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Musculoskeletal disorders in labor-intensive agriculture

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ABSTRACT

This paper gives an overview of the extent of musculoskeletal disorders (MSDs) in agriculture, and a historical perspective on how ergonomics has been used to reduce the health effects of labor-intensive agriculture. A summary of exposure to MSD physical risk factors within various classes of crops, along with various administrative and engineering controls for abating MSDs in agriculture is given. These controls range from programmed rest breaks to mechanized or partially-mechanized operations. Worker-based approaches such as prone carts and platforms, and load transfer devices hold promise in combating the prevalent stooped work in agriculture. Including the worker as an integral contributor to all aspects of developing and implementing an intervention, and considering the psychosocial and socio-cultural aspects of the work environment are crucial elements of effective interventions for reducing MSDs. Despite the advent progress in new technologies in agricultural practices, reliance on labor, especially in fresh market fruits and vegetables, will always be a major cornerstone of agriculture for at least the foreseen future. It is encouraging to see the increased interest among health and safety professionals, epidemiologists, engineers, social scientists, and ergonomists throughout the world who are committed to the plight of reducing MSDs and other health problems among agricultural workers.

1. Introduction

The agriculture sector employs about half the world's entire workforce, with an estimate of 1.3 billion workers (ILO, 2003). In most countries, agriculture is recognized as one of the most hazardous industries. There is a host of injuries and illnesses in agriculture that have been consistently identified through epidemiological and community-based studies as in need for controlling due to their high reporting rates among agricultural workers. These include musculoskeletal disorders, respiratory disease, noise-induced hearing loss, pesticide-related illnesses, and increased reporting of cancer cases (Arcury and Quandt, 2003; Arcury et al., 2002; Earle-Richardson et al., 2003; Gamsky et al., 1992; Garcia et al., 1996; Kirkhorn and Schenker, 2002; Lantz et al., 1994; McCurdy et al., 2003; Mobed et al., 1992; Rautiainen and Reynolds, 2002; Von Essen and McCurdy, 1998). However, it has been consistently shown that musculoskeletal disorders (MSDs) are the most common of all occupational non-fatal injuries and illnesses for farm workers, especially those who are involved in labor-intensive practices (McCurdy et al., 2003; Meyers et al., 1997; Villarejo, 1998; Villarejo and Baron, 1999). Labor-intensive practices are still common in the maintenance and harvesting of most fresh fruits and vegetables throughout world, but especially in developing countries. This is consistent with other industries, where MSDs are the most prevalent and costly of all work-related injuries (Bernard et al., 1997; NRC and IOM, 2001).

This paper gives an overview of the extent of MSD in agriculture and a historical perspective on how ergonomics has been used to reduce the health effects of labor-intensive agriculture, with focus on abating the physical determinants of MSDs. The remaining challenges and opportunities in this crucial industry are also discussed.

2. Musculoskeletal disorders in agriculture

Agricultural workers involved in labor-intensive practices are exposed to a multitude of MSD risk factors. The literature has shown three main risk factors that are of utmost priority in agriculture (Meyers et al., 2000, 1997, 2001). These include: lifting and carrying heavy loads (over 50 lb); sustained or repeated full body bending (stoop); and very highly repetitive hand work (clipping, cutting).

There are some similarities in the general classes of MSD risk factors within various types of production agriculture. However, the uniqueness of crop maintenance, harvesting, and packing is expected to result in the distinct manners of how workers are

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Table 1
Type of work and the associated risk factors and body region affected for selected five crops of production agriculture in the US.

Crop class	Estimated percent of US farms	Major type of work	Risk factors	Body region most affected (potential for MSDs and other problems)
Oil, seed and grain (e.g., soybean, corn, wheat)	24%	Driving farm machinery during cultivation and harvesting	Vibration (driving), prolonged vigilance	Whole body and lower back, general and visual fatigue
Vegetable and Melon (e.g., processing potatoes)	1.6%	Soil preparation, planting and cultivation (machine-aided)	Extreme climates, vibration and noise (powered machinery)	Whole body, lower back, ears
		Harvesting	Forceful repetitive cutting, prolonged and repetitive stooping, lifting and carrying heavy loads	Hand/wrist, lower back
Fruit and tree nut crops	3.5%	Harvesting	Climbing ladders with heavy loads, excessive reaching, repetitive cutting/clipping, lifting and carrying heavy loads	Whole body, shoulder, hand/wrist, lower back
		Weeding and pruning	Forceful use of hoe, repetitive cutting	Shoulder, hand/wrist
Greenhouse, nursery and floriculture	3%	Handling containers, propagation	Repeated stooping, pinching, repetitive cutting	Hand/wrist, lower back
Fresh market vegetable (e.g., fresh tomatoes, lettuce)	1.6%	Harvesting	Forceful repetitive cutting, prolonged and repetitive stooping, lifting and carrying heavy loads	Hand/wrist, lower back

