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Scott Schneider Column Editor

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Ergonomics

Reducing Risk Factors for the Development of Work-Related Musculoskeletal Problems in Nursery Work

Scott Schneider, Column Editor

Reported by Ira Janowitz, James M. Meyers, Diana G. Tejeda, John A. Miles, Victor Duraj, Julia Faucett, and John Kabashima

Background

The University of California (UC) is conducting a 4-year intervention trial in cooperation with three large commercial nurseries to use engineering controls to reduce the incidence of work-related musculoskeletal disorders (WRMSDs) among workers performing selected, highly repetitive lifting and carrying tasks. The UC team identified 85 such injuries involving 1246 lost work days among the cooperating pool of 1290 workers for the years 1993 and 1994. The team and cooperators then selected for intervention specific high risk jobs involving the manual handling of plants in 1- and 5-gallon plastic containers. A set of handles for carrying and moving plant containers was developed, and is now being subjected to a 12-month intervention trial, after which their effect on the incidence of musculoskeletal disorders and related symptoms associated with these jobs will be evaluated.

This column reports on the impact these handles have on specific ergonomic risk factors identified in these tasks and associated with the targeted disorders. The revised National Institute for Occupational Safety and Health (NIOSH) lifting equation, the lumbar motion monitor (LMM), and a protocol to compare the effect of the change from a pinch to a power grip were all used to assess the effect of the intervention. All measures indicate large-magnitude reductions in targeted risk factor exposures, including extreme stooped postures, repetitive finger pinch grip, and repetitive lifting and lowering of containers.

Introduction

Review of reported injury data for a 10-year period for California agriculture by AgSafe[1] suggested a high incidence of sprain/strain type injuries (48.9% of reported injuries) and overexertion (30.2% of reported injuries) across all crops and commodities. A multidisciplinary team of UC researchers was formed to apply ergonomics methods to the analysis and prevention of these injuries. Plant nurseries were selected as an initial intervention site because they offer a stable work force, are a significant and growing sector of the California agricultural economy, and share some characteristics with field agriculture, construction, and manufacturing industries.[2,3] A previous column in this journal[4] cited a long list of studies which demonstrated the effectiveness of engineering controls in reducing risk factors for WRMSDs.

Three large nursery companies are formally cooperating in the project. All three specialize in container-grown outdoor bedding and ornamental plants, primarily for delivery to retail nurseries. These cooperators are all large operations by industry standards, and between them account for some 1290 employees at the involved work sites.

High Risk Job Tasks

To identify high risk job tasks, cooperators' injury (Occupational Safety and Health Administration 200 logs) and first aid records were reviewed, all jobs were described and screened for ergonomic risk factors using a two-tiered checklist method, and workers and supervisors were asked to identify difficult job tasks.[5] Together with the cooperators, the project team selected for intervention job tasks identified as involving high risk for musculoskeletal injury. Among high priority job tasks were:

1. Handling plant containers for transport to field (Figure 1)
   a. Transporting plants from conveyor belt to trailer

   The worker grasps one 5-gallon container in each hand, or three or four 1-gallon containers in each hand, and places them on a trailer located either to one side of him or behind him. This job cycle is repeated 13 to 20 times per minute.
   b. Transporting containers from a trailer to a planting bed

   The worker grasps one 5-gallon container in each hand, or three or four 1-gallon containers in each hand, carries them up to 55 ft, and places them on the ground along a predetermined row. This is repeated three to five times per minute.
2. Spacing plants

   As the plants grow, they must have adequate room to expand. Thus, plant containers must periodically be moved and spaced farther apart in a ground-to-ground transfer. Workers grasp one 5-gallon container in each hand, or three or four 1-gallon containers in each hand, carry them up to 55 ft, and place them on the ground in new rows. This job cycle is repeated three to five times per minute.

The following risk factors for the development of work-related musculoskeletal problems are present in these tasks:

- highly repetitive bending and twisting of the trunk
- high force (in a pinch grip)
- awkward postures: severe trunk flexion and moderate to severe shoulder flexion
- static muscle effort (when carrying containers)
- contact stress from the edge of the containers on the sides of the fingers and thumb
- high energy demand
- cold ambient temperatures (in the mornings)

