Small Changes Make Big Differences

The role of ergonomics in agriculture

Agriculture is one of the most hazardous occupations, not only in terms of fatalities but also musculoskeletal disorders (MSDs). MSDs are injuries to and compromised function of the body's system of muscles, tendons, ligaments, nerves, and spinal discs. Ergonomics is the term we commonly use in the evaluation and design of tools and workplaces to minimize the risk of MSDs.

Ergonomics is about fitting the job to the worker, by looking at the worker-workplace interface and helping workers avoid awkward postures, excessive forces, and repetitive motions. The term is based on two Greek words: *ergon*, meaning work, and *nomos,* meaning natural laws. Its first use can be traced to 1857, which was around the time when significant strides were being made in the early mechanization of agriculture.

Looking at this topic from the worker's perspective, the area of biomechanics is about understanding the motions, forces, and mechanisms of the body, from overall movements to specific muscles, tendons, and other tissues. Broadening this concept of human capabilities and limitations is the area of human factors, in which cognitive, physiological, psychological, and social elements are considered in the overall worker-workplace interface for improving safety and health.

A collaborative robot that assists workers in transporting strawberries during harvest. ***Photo courtesy of Stavros Vougioukas, University of California-Davis.***

In 2001, the National Academies Press published *Musculoskeletal Disorders and the Workplace: Low Back and Upper Extremities* (www.nap.edu/catalog/10032/musculoskeletal-disorders-and-the-workplace-low-back-and-upper-extremities). For all industries, it estimated a $45 billion to $55 billion annual cost for MSDs, and one million people taking time from work due to MSDs. For the scope of this issue in agriculture, we can look back to California's AgSafe program, which published a study of fatal and non-fatal injuries in California agriculture in 1991. Non-fatal injuries were primarily sprains and strains (43%) and caused by overexertion (25%). Overexertion was close behind being struck by something (28%) and just ahead of falls (17%). In a later survey in 2004 with a follow up in 2013 by the Western Center for Agricultural Health and Safety, 1,947 California farm operators reported 160 injuries, 29.4% of which were sprains and strains, and 24.2% of which were caused by overexertion and strenuous movements. In general, MSDs predominate among nonfatal injuries in agriculture and often involve extremities or the back.

Interventions in agriculture

Although many intervention efforts have been made over the last couple of decades, permanent solutions are hard to come by, for various reasons. In labor-intensive agriculture, solutions are often crop-specific. When labor shortages exist, more resources are focused on mechanization, which can eliminate existing risks but can also introduce new risks at the same time.

A successful intervention was the introduction of smaller harvest tubs for hand-harvesting of wine grapes. The smaller tubs reduced the average load from 57 to 46 pounds, bringing the weight below the common 50-pound limit used in general industry. Even though the NIOSH lifting equation suggests a much lower recommended weight limit for this job (www.cdc.gov/niosh/docs/94-110/default.html), this relatively small change made a big difference in workers'

self-reported pain and discomfort, and the intervention was broadly adopted throughout the industry.

Work continues on orchard ladders with shorter spacing between rungs. Biomechanical studies in the field and in the lab indicate a strong preference for rung spacing that is less than the standard 12 inches by one inch or more. This small change appears to make a big difference. The relevant factors for preference may not necessarily be just worker anthropometry (e.g., height) but may also relate to joint health, body weight, and range of motion.