exposed to MSD hazards, and how the corresponding musculoskeletal injuries and disorders are manifested. This challenging unique situation has generally resulted in the need to develop prevention and intervention strategies that address specific aspects of the crop and farming conditions at hand. This also may deem previously developed effective approaches to containing MSDs in other occupational settings rather limiting without addressing the specifics of the studied commodity. In other words, the off-the-shelf tools and technologies commonly used for addressing most occupational MSD risk factors in other industries, such as manufacturing, are generally deemed limiting in agriculture.

Several groups in the US and other developed and developing countries have identified the specific types of MSD risk factors present in a number of differing types of crops and commodities in production agriculture. For instance, Fathallah et al. (2006) provided a detailed account about the sources of MSD and other occupational risk factors in different sectors of the production agriculture industry in the US. A summary of these risk factors is given in Table 1 for the following selected general production agriculture crop classes: 1) Oil, seed and grain crops, 2) Vegetable and melon crops, 3) Fruit and tree nut crops, 4) Greenhouse, nursery and floriculture crops, and 5) Fresh market vegetable crops.

3. Ergonomic interventions in agriculture – past and present

Farmers have been historically self reliant and, out of economic and practical necessities, have been coming up with innovative approaches to solve most of their production and workplace problems. Unfortunately, these innovations in agricultural best practices may be at the expense of the farmers and farm workers' health and safety. The best example is introduction of the tractor into agricultural practice in the late 1800s. The tractor allowed farmers to increase their production capabilities and continued to do so for decades to come as new implements and hydraulic-powered systems were introduced to the tractor. However, since its introduction and until our present day, the tractor continues to be a major source for fatalities and severe injuries to operators and people around them. One major source of these deaths and injuries is the lack of a roll-over protection structure (ROPS) on more than half of the tractors used throughout the world, especially in developing countries. For instance, in the US, tractors produced after 1987 are required to have ROPS installed on them. Nonetheless, despite numerous statistics showing the effectiveness of ROPS in reducing tractor injuries and deaths, there are no regulations or incentives to either retrofit or phase-out the millions of non-ROPS tractors still in use on US farms. The problem is even worse in some developing countries, where most tractors are non-ROPS vehicles, and where little or no regulations exist to control for such proven dangerous vehicles.

Another example is the development of the tomato harvester in California in the mid-seventies, which dramatically transformed the processing tomato industry by facilitating a multifold increase in harvesting capabilities. However, the machine introduced new sets of challenges to workers who operate the machine such as high exposures to whole-body vibration (see Fig. 1), harvesting dust, and engine exhaust fumes, which have consequences on the surrounding environment.

Historically, farmers throughout the world have been implementing "ergonomic" solutions to improve productivity and increase comfort. A good example include the introduction of threshers to replace manual threshing of rice paddy, wheat and other grains in farms in India, China, Sri Lanka, Thailand, Philippines, and other countries in Southeast Asia and Africa (Africa Rice Center, 2006; Chamsing et al., 2006; Jafry and O'Neill, 2000; Mohatny et al., 2008; Prasanna et al., 2004). For instance, the introduction of one locally-built, accepted, and affordable rice thresher system in several African countries has resulted in a major

Fig. 1. A worker sorting tomatoes on the platform of a moving tomato harvester.

Fig. 2. Adjustable extended handle for handling nursery potted plants.

increase in productivity and reduction of labor demand by eliminating not only the manual threshing, but also the need for manual sifting and winnowing (Africa Rice Center, 2006).

As in other industries, one can classify the major types of potential interventions for controlling and preventing MSDs in agriculture into administrative and engineering controls. Administrative and engineering controls in agriculture have been well described in detail before (Fathallah et al., 2006); hence, a brief description of each will be presented.

