

EVALUATING STRENGTH & ENERGY REQUIREMENTS
FOR WORKERS PICKING VEGETABLES

by

R.A. Cavaletto, Assoc. Prof.
Cal Poly
Agri. Engr. Dept.
San Luis Obispo, CA

J. Miles, Prof.
UC Davis
Biological and Agri. Engr. Dept.
Davis, CA

J. Meyers, Prof.
UC Berkeley
School of Public Health
Berkeley, CA

J. Mehlschau, Student
Cal Poly
Agri. Engr. Dept.
San Luis Obispo, CA

Written for Presentation at the
1994 ASAE Summer Meeting
Sponsored by
ASAE

Hyatt Regency Crown Center
Kansas City, MO
June 19-22, 1994

Summary:

This paper discusses the need to obtain field data to evaluate the strength and energy requirements for workers picking a variety of vegetables. This information is central to the evaluation of hazards related to repetitive motion, excessive stress, and fatigue. Results can be used to select activities which should be targeted for future engineering design projects. Preliminary data from a commercial broccoli harvesting operation is included.

Keywords:

Ergonomics, Human Factors, Cumulative Trauma Injury

The author(s) is solely responsible for the content of this technical presentation. The technical presentation does not necessarily reflect the official position of ASAE, and its printing and distribution does not constitute an endorsement of views which may be expressed.

Technical presentations are not subject to the formal peer review process by ASAE editorial committees; therefore, they are not to be presented as refereed publications.

Quotation from this work should state that it is from a presentation made by (name of author) at the (listed) ASAE meeting.

EXAMPLE — From Author's Last Name, Initials. "Title of Presentation." Presented at the Date and Title of meeting, Paper No. X, ASAE, 2950 Niles Rd., St. Joseph, MO 64503-9659 USA.

For information about securing permission to reprint or reproduce a technical presentation, please address inquiries to ASAE.

Evaluating Strength & Energy Requirements for Workers Picking Vegetables

by

R.A. Cavaletto, J. Miles, J. Meyers & J. Mehlschau¹

Abstract

This paper discusses the need to obtain field data to evaluate the strength and energy requirements for workers picking a variety of vegetables. This information is central to the evaluation of hazards related to repetitive motion, excessive stress, and fatigue. Results can be used to select activities which should be targeted for future engineering design projects. Preliminary data from a commercial broccoli harvesting operation is included.

Introduction

While acute trauma represents a significant cost to the agricultural industry, cumulative trauma injuries are being recognized more frequently and have the potential to be even more costly. The costs include not only the actual cost to repair the injury, but also include costs associated with turnover, absenteeism, moral, product defects, production barriers, increased paper work, and potential fines.

California Workers' Compensation data from 1981 to 1990 show that approximately 52% of the non-fatal injuries in Vegetable and Melon Crops, Standard Industrial Classification 016, are strains and sprains and that the largest single cause of injuries is overexertion.

The State of California has proposed an Ergonomics Regulation to address the problem of cumulative trauma injuries. The regulation is currently under review and is to be implemented by January 1, 1995. The proposed regulation will have wide ranging impacts including how medical treatment will be conducted and when, by who, and how worksites and procedures must be evaluated for potential problems.

Strength and energy requirements of workers are necessary to properly assess training intervention, administrative regulations and engineering controls.

Literature Review

Over half (185,400) the occupational illnesses reported in 1990 were disorders associated with repeated trauma (National Safety Council, 1992). Agriculture had 700 reported illnesses (farms with fewer than 11 employees not included). As more information about cumulative trauma disorders is made known in the agricultural community, more of these injuries are sure to be reported.

¹Authors are Richard A. Cavaletto, Assoc. Prof., Jeff Mehlschau, Student, Cal Poly, Agricultural Engineering Dept. and John Miles, Prof. UC Davis, Biological and Agricultural Engineering Dept., & James Meyers, Prof., UC Berkeley, School of Public Health.

Three major factors that increase the risk of cumulative trauma injuries are (MacLeod et al., 1990):

- Repetition- the number of repetitive motions made per work day,
- Force- the exertion used to do the job,
- Posture- awkward positions assumed while working.

Other factors also include physical conditions, such as cold and vibration, and certain personal characteristics.

Quantifying the number of receptions, forces or postures that increase the risk for a particular person a given amount is difficult. Guides such as the *Work Practices Guide for Manual Lifting* (NIOSH, 1981) have been developed to help quantify these factors. NIOSH limits are given as Strength Design Limit (SDL), 99% men and 75% women are capable of this force, and Strength Upper Limit (SUL) or Maximum Permissible Limit, 25% of men and 1% of women are capable of this force. Back Compression Design Limit is 770 lb and Back Compression Upper Limit is 1430 lb.

Also included in these guides are limits for energy expenditure rates during work. Suggested limits are:

- Occasional Lifting (one hour or less)
 - Physically fit male- 9 Kcal/min, female- 6.5 Kcal/min.
- Continuous (8 hr) Not exceed 33% of aerobic capacity
 - Physically fit male- 5 Kcal/min, female- 3.5 Kcal/min.

