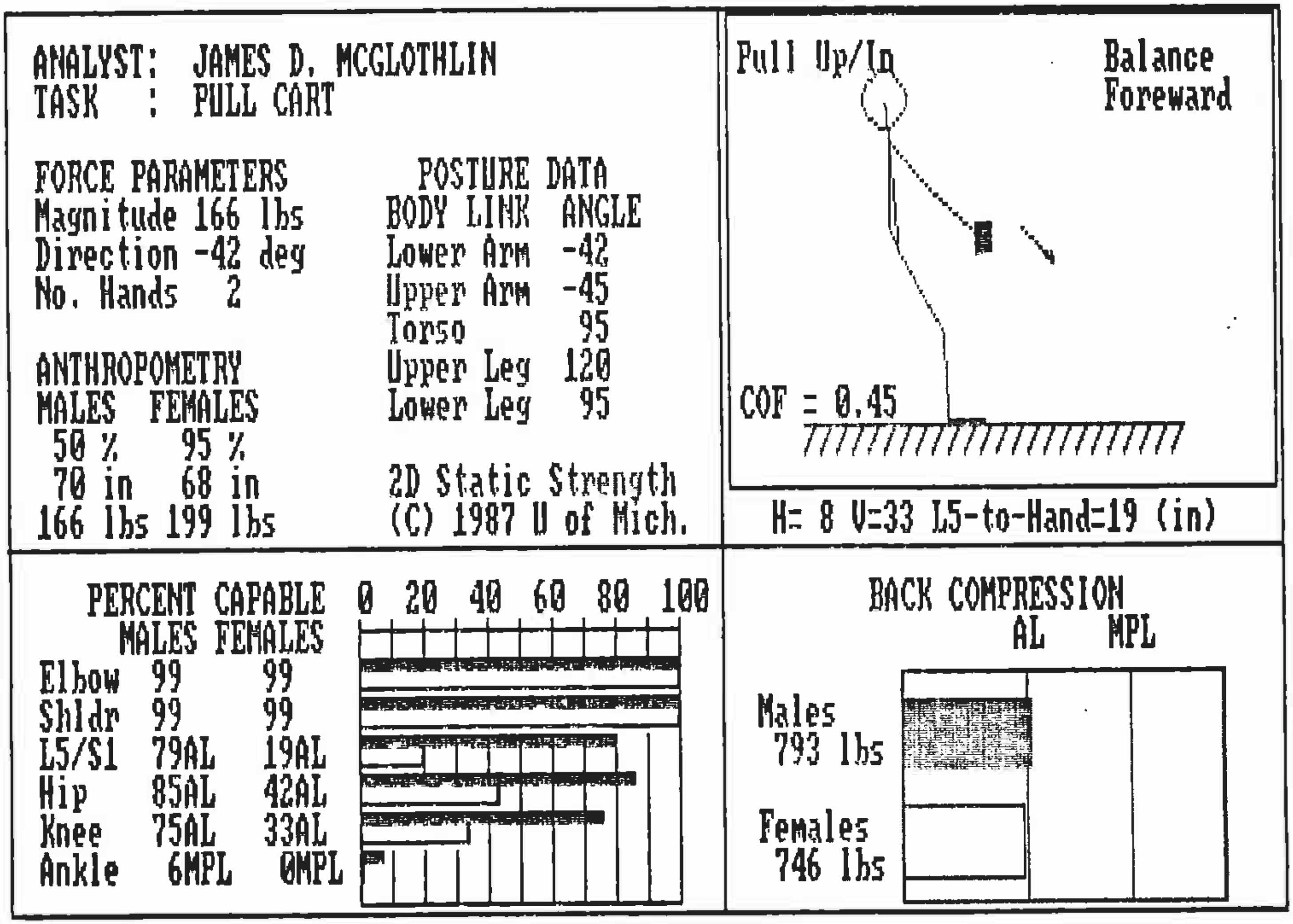


Figure 10b. Biomechanical analysis of deliveryman pulling a soft drink-loaded, 4-wheel hand truck weighing 166 lb.