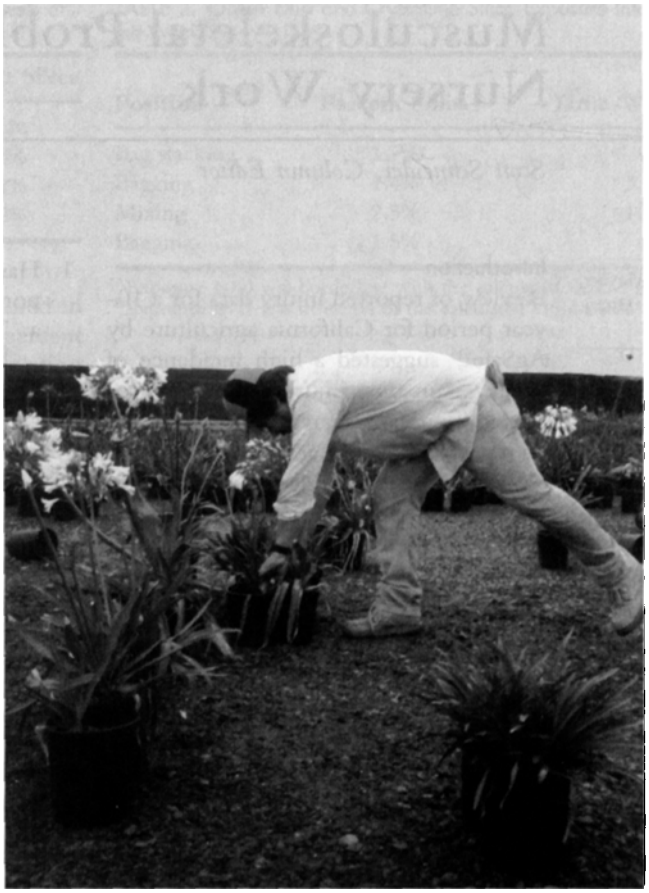

FIGURE 1.

The highest priority risk factors were stooped posture; static, high force grip; and highly repetitive pinch grip.

Interventions

Once priority job tasks for intervention were agreed upon, design constraints for intervention development were agreed upon by management and labor at the nurseries. Among these constraints were:

1. identification of tasks which all parties agree are problems
2. concentration on engineering interventions by providing tools and procedures which will not require extensive training or behavior modification for workers.
3. focus on inexpensive solutions with the potential for short pay-back periods, because of industry concerns about the costs associated with re-engineering of their operations.
4. limitations on job displacement for nursery workers involved in the tasks selected for intervention.

In focusing on manual materials handling, it was helpful for us to look for opportunities to do things which will have a positive effect on risk factors for WRMSDs[6] and the modifiers used to calculate the revised NIOSH lifting equation. These were:

1. improve coupling (grip), changing it from a pinch to a power grip if possible
2. reduce moments by getting the load closer when lifting and carrying
3. improve trunk and upper extremity posture
4. reduce the speed and/or acceleration of lifting movements
5. reduce the amount of force required (change the weight of the load)

The initial primary intervention was the use of a handle for picking up and moving the 1- and 5-gallon plastic containers in which plants are grown. The handle is essentially a hand grip attached to a vertical stem, which has at its base a system for coupling the tool to the container (see Figures 2 to 4). These handles substitute a power grip for a pinch grip and allow the containers to be placed on the ground without stooping. For 5-gallon containers, a tool in each hand is used to pick up one container each. Multicontainer handles for 1-gallon containers were developed to pick up three containers with each tool so as to maintain production at current levels.

Because container lip structures differ, it has not been possible to design a universal coupling system which would work with all structures. Instead, there are a total of six unique coupling systems. The handles are generally constructed of aluminum to maintain minimum tool weights, but some steel has been utilized where material strength is imperative, such as in parts of the 5-gallon tool, which must carry up to 25 pounds (11.36 kg).

Two handle shapes have been utilized, each with different advantages. A T-shaped hand grip for 5-gallon contain-

FIGURE 2.

ers helps protect the worker from prickly plants when gripped on the far side from the plant. When the plant is small or not prickly, it can be gripped nearer to the plant, resulting in a lower potential torque on the wrist. Left- and right-hand grips for 1-gallon containers are angled in both vertical and horizontal planes to achieve neutral postures of the wrist while carrying the containers.

A curved handle has also been developed. It allows for either a low grip, near the bottom of the curve, when containers are elevated, as on a trailer, or a high grip when they are on the ground. There

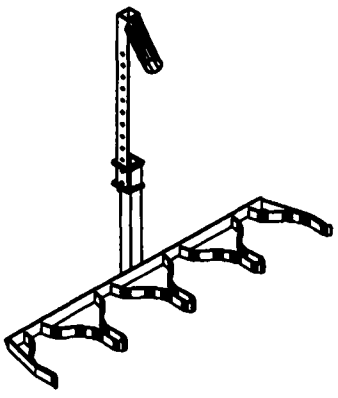

FIGURE 3. One-gallon cradle.