3.1. Administrative controls

Engineering controls are often preferred for ergonomic interventions; however, due to economic, technical, or practical reasons, these types of controls may not be feasible to successfully implement in a farming situation. Hence, under these limiting circumstances, MSD risk factors can be mitigated by the use of administrative controls. These controls rely on workplace policy, procedures, and practices to change worker exposure to MSD risk factors. Examples range from reducing or eliminating piece-rate pay structure to job rotation and training workers to identify potential MSD risk factors.

One proven effective administrative control is the use of programmed rest breaks as a potential intervention for MSDs (Faucett et al., 2007). The results of the study showed that intermittent brief rest breaks appear to reduce the symptoms of fatigue and musculoskeletal discomfort, while productivity appears to be minimally affected. This intervention was permanently and successfully implemented into tree nurseries in California.

3.2. Engineering controls and interventions

Engineering controls for labor-intensive agriculture include three classes of interventions: 1) Approaches to alter workspace–worker interface; 2) Mechanical worker protection or worker aids; and 3) Fully- or partially-mechanized operations (Fathallah et al., 2008).

Several examples of changing the interface between worker and his/her workspace have been shown to hold promise in reducing the risk of MSDs among agricultural workers. This approach is usually achieved by providing alternative tools or alters the workspace to reduce the risks of awkward postures. Examples of altering the workspace to reduce trunk bending are raised beds in strawberries and trellising, which is very common in grapes, but also has a potential in fruit trees such as apples.

Many tools have also been developed to reduce the amount of bending required from the agricultural worker. For example, extended-handle carriers for potted plants in nursery work substantially reduce stooping or squatting when handling these pots (see Fig. 2). Also in nursery, use of shears for cutting plants for future propagation is a very common task; however, one that exposes workers to severe risk of hand/wrist MSDs. Use of bench-based pneumatically-powered cutter eliminates the need for manual cutting and potentially increases productivity (Fig. 3). Anecdotal evidence from nursery owners indicates that workers with partial disability due to carpal tunnel syndrome from excessive use of cutting shears were able to return to their propagation cutting task due to the powered shears. In weeding, motorized tools (see Fig. 4) hold promise in minimizing the need for trunk bending and twisting (Ramahi and Fathallah, 2006), and a redesigned hoe in Nigeria (altering its length and angle to fit the anthropometric characteristics of targeted population) has a potential for reducing postural risk and recued energy demands (Jafry and O'Neill, 2000).

Worldwide, tree fruit harvesting stills rely heavily on manual picking through the use of ladders and bags (citrus, stone fruits), or

Fig. 3. A worker using a pneumatic shears to cut plant material in nursery propagation.

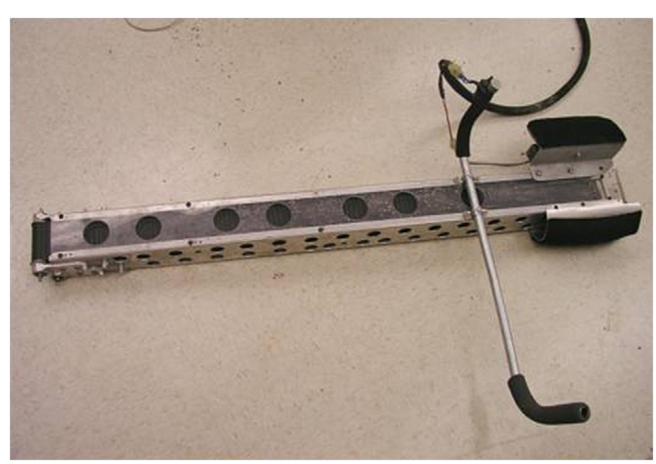

Fig. 4. Motorized weeding tool that maintains the worker in a more "neutral" posture.

baskets (apples) (see Fig. 5). As shown in Table 1, this picking practice exposes workers to excessive lifting loads, repetitive cutting, as well as fall hazard from ladder climbing and descending. However, recent development and implementation of motorized picking platforms in Europe and the US has eliminated the need for two main risk factors: ladder use and the carrying of bags or baskets (see Fig. 6). These platforms allow workers to stand on platforms (in certain cases adjustable) built on top of a vehicle, which brings the worker closer to the fruits. The worker main task is to pick from the fruit trees and place the fruits on collecting conveyor belts as the vehicle move down the tree row. This system requires specific inner-row spacing to fit the vehicle, and in many instances, canopy height and shape has to be altered for optimal productivity. In California and Washington, tree fruit harvesting is dominated by migrant male workers. Due to the reduced energy and strength demands, the introduction of the picking platform has opened up the opportunities for a larger percentage of male and much more female workers to be hired in the harvest season. Given the shortage of agricultural workers in the US and other industrialized countries, it is anticipated that the use of these picking platforms to increase, especially in larger tree fruit farms.