```
                    STATIC STRENGTH PROGRAM
--------------------------------------------------------------------

ANALYST:  JAMES D. MCGLOTHLIN              Fri Jul  5 12:55:50 1991

TASK    :  PULL CART
   FORCE PARAMETERS                        POSTURE DATA
Magnitude  166 lbs               LINK ANGLES FROM HORIZONTAL
Direction  -42 deg                    Lower Arm   -42 deg
No. Hands    2                        Upper Arm   -45 deg
                                      Torso        95 deg
   ANTHROPOMETRY DATA                 Upper Leg   120 deg
ITEM       MALES   FEMALES            Lower Leg    95 deg
%tile       50 %     95 %
Heigth      70 in     68 in           H =   8 in V =  33 in
Weight     166 lbs   199 lbs          L5/S1-to-Hand =  19 in
--------------------------------------------------------------------
                         PERCENT CAPABLE
                          25%       50%       75%       100%
                 |---------|---------|---------|---------|------|
Elbow  Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM    99%|  Elbow
       Females   |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF    99%|
Shldr  Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM    99%|  Shldr
       Females   |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF    99%|
L5/S1  Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM            79%|  L5/S1
       Females   |FFFFFFFF                                    19%|
Hip    Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM          85%|  Hip
       Females   |FFFFFFFFFFFFFFFFF                           42%|
Knee   Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMM              75%|  Knee
       Females   |FFFFFFFFFFFFFF                              33%|
Ankle  Males     |MMM                                          6%|  Ankle
       Females   |                                             0%|
                 |---------|---------|---------|---------|------|
                          25%       50%       75%       100%
                         BACK COMPRESSION
                         500     1000      1500      2000   LBS
                 |---------|----|----|-------|-|---------|----------|
       Males     |MMMMMMMMMMMMMMMM                         793 lbs  |
       Females   |FFFFFFFFFFFFFFF                          746 lbs  |
                 |---------|----|----|-------|-|---------|----------|
                         500     1000      1500      2000   LBS
                                 AL           MPL
                                 770          1430

COF:  Males=0.45  Females=0.40          Balance Foreward
--------------------------------------------------------------------
```

Figure 10c. Biomechanical summary information of deliveryman pulling a soft drink-loaded, 4-wheel hand truck weighing 166 lb.

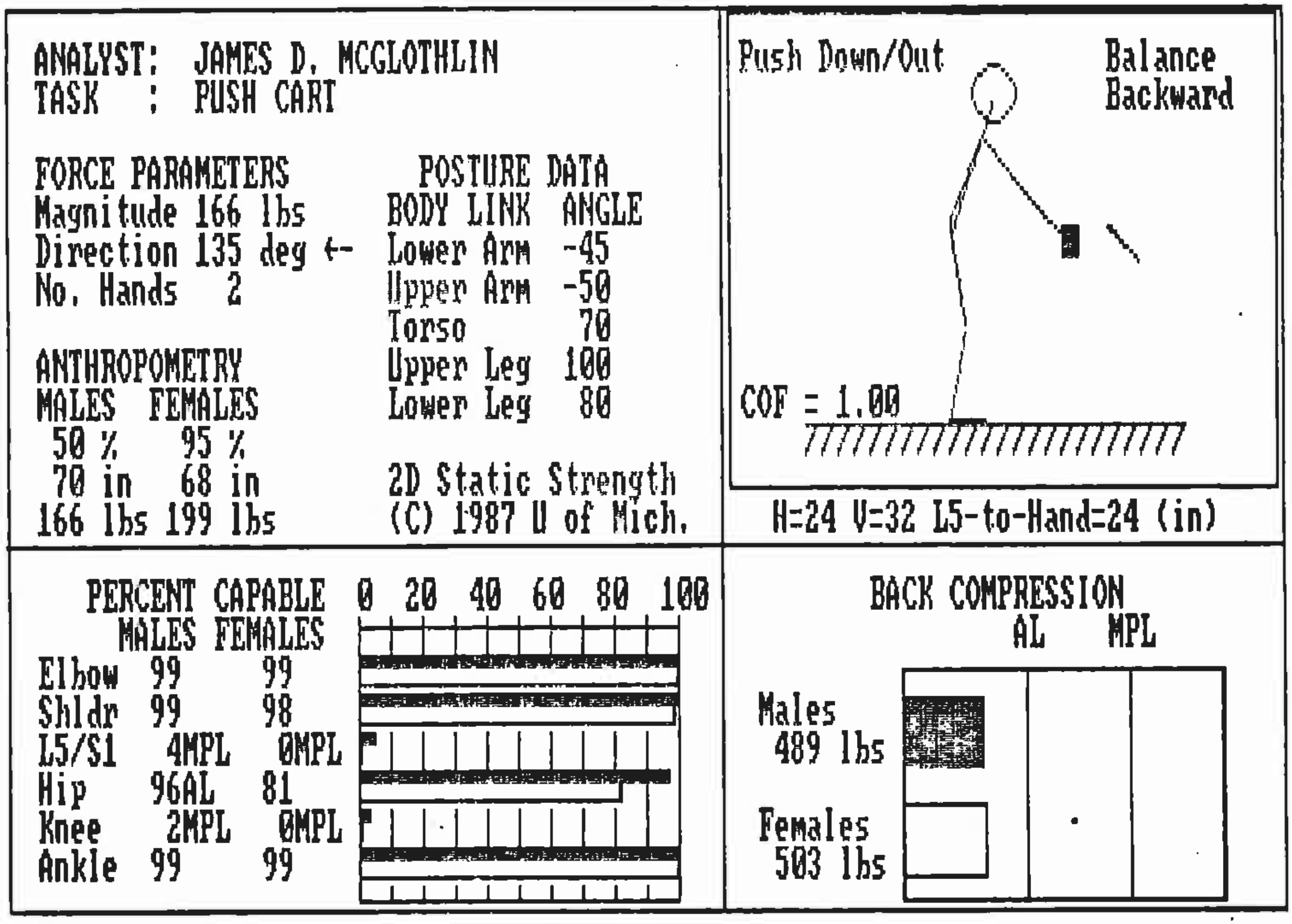


Figure 11a. Biomechanical analysis of deliveryman hypothetically pushing a soft drink-loaded, 4-wheel hand truck weighing 166 lb.