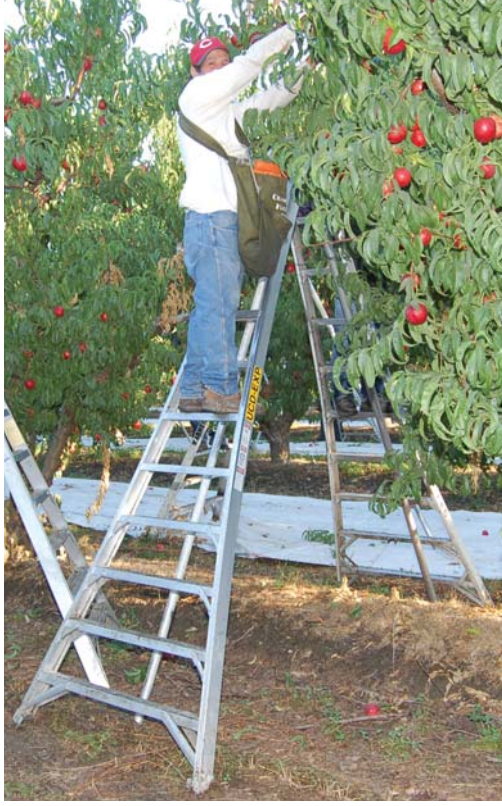
Machine solutions are gaining attention as labor shortages become more of a challenge in agriculture. Machines often eliminate certain hazards but can also introduce new ones. Conveyor systems in labor-intensive harvesting can improve productivity, but they can inadvertently eliminate the natural rest breaks that occur during the walking and carrying phases of the work. These breaks allow temporary relief of highly compressed spinal vertebrae during prolonged work in a stooped posture. Research in strawberry production showed that a five-minute break every hour during harvest improved the workers' well-being and reduced their fatigue, without affecting productivity.

Tractors, harvesters, and other self-propelled machines have benefited greatly from applied ergonomics over the years. The locations and operating forces of machine controls and the adjustability and vibration dampening of operator seats are good examples of efforts to fit the job to the worker. Color-coding of certain controls helps with human factors. Recent work by several ASABE member researchers has looked at control colors and visibility in depth, as operator cabs are being equipped with even more electronics and auto-guidance systems that require timely operator responses.

ROPS, of course, have been a great success in agricultural safety. New work on auto-deploying and foldable ROPS promises to move the field forward. But even here there are opportunities for ergonomics, biomechanics, and human factors considerations, such as improving the correct use of foldable ROPS. The effectiveness of a foldable ROPS depends on the operator unfolding the ROPS into the upright position. This process can include stopping the tractor, loosening clips and pins, dismounting from the tractor, and exerting considerable force, especially if the hinge joint is compromised. The reach distances, postures, required force, duration of the task, or simply remembering to perform the task also present opportunities for improved design. This is where a small change can make a big difference.

Emerging areas in agriculture

We see a shift toward less physically demanding and more mentally demanding jobs in agriculture. As new technologies are developed and deployed, their physical and cognitive implications for operators are sometimes overlooked. The increased use of handheld devices and computers to manage equipment is a case in point. The design and usability of the software that interfaces with equipment have important human factors aspects for safe, efficient, and error-free use. This shift toward digital interfaces with machinery places particular challenges on both the aging and young workforces in agriculture, as youth and elderly cognitive capabilities may not match with the operational requirements of a newly developed interface.



Nectarine harvesting using a tripod ladder with shorter rung spacing. ***Photo courtesy of UC-AERC.***

Recent advances in robotics are also making their way into agriculture. For instance, tree nurseries have started deploying small robots to help space tree containers, a physically demanding job that historically resulted in high MSDs among nursery workers. Collaborative robots are under development for strawberry production to assist workers in transporting heavily loaded containers and, through the use of wearable sensors, monitor workers' exposure to stooped postures and provide programmed breaks for recovery. While these devices are ideal for reducing the physical demands on the workers, we need to be aware of new safety issues that these devices may introduce to the work environment, such as tripping and struck-by hazards.

As we work on improving the productivity, efficiency, and environmental impact of agricultural systems, we must not overlook the importance of the human-workplace interface. The principles of ergonomics and their proper implementation in agricultural systems can make a big difference in worker safety and health, while improving productivity and efficiency. After all, most of us already have an ergonomic office chair, an ergonomically adjusted computer screen, and an easily accessible coffee cup.

ASABE member Fadi Fathallah, Professor, Department of Biological and Agricultural Engineering, University of California-Davis, USA, fathallah@ucdavis.edu.

ASABE member Victor Duraj, Associate Development Engineer, Department of Biological and Agricultural Engineering, University of California-Davis, USA, vduraj@ucdavis.edu.