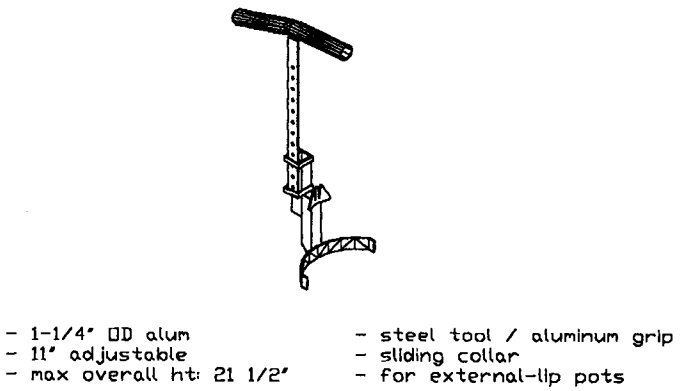

FIGURE 4. Five-gallon point-pick with double grip.

is no standard trailer design among the cooperating nurseries, and some features, such as steel lips welded around the edge of the trailer, are presenting obstacles that have yet to be overcome.

Data Collection Methods

To control for variables such as ambient temperature, fatigue changes during the day, and differing plant maturity, 3 minutes of data collection for both the "before" and "after" conditions were carried out on the same day for each worker within a few minutes of each other. All testing was carried out in a typical field with actual workers from that location. The same plants were handled during each 3-minute test and moved the same distance.

Revised NIOSH Lifting Equation

Measurements for the revised NIOSH lifting equation were carried out according to the Applications Manual.[8] The product of the NIOSH equation is the recommended weight limit (RWL). A lifting index is generated by dividing the actual weight by the RWL. A lifting index of 1 indicates that the load is one that nearly all healthy industrial workers could perform over an 8-hour shift.

Forward Bending

Dynamic postural data were collected using the LMM.[9] An in-field calibration method was developed to assure that the LMM would yield accurate results after having been transported over rough terrain. To analyze the effect of using the handle throughout the job cycle, we calculated the percentage of the cycle that each worker's lumbar spine was bent forward more than 20°.

Energy Expenditure

Heart rate was monitored as an indicator of the metabolic load of the task using chest leads and a telemetry system. The percentage of aerobic capacity was then estimated from the heart rate using the approach outlined in Reference 10. The objective here was to assure that the use of the handles would not increase the metabolic load on the workers.

Grip

A protocol was developed to compare the effects of the handles in substituting a power grip for a pinch. In the preintervention condition, workers routinely lift three 1-gallon containers or one 5-gallon container in each hand using a finger pinch grip. A platform was outfitted with a Chatillon force measurement dynamometer to measure upward pull force capability under the preintervention and postintervention conditions. Actual plants in containers were connected to the dynamometer, with workers pulling upward on plant containers with and without the handles.

The object weight was divided by the maximum upward pull force to generate a ratio of weight to maximum upward pull with a given container. Overall actual-to-maximum lift force ratios for the preintervention and postintervention task requirements are expressed as percentage of grip capability. EMG studies are planned for the fall of 1997 to further analyze the percentage of maximum voluntary contraction required under preintervention and postintervention conditions.

Results

Results from the above measurements of ergonomic effects of interventions are very positive. The handles are significantly reducing the risk factors targeted. The average lifting index was reduced from 2.27 to 1.20 for 1-gallon containers and from 5.20 to 3.26 for 5-gallon containers. The percentage of the job cycle bent forward more than 20° was reduced from 64.46 to 43.95 percent with 1-gallon containers and from 22.00 to 11.15 percent with 5-gallon containers. All of these results were significant (t test, $p < 0.005$). There was no statistically significant change in energy expenditure.

Our grip testing protocol indicated that, when using handles for 1-gallon containers, workers had to exert an average of 9 percent of their grip capability, whereas when not using the handles, they had to exert 48 percent of their grip capacity. When using handles for 5-gallon containers, workers had to exert only about 12 percent of their grip capability, whereas when using a pinch grip, they had to exert 25 percent of their grip capacity.

Discussion

In a complex work setting there are any number of complicating or intervening elements or occurrences with potential for affecting data collection. In most cases we have found approaches such as the revised NIOSH lifting equation and the LMM to be acceptable and effective in the nursery workplace. Our protocol does require removing a worker from regular work for a period, but allows for performance of the targeted job task in the field setting.