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                      STATIC STRENGTH PROGRAM
----------------------------------------------------------------------
ANALYST:   JAMES D. MCGLOTHLIN                Fri Jul  5 12:58:28 1991

TASK   :   PUSH CART
   FORCE PARAMETERS                         POSTURE DATA
Magnitude   166 lbs                  LINK ANGLES FROM HORIZONTAL
Direction   135 deg                       Lower Arm  -45 deg
No. Hands     2                           Upper Arm  -50 deg
                                          Torso       70 deg
   ANTHROPOMETRY DATA                     Upper Leg  100 deg
ITEM      MALES   FEMALES                 Lower Leg   80 deg
%title     50 %     95 %
Heigth     70 in     68 in                H =  24 in V =  32 in
Weight    166 lbs  199 lbs                L5/S1-to-Hand =  24 in
----------------------------------------------------------------------
                          PERCENT CAPABLE
                        25%       50%       75%      100%
                 |---------|---------|---------|---------|----|
Elbow  Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  99%  | Elbow
       Females   |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF  99%  |
Shldr  Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  99%  | Shldr
       Females   |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF  98%  |
L5/S1  Males     |MM                                          4%  | L5/S1
       Females   |                                            0%  |
Hip    Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM   96%  | Hip
       Females   |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF          81%  |
Knee   Males     |M                                           2%  | Knee
       Females   |                                            0%  |
Ankle  Males     |MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM  99%  | Ankle
       Females   |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF  99%  |
                 |---------|---------|---------|---------|----|
                        25%       50%       75%      100%
                          BACK COMPRESSION
                       500       1000      1500       2000  LBS
                 |---------|----|----|-------|-|---------|---------|
       Males     |MMMMMMMMMM                               489 lbs |
       Females   |FFFFFFFFFFF                              503 lbs |
                 |---------|----|----|-------|-|---------|---------|
                       500       1000      1500       2000  LBS
                              AL          MPL
                             770         1430
COF:  Males=1.00  Females=1.00          Balance Backward
----------------------------------------------------------------------
```

Figure 11b. Biomechanical summary information of deliveryman hypothetically pushing a soft drink-loaded, 4-wheel hand truck weighing 166 lb.