In situations where the workspace is difficult to be altered some mechanical worker protections or worker aids could be used to control MSDs among agricultural workers. These include using a workstation that supports the body in a more neutral spinal posture, for example lying prone or sitting upright (Fig. 7). The use of prone workstations as an intervention for stooped work shows much potential in labor-intensive agriculture, especially where labor costs are very high. For instance, the use of prone platforms, where 10–15 workers harvest crops while laying prone on long platform pulled by a tractor, have been gaining popularity in Europe (Fathallah et al., 2004). However, additional research is needed on the human performance issues related to the risks of static prone work postures and the economic issues related to productivity and improving worker comfort in large commercial agricultural production.

Another type of worker aid that holds promise in reducing lower back disorders among agricultural workers is the "load transfer device". The device transfers a portion of the weight and moment of the upper body from the low back tissues to the hips and/or legs (see Fig. 8 for an example). Laboratory studies indicate that this concept holds promise in reducing the risk to the lower back in tasks requiring severe stooped postures (Abdoli et al., 2006; Barrett and Fathallah, 2001; Gregory et al., 2006; Milosavljevic et al., 2004; Mirka et al., 2003). However, further research is needed to determine their efficacy and practicality.

Lastly, the traditional engineering control has been through the use of mechanized operations, which totally or partially eliminate the need for intensive labor. Successful stories in this area include the cotton picker, hay mower, mechanical planter, and the processing tomato harvester discussed earlier. Given economic feasibility, farm machinery and mechanization provide the ideal

Fig. 5. Traditional tree fruit harvesting using a ladder and a bag.

Fig. 6. Example of a tree fruit picking platform.

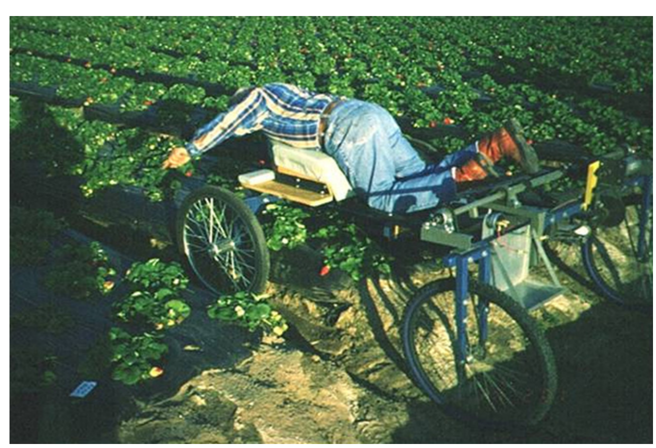

Fig. 7. An example of a prone workstation to control the need for stooping.

Fig. 8. Personal load transfer device worn by a farm worker (ErgoAg, Aptos, CA).

solution to relieve farm workers from manual labor, especially in the harvest of almost all types of grains and processing fruits and vegetables. However, to this date, the use of farm machinery is still rather limited in the harvesting of most fresh fruits and vegetables. This is mainly due to the inevitable potential damage to the crop, as well as the need for selective picking commonly done for required ripeness (e.g., fresh strawberries), and quality and esthetic control (e.g., most tree fruits). In smaller farms and in rural and poor areas throughout the world, even certain crops like wheat, where the use of farm machinery is ideal, economic, topographical, technical, and even socio-cultural limitations make such an option infeasible. These realities make the reliance on human power as one of the major source for cultivating and harvesting many crops in agriculture. However, as discussed earlier, this heavy reliance on farm workers exposes these workers to a host of MSD risk factors that affect multiple regions of the body, with the lower back and hand/wrist being the most commonly affected.