The use of the revised NIOSH lifting equation allowed us to integrate changes in the horizontal and vertical location of the load with respect to the worker, and

TABLE 1. Results of Ergonomics Measures

	Without Handles		With Handles	
	1 Gallon	5 Gallon	1 Gallon	5 Gallon
Lifting index	2.27	5.20	1.20	3.26
Forward bending	64.46%	22.00%	43.95%	11.15%
Energy expenditure	51.4%	50.3%	46.5%	50.0%
Grip capacity	48%	25%	9%	12%

changes in the type of grip used, into a single variable that could be used to evaluate the effect of our interventions.

Subsequent planned data collection using the full capabilities of the LMM will include analysis of twisting and side bending, as well as consideration of dynamic motion (velocity and acceleration), using the Ohio State University model proposed by Marras *et al.*[6]

It must be reiterated that despite concern for potential sources of error in methods employed, the large, statistically significant differences in results in each area for task performance with and without handles inspires confidence that a measurable effect is occurring as described.

Conclusions

This project had three primary goals. The first was to demonstrate that ergonomic methods and approaches developed in other industries have practical application to agricultural work. The second was to demonstrate that identified ergonomic risk factors can be targeted and either eliminated or significantly reduced through engineering intervention acceptable to workers and employers. The final goal was to demonstrate that reduction of exposure to selected ergonomic risk factors will result in reduced incidence of musculoskeletal disorders and symptoms.

The first goal was readily achieved in the practical and useful description of risk factors for WRMSDs associated with nursery jobs and the productive use of this information to design tools to reduce the risk factors. The second goal is addressed by this column. The third goal will be addressed in the project's final reports, in which final data on WRMSD incidence and symptoms are analyzed and reported.

While the data reported here are largely preliminary and will be supplemented and augmented by further data collection and analysis still underway, they do show persuasive evidence of the impact of the designed intervention tools and strategies on the targeted risk factors.

Repetitive or sustained stooping, which is present in much agricultural field work, is a serious risk factor for chronic back injury. Stooped posture or trunk inclination is reduced in all nursery workers using the tools. In an industry where stooped posture frequently reaches or exceeds 90°, this is important progress.

One of the nursery industry's most serious and unique ergonomic risk factors is the pinch grip required to handle plant containers. Use of the handles completely eliminates this grip, substituting a power grip. These are important improvements with respect to hand, arm, and other upper extremity WRMSDs.

All of these ergonomic risk factor reductions are important, both individually and in combination. However, for this work to have an industry-wide impact, it is important that the interventions be low cost, fit with predominant work practices, and at least not increase worker energy expenditure or reduce current productivity levels. The 5-gallon handles appear to meet all of these criteria. They are of low complexity and involve low material or production costs. They fit well with current container handling practices and equipment investments. Perhaps most important for eventual field impact is the fact that workers anecdotally reported that they liked the handles, especially for ground-to-ground transfers. While their effective use does require a period of adaptation, once achieved, workers report a clear preference for handling containers with the tools. Further development is needed for the 1-gallon tools. Lack of control over the varieties of 1-gallon containers used in some of the nurseries has impaired our ability to fully develop and test the use of the 1-gallon handle. Some intermediate-size (2 to 2.5-gallon) containers have recently been introduced for flowers. Minor modifications of the present handle designs should work well for these containers.

These are important results. They tell us that agricultural field jobs which involve serious risk factors for musculoskeletal disorders can be effectively addressed using accepted ergonomics approaches. Further, they suggest an underrealized opportunity for intervention in these jobs using small tools. For the past several decades, engineering development in agriculture has concentrated on large machines, leaving small tools used throughout the industry largely untouched and unconsidered. It is time to take another look at many of the jobs and tasks which are routine in agriculture and which are largely taken for granted as immutable.

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Editorial Note: Ira Janowitz is an ergonomics consultant on the staff of the University of California San Francisco Ergonomics Program in Richmond. He has degrees in industrial engineering, management, and physical therapy, and has been involved in occupational health and safety programs since 1977. Mr. Janowitz is Board Certified as a Professional Ergonomist. He is a member of several professional organizations, including the Human Factors and Ergonomics Society and the Orthopedic Section of the American Physical Therapy Association. He has published several articles and book chapters on the prevention and management of work-related musculoskeletal problems, and has assisted many employers, unions, and insurance companies in addressing these issues.

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