X. APPENDIX A

HEALTH EFFECTS OF MANUAL MATERIALS HANDLING

A. CUMULATIVE TRAUMA DISORDERS OF THE UPPER LIMBS

Reports of chronic musculoskeletal disorders have been documented as far back as the year 1717 by the physician, Ramazini, who documented that certain occupations caused certain violent and irregular motions and unnatural postures of the body, which resulted in impairment and disease.[1] Several case reports over the years have cited certain occupational and nonoccupational risk factors which give rise to musculoskeletal injuries.[2,3,4,5] 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. Several cross-sectional and case control retrospective studies of occupational CTDs have been employed.[6,7,8,9,10,11] The conclusions from these studies have drawn us closer to identifying risk factors with disease outcome.

Work-related Cumulative Trauma Disorders (CTDs) of the upper limbs 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, new occupational groups at risk for developing cumulative trauma disorders continue to be identified.

One of the most commonly reported disorders of the upper limb 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.[10] Symptoms of carpal tunnel syndrome (CTS) 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.[12,13,14]

The diagnosis is confirmed by physical examination and/or electrodiagnostic studies.[13] CTS can be managed with conservative measures, such as wrist immobilization and nonsteroidal anti-inflammatory medications.[12] 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.[12] Recognition and evaluation of work-related risk factors which may cause CTS should be conducted in order to implement controls to reduce such risk factors. Engineering controls are the preferred method, with administrative controls such as work enlargement, rotation, etc., as an interim measure. For all workers with symptoms suggestive of CTS, an occupational history should be obtained that includes a description of tasks involving use of the hands. Failure to eliminate contributory job factors can result in recurrence or progression of symptoms, impaired use of the hand, and the need for surgical treatment. Redesign of tools, workstations, and job tasks can prevent occurrence of CTS among coworkers.[12] Surveillance of work-related CTS, including the use of health-care-provider reports, can aid in identifying high-risk workplaces, occupations, and industries and in directing appropriate preventive measures.[15]

B. BACK INJURIES

Eighty percent of all Americans will suffer low back pain sometime during their lifetime.[16,17,18,19] Over 30 million Americans currently experience low back pain;[20] 13 million of those cases have resulted in reduced ability to function.[21] Ten million cases of back impairment are in the employed U.S. population between the ages of 18 and 64.[21] Each year, seven million people will be added to the total number of Americans who have suffered back injuries.[22] Lost time from work has increased significantly over the past 30 years, while the incidence of low back pain has stayed the same.[23] Estimated total costs for low back pain is approximately 16 billion annually (compensable and noncompensable) in the United States.[20] 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.[24] According to the National Council on Compensation Insurance, low back injuries make up 25 percent of the claims for indemnity benefits, a claim made by a worker who has lost time from work because of a job-related injury. 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 being paid for through workers' compensation, with nearly 30 percent of the total workers' compensation payments being spent on back cases.[24] The distribution of low back compensation costs is skewed: 25 percent of low back cases account for 95 percent of the costs.[25] Current estimates for low back compensation costs are approximately 6,807 dollars as the average or mean costs, and 390 dollars for the median.[25] 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.[25] The higher cost for the few cases were attributed to more hospitalization, surgery, litigation, psychologic impairment, and extended loss of time from work. Age, gender, and occupation are risk factors for the occurrence and severity of low back injuries. Old workers are more likely than younger workers to have severe back disorders.[26] More women than men are likely to have restricted-activity, bed disability, and work loss days.[27]

Hildebrandt[28] 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, work postures in general; static work load: static work postures in general, prolonged sitting, standing or stooping, reaching, 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: constitutional: age, gender, weight, back muscle strength (absolute and relative), fitness, back mobility, genetic factors; back complaints in the past, psychosocial: depression, anxiety, family problems, personality, dissatisfaction with work or social status of work, tense and fatigued after work, high degree of responsibility and mental concentration; other: degree of physical activity, smoking, alcohol, coughing, work experience.