These limits should be reduced for physically overweight or deconditioned workers. Major factors affecting metabolic energy expenditure rate are (NIOSH, 1981):

<u>Worker Variable</u>	<u>Task Variable</u>
Gender	Load
Body Weight	Frequency of Loading of Body
Lifting Techniques	Vertical Travel Distance
	Vertical Origin of Lift
	Temperature and Humidity

Software has been developed to aid the analysis of both strength and energy calculations. The Center for Ergonomics, University of Michigan has developed several programs that are useful. They are: 2D Static Strength Prediction Program™ Version 4.2e, 3D Static Strength Prediction Program™ Version 2.0, and Energy Expenditure Prediction Program™ Version 1.52.

Data Collection

Determination of strength and energy needs requires the analysis of worker tasks. Several methods have been developed to collect kinematic data. This data can be used in static prediction models. These techniques are summarized by Chaffin (1984). They are : a) Goniometry - a protractor with two reference arms, manual and electronic types are available, b) Flexometer - joint measurement is referenced to gravity through a pendulum, c) Spatial Imaging - use of a camera (s) to record the

location of reference points noted by reflective tape or light-emitting diodes. The use of these techniques in a laboratory is very challenging. Trying to use them in the field adds another magnitude of complexity.

A recently developed device looks like an artificial spine that attaches to a person's back. As the person stretches, rotates, twists the device goes through the same motion. Sensors detect this motion and send data to a nearby computer.

A single video camera was chosen to record the motion of the workers. While this limits the accuracy of our data it is reasonable considering the other variables to contend with in the field. Wide angle shots were taken to observe the workers for energy data. Close up shots were taken to aid in determining angles of the worker's body and extremities. A counter with single frame (1/30 S) accuracy was also superimposed on the video to facilitate the measurement of time.

Commodities under study include lettuce, cabbage, cilantro, peppers, and broccoli. This paper includes preliminary data from a commercial broccoli harvesting crew. The crew consisted of 8 men picking the crop (See Figure 1). Four women on the harvester bunched the broccoli using pneumatic bunchers. They then passed the bunches on to two men who packed the cartons. The cartons were then conveyed forward to a load trailer. One man stacked the cartons on the trailer. The crew forman also served as the tractor driver. Once the tractor was in the row and aligned, he left the tractor and worked with the crew. When the tractor reached the end of the row, he then got back on the tractor and made the turn into the next row. The forman set the speed of the tractor depending upon the crop density. The speed was observed to be 0.3 km/h. All crew members are paid \$6.80/h.

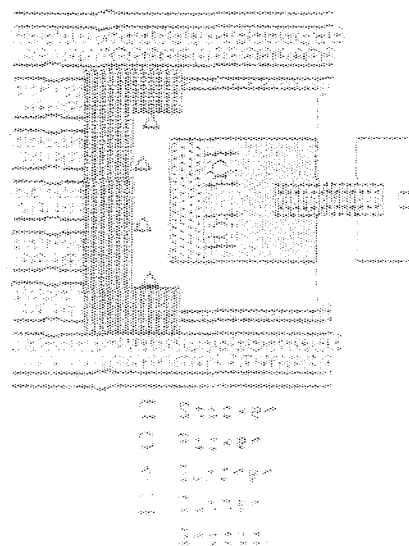


Figure 1. Layout of broccoli harvesting equipment and crew.

Results

The broccoli harvesting crew began its day at 6:30 am by doing some simple stretches (See Figure 2). The forman used this opportunity to make sure each worker was up to doing a days work. It was observed in the men picking the crop that the youngest men took the outer most positions. These positions required the broccoli to be thrown the farthest. During the early morning, while the dew was still present, the men wore rubber boots and pants. As the day warmed up and dried out they then changed to lighter clothing.

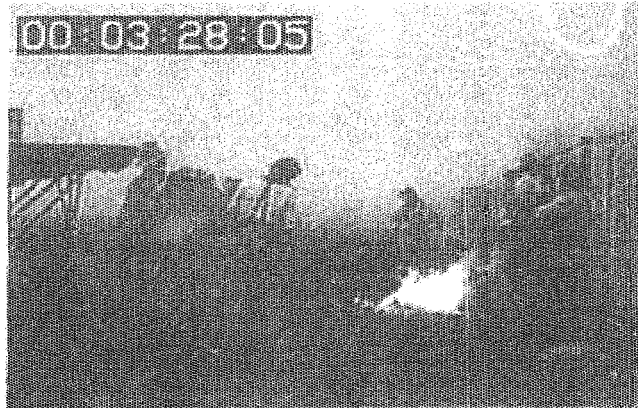


Figure 2. Harvest crew doing stretching exercises before starting work.

Cutters The typical work cycle for a cutter is: bend over, cut a stalk of broccoli, partially stand up, take a step forward, bend over, cut a stalk of broccoli, stand up, trim the broccoli and then toss it on to the bunching table (See Figure 3). This cycle is repeated 10 to 15 times per minute. The energy expenditures in a typical work cycle are shown in Table 1.