There have been several advances in developing new technologies and techniques to be used in agriculture. Fathallah et al. (2008) provided a summary of the potential for new mechanized and automated technologies in agriculture. They indicate that the future of agriculture includes an increased use of mechanization and automation, and with it, a reduction in the demand for labor-intensive practices. Some of these technologies, especially the ones that integrate precision-agriculture techniques, such as information from Global Positioning System (GPS), into traditional agricultural practices, might have a positive impact on reducing exposures to MSD risk factors among agricultural workers. For instance, in weeding practice, a new GPS-based approach is currently being developed that can both accurately map the location of each crop plant during transplanting, as well as use GPS controlled automatic weed knife to remove weeds growing in the row between crop plants. Combined, these two technologies will reduce the need for the physically demanding manual weeding and the need for herbicides by automating a large amount of the weed control effort. Another added benefit of the approach is the reduced need for herbicide application and worker exposure to emergence of soil fumigants, which has been shown to have negative environmental impact. This emerging technology holds promise for large US framers who already utilize GPS in their operations. Nonetheless, this and other new technological advances may still be years away from full implementation in industrialized nations, and may never be economically feasible in non-industrialized nations and in smaller and family farms.

4. Discussion and conclusion

Compared to other industries, ergonomic interventions and solutions have been late coming into agriculture. Nonetheless, the past decade or so has seen an increased interest to develop and implement ergonomic interventions in agriculture worldwide. Some of these ergonomic "simple solutions" can easily be implemented into many agricultural situations, and many are relatively inexpensive to obtain or can be self-fabricated (NIOSH, 2001). However, the greatest barrier in implementing these types of simple solutions is the awareness of the employer or the worker that a solution exists (Chapman et al., 2004); hence, emphasizing the need for improvements in communicating and educating the affected workforce about ergonomic concerns, and the existence of and accessibility to these solutions.

As in other industries, but particularly in agriculture, effective ergonomic interventions must be developed and implemented using a team approach and as a part of a comprehensive risk management approach. The most crucial members of the team are the farm workers themselves. Worker participation in developing ergonomic interventions in agriculture is paramount in providing the crucial feedback on efficiency, comfort, and socio-cultural issues that may affect worker acceptance and understand barriers to adoption (Fathallah et al., 2006). For instance, prone workstation (Fig. 7), which in concept should constitute a viable solution for reducing stooped postures, was rejected by East Indian women workers in one California operation since it was unacceptable for them to be lying down in a mixed-gender working environment. Such potential socio-cultural barriers may be alleviated if worker participation was included.

The focus of this paper has been mostly on dealing with the physical aspects related to MSDs among agricultural workers. Although physical risk factors are major contributors to MSDs in agriculture, other psychosocial, organizational, cultural, and socio-economic factors could be important contributors to the development and prevention of these disorders. Most agricultural workers face a host of psychosocial, cultural, economic, and legal constraints that may contribute to negative MSD and other health outcomes. These constraints are particularly evident among migrant or seasonal workers who sometime constitute the majority of the agricultural worker population in many regions of the world, especially in the US, Europe, the Middle East, and Southeast Asia. They include issues such as limited access to health care services, transitory and poor housing conditions, lack of social and/or governmental support, linguistic and cultural barriers, vulnerable and non-contractual employment, as well as limited or non-existent safety training and awareness. These non-physical factors may pose serious barriers to the successful implementation and adoption of any intervention approach. This makes it imperative to have an intervention strategy that recognizes and accounts for the multi-faceted nature of the problem, and the need for a multidisciplinary and comprehensive risk management approach to deal with such commonly complex situations in many agricultural settings.

There is still a long way to go to make agriculture a safe and healthy environment. There should be more consorted and collaborative efforts among health and safety professions, epidemiologists, engineers, social scientists, and ergonomics throughout the world to share their experiences about what works and what does not work in making agriculture a safer industry. Governmental and non-governmental entities, and international organizations concerned with occupational health (e.g., WHO and ILO), as well as professional organizations such as the International Ergonomics Association could play a key role in facilitating and promoting such regional and global collaborative efforts. The recent regional and international conferences on agricultural ergonomics, and the recognition for the need for focused groups on this area within various professional societies, are indications of the increased interest throughout the world to contribute to the plight of reducing MSDs and other health problems among agricultural workers.

In conclusion, this paper emphasized that MSDs in labor-intensive agriculture are still ranked among the top health problems facing agricultural workers. There are several intervention approaches to abate MSDs in agriculture including engineering and administrative controls, and this paper summarized many examples of these interventions. Successful interventions should take into account the worker as an integral part of the intervention approach and should consider the psychosocial and socio-cultural aspects of the work environment. Lastly, despite the advent progress in new technologies in agricultural practices, reliance on labor, especially in fresh market fruits and vegetables, will always be a major cornerstone of agriculture for at least the foreseen future, especially in economically developing countries.

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