Construction, mining, transportation, and manufacturing are the occupations which show high rates of low back injuries.[29] 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 work days per year and the largest amount of compensation paid.[30] Occupational risk factors for low back injuries include manual handling tasks,[31] lifting,[32] twisting,[32] bending,[32] falling,[31] reaching,[33] excessive weights,[34,32,35] prolonged sitting,[36] and vibration.[37,38] Some nonoccupational risk factors for low back injury includes obesity,[39] genetic factors,[40] job satisfaction.[41]

Approximately one-half of all compensable low back pain is associated with manual materials handling tasks.[42] 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; falling in 7 to 13 percent.[32]

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 was away from the job, the less likely the worker would return to work.[43,44] Deterrents to returning to work include the worker, such as psychological disability, management, no follow-up or encouragement, union, rigid work rules; the practitioner, too much treatment;[45] and attorneys, lump sum payment versus rehabilitation (rehabilitation is 4.5 times higher on average than lump sum payment).[46] According to Don Chaffin, Ph.D., Director of the University of Michigan's Center for Ergonomics and a professor of industrial and operations engineering and occupational health, a worker who has already suffered back pain is three to five times more likely to get hurt again.[24]

Industry has used three general approaches to attempt to reduce the problem of low back pain including: (1) job design, (2) training and education, and (3) job placement. Control and prevention of low back pain can be accomplished through the evaluation of jobs and the identification of job risk factors. Studies have shown that good job design can reduce up to one-third of compensable low back pain.[42] Bending, twisting, reaching, handling of excessive loads, prolonged sitting, and exposure to vibration are the commonly recognized risk factors for back injuries. Redesign of jobs can lead to the reduction of these 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 well laid out so as to reduce twisting; sit/stand workstations should be allowed where possible with good seat design so as to reduce prolonged sitting and standing; good package design such as hand holes for better coupling by the worker, package size so the worker can hold the load close to the body, and package weight so as not to exceed human capabilities.[47] Interim changes to reduce back injuries include job placement;[48] strength and fitness testing;[49,50,51] strength and fitness training (work hardening),[52,53] and work enrichment, enlargement, or rotation to reduce cumulative exposure. In addition to educating and training the worker, unions, and management about risk factors which 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.[54]

1. Evaluation Criteria for Risk of Back Injury

The NIOSH Work Practices Guide for Manual Lifting,[47] was developed using medical, scientific, and engineering resources to develop quantitative recommendations regarding the safe load weight, size, location, and frequency of a lifting task. The recommendations assume that:

a. the lift is smooth;

b. the lift is two-handed and symmetric in the sagittal plane (directly in front of the body with no twisting during the lift);

c. the load is of moderate width, e.g., 30 in or less;

d. the lift is unrestricted;

e. the load has good couplings (handles, shoes, floor surface); and

f. the ambient environment is favorable.

It is further assumed that other material handling activities such as holding, carrying, pushing, and pulling are minimal; that the individual performing the lifting activities is at rest when not lifting; and those involved in lifting are physically fit and accustomed to labor.

The formula used to analyze the various tasks is as follows:

Action Limit (AL) (lb) = 90 (6/H) (1-.01¦V-30) (.7+ 3/D) (1-F/Fmax); (Maximum Permissible Limit (MPL) = 3 AL); where:

H = horizontal location forward of midpoint between ankles at origin of lift
V = vertical location at origin of lift
D = vertical travel distance between origin and destination of lift
F = average frequency of lift (lifts/minute)
Fmax = maximum frequency which can be sustained (table of values provided in Work Practices Guide)

Tasks analyzed in this manner are divided into three categories:

1. those above the Maximum Permissible Limit (MPL) which are considered unacceptable and which require engineering controls;

2. those between the AL and MPL which are unacceptable without administrative or engineering controls; and

3. those below the AL which are believed to represent nominal risk to most industrial work forces.