Figure 3. Male cutter bent over harvesting broccoli.

Table 1. Energy expenditure for a broccoli cutter, male, 170 lb using Energy Expenditure Prediction Program™ Version 1.52

Task	Freq.	Load lb	Incremental Energy Kcal
Stoop Lower bend over	2	.5	.12
Heavy Hand Work cutting			.02
Stoop Lift standup	2	1	.14
Carry at Waist step forward	2	1	.05
Light One Arm Work trimming	6		.07
Heavy One Arm Work throwing	1		.01
Standing Energy			.06
Standing Bent Energy			0.11
Total Energy			0.57
Job Cycle Duration (min)			0.08
Energy Expenditure Rate (KCAL/min)			7.16

This energy expenditure rate is less than the short term limit of 9 KCAL/min, but more than the continuous limit of 5 KCAL/min.

The back compression stress seen by a 170 lb male worker, approximately 460 lb, is well under the SDL of 770 lb. The weight of his own body is the cause of the stress. Obviously workers that weigh more have higher back stress.

An area of concern with these workers is their throwing arm. Due to the height of the bunching table and their position with respect to it, some of the workers use an upward angled back-handed throw (See Figure 4). This awkward position will be studied more fully.



Figure 4. Cutter throwing the broccoli on to the bunching table. Note the awkward position of the arm and wrist.

Bunchers The women bunching the broccoli did 8 to 12 bunches per minute. The height of the bunching equipment was not adjustable and it was evident that some women had to get up a little higher to push the broccoli into the buncher to activate it (See Figure 5). The layout also required the women to rotate approximately 120° to place the broccoli on the packing table. Stress and fatigue of the shoulder area is a likely result of their work. Their energy expenditure rate is approximately 2.9 KCAL/min.



Figure 5. Women activating the pneumatic buncher to bind stalks of broccoli together.

Packers These men worked at a non-adjustable work station (See Figure 6). It was observed that one of the packers had put a stack of unopened cardboard boxes, approximately 15 cm high, on the platform to raise his height. This made him

higher than the carton and aided him in using his weight to close it. The other worker had to "jump-up" to get enough force to close the carton. Several days later, it was observed that the second packer was also standing on a raised platform of unopened cartons to increase his height. The energy expenditure rate for the packers is approximately 3.8 KCAL/min.

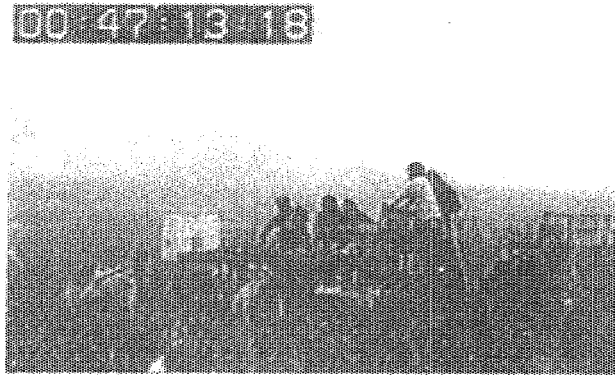


Figure 6. Packers place broccoli in cartons and seal them before giving them to the load stacker.

Conclusions

The workstations of many agricultural employees can benefit from ergonomic analysis. Regulations are soon going to require workstations to be studied from a human factors point of view. Also employees are becoming more aware of cumulative trauma injuries and are concerned for their health. Before solutions to workstations and work procedures can be suggested, proper analysis needs to be completed. Only then can we be sure our solutions are better than the original situation.

The use of a video tape to record worker action is an important tool. Evaluation in the field presents unique challenges due to equipment, physical structure of the crop, and the physical environment.

The preliminary analysis of broccoli harvesters suggests that there are areas that should be looked at more closely. They include the heights of the buncher table, pneumatic buncher, and the packer table. In addition, the lay out of the buncher workstation to minimize twisting and the conveyance of the broccoli from the cutter to bunching table should be investigated.

References

1988. Energy Expenditure Prediction Program™ Version 1.52. The Center for Ergonomics, The University of Michigan. Ann Arbor, MI

1990. 2D Static Strength Prediction Program™ Version 4.2e. The Center for Ergonomics, The University of Michigan. Ann Arbor, MI

1993. 3D Static Strength Prediction Program™ Version 2.0. The Center for Ergonomics, The University of Michigan. Ann Arbor, MI

Chaffin, D.B. and G.B.J. Andersson. 1984. Occupational Biomechanics. Wiley-Interscience Publication, New York.

MacLeod, D., P. Jacobs and N. Larson. 1990. *The Ergonomics Manual*. ErgoTech Incorporated. Minneapolis, MN

National Safety Council, 1992. *Accident Facts, 1992 Edition*. Itasca, IL.

NIOSH, 1981. *Work Practices Guide for Manual Lifting*. DHHS (NIOSH) Publication No. 81-122