The Work Practices Guide indicates that corrective action is needed for jobs which exceed the Action Limit. The incidence and severity rates of musculoskeletal injury have been found to increase in populations "exposed to lifting conditions" described by the Action Limit. It has been determined that over 75 percent of women and over 99 percent of men could (safely) lift loads described by the Action Limit. Snook used a simple percentage capable index based upon psychophysical strength and concluded from a study of 191 cases of low back pain that the proper design of manual handling tasks can reduce up to one-third of industrial back injuries.[42]

2. 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.[55] Gruber 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.[56] Vibration, major structural resonances occurring in the 1 to 20 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.[57] Biodynamic strain, microtrauma, and intraluminal/

intraabdominal 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 vertebrogen pain syndromes, spine deformities, sprains and strains, appendicitis, stomach troubles, and hemorrhoids.[56]

The effects of whole-body vibration have been studied in several jobs, including crane operators,[58] personal motor vehicles,[59] and fork lift operators.[60]

The incidence of permanent work disabilities due to back disorders in crane operators exposed to vibration was compared with a control group by Bongers, Boshuizen, Hulshof, and Koemeester. 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.[58]

A case control study of the epidemiology of acute herniated lumbar invertebral disc in the New Haven, Connecticut, area was conducted.[59] 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 fork lift truck driving on low back trouble.[60] The occupation of fork lift truck driving submits workers to five conditions which can be assumed to increase the risk for contracting low back trouble including: assuming static sedentary position while driving, twisting of the truck in relation to the pelvis, stooping positions, deep sideways trunk bending and whole-body vibration. Brendstrup and Sorensen used the responses to a questionnaire concerning low back trouble of 240 male fork lift truck drivers who drove at least four hours daily as compared to two reference groups: skilled workers and unskilled workers. Fork lift 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 fork lift truck drivers had a significantly higher rate (22 percent) of absence from work due to low back trouble than both control groups (7 percent and 9 percent).

It was concluded that fork lift driving can be a contributing cause of low back trouble.

XI. APPENDIX B

REVISED NIOSH EQUATION FOR THE DESIGN AND EVALUATION OF MANUAL LIFTING TASKS

The 1981 NIOSH Work Practices Guide for Manual Lifting, and the 1992 version called the "Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks,"[61] 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 1992 version includes asymmetric lifting and hand/container coupling guidelines. Because of the additional parameters used to evaluate manual materials handling, and slight adjustments in the equation, the 1992 equation will be used.

The new guide has one weight limit which is called the recommended weight limit (RWL). This equation will be used for selected manual materials handling tasks, and compared with a computerized biomechanical model from the University of Michigan, Version 4.1E.

The calculation for the recommended weight limit is as follows:

$$RWL = LC * HM * VM * DM * AM * FM * CM$$

(* indicates multiplication)

The equation is detailed in Tables 1 to 3.

Table 1. Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks

COMPONENT	METRIC	U.S. CUSTOMARY
LC = LOAD CONSTANT	23 kg	51 lb
HM = HORIZONTAL MULTIPLIER	(25/H)	(10/H)
VM = VERTICAL MULTIPLIER	(1-(.003¦V-75¦))	(1-(.0075¦V-30¦))
DM = DISTANCE MULTIPLIER	(.82+(4.5/D))	(.82+(1.8/D))
AM = ASYMMETRIC MULTIPLIER	(1-(.0032A))	(-(.0032A))
FM = FREQUENCY MULTIPLIER	(see Table 2)	(see Table 2)
CM = Coupling Multiplier	(see Table 3)	(see Table 3)
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 hr; $\leq$2 hr; or $\leq$8 hr assuming appropriate recovery allowances (see Table 2).		

Table 2. Frequency Multiplier

Frequency Lifts/Min	Work Duration					
	≤1 hr		≤2 hr		≤8 hr	
	V <75	V ≥75	V <75	V ≥75	V <75	V ≥75
0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

Table 3. 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

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