Discovering the physical onerous activities in manual sesame seed harvest using postural analysis

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Abstract: The sesame oil is accounted as high-priced and high-quality oil, but its production is less than that of major oilseeds due to labor-intensive harvest similar to many agricultural activities. These types of activities are often onerous leading the workers to occupational risk factors such as musculoskeletal disorders. Thus, the aim of this study was to evaluate the manual sesame seed harvest (consisting of work tasks of mowing, tying and shaking) regarding postural workloads to identify onerous activities during this operation which would help to mitigate some problems of the sesame seed production chain. Ovako Working posture Analysis System (OWAS) was used for working posture analysis of twenty-six male workers employed for this study. Results showed that stooped and squatting postures were the most common awkward postures similar to other agricultural activities. Posture rotation was recommended as a potential simple ergonomic solution in the present study. Whereas the work task of tying had the highest requirement for corrective measures, most onerous work task could be shaking, due to the low probability of success of posture rotation implementation in it. About this work task, onerous acts may not be mitigated but by introducing a tool. But about some work tasks (i.e. in the work tasks of mowing and tying) ergonomic recommendations including posture rotation could be introduced when the mechanization and technology are still not entered. Overall, further studies would be conducted to discover the effects of some simple ergonomic interventions and manual or mechanized tools in manual sesame seed harvest.

Keywords: agricultural mechanization, ergonomics, occupational health, manual worker, musculoskeletal disorders (MSDs), oilseed, sesame harvesting

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1 Introduction

Sesame is one of the major oilseeds, which is used in food and industry (Anilakumar et al., 2010; Nzikou et al., 2009). The results of studies (Hwang, 2005; Anilakumar et al., 2010) indicated that major sesame producer countries locate in Asia, and among the five continents, Asia has the highest area of harvest (4.6 million hectares), which produces around 70% of 3.7 million tons sesame seed in the world annually. Sesame, with about oil content of 50%, is the highest in comparison with most of the famous oilseeds such as soybean. However, due to labor-intensive harvest, its production is less than that of major oilseeds. Moreover, sesame oil is accounted as high-priced and high-quality oil. Therefore, it seems that if problems linked to labor-intensive works in sesame product chain, especially in harvest operations were considered, improvement of economic profits and farmers' livelihood would be achieved.

Labor-intensive works in agricultural production processes are common (Fathallah, 2010; Hayati et al., 2018; Marzban and Hayati, 2018), although agricultural mechanization brings more comfort and safe conditions in some activities. Agricultural workers face immense challenges regarding occupational safety and health and often work under hazardous conditions (Niu et al., 2014).

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Musculoskeletal disorders have been a widespread problem in agricultural labor-intensive works, which resulted from occupational risk factors such as static positioning, forward bending, heavy lifting and carrying (Davis and Kotowski, 2007; Hayati et al., 2015a).

Low back pain and discomfort was reported in manual date palm harvest (Marzban and Hayati, 2014). Longtime squatting and standing, respectively, during manual and mechanized cow milking, increased low back pain and musculoskeletal disorder risks among milking labors (Hayati et al., 2015b). Excessive physiological stress associated with exposure to solar radiation was reported during work with walk-behind power tillers (Tiwari and Gite, 2006). Besides drudgery in labor-intensive farm works, human injuries and their costs are the major problems in all the agricultural sectors, and their prevention is a significant concern in ergonomic issues (O'Neill, 2000). For example, the ladder-related injuries were accounted 31% of all causes of injuries in Washington State orchard workers and their compensable claims were the most frequent, most expensive in terms of medical aid, time loss and other costs (Hofmann et al., 2006). Therefore, paying attention to labor-intensive farm works especially in sesame seed harvest operation in order to the improvement of the working conditions by using ergonomic studies seem to be important.

Manual harvest methods of various agricultural crops are usually different from each other. For example, manual picking the potato is frequently performed in both knee bent posture (Das et al., 2013); kneeling posture was excessively observed in manual radish picking (van Dieen et al., 1997); manual date palm harvest with frequent climbing and cutting (Marzban and Hayati, 2014); manual harvest at vineyards with repetitive reaching and handgrip; or manual apple harvest with frequent reaching and picking among (Kirkhorn and Earle-Richardson, 2006). However, the manual harvest of sesame is different from other seed, fruit, tube, and bulb manual harvests. In order to obtain the sesame seed, the mature plant is harvested, maintained in a specific situation to be dried, and, then, shaken to extract the seeds. In sesame seed harvest, workers should spend a lot of time for the manual sesame seed harvest in the particular physical works. It is possible that a different harvest nature has the different occupational risk factors.

Overall, economic potential, drudgery and its costs and different nature of sesame seed harvest were the main reasons to investigate the postural evaluation of manual sesame seed harvest to identify onerous activities during this operation. Introduction of onerous activities of sesame seed harvest could help to effectively suggest the ergonomic solutions to mitigate them. By making this circumstance, sesame production would increase due to decline in drudgery and its potential cost which results in improvement of farmer health and livelihood.

2 Material and methods

2.1 Participants

Twenty-six male workers with mean age of 41 years (Standard Deviation (SD) = 12 years), mean height of 173 cm (SD = 6 cm), mean weight of 67 kg (SD = 5 kg) and mean body mass index (BMI) of 22 kg m^{-2} (SD = 2 kg m^{-2}) took part in this study. Four workers were overweight (BMI 25-29.9 kg m^{-2}) and one was underweight (BMI <18.5 kg m^{-2}) (World Health Organization, 2000). Employed participants had no any musculoskeletal symptom and at least five years' work experience. They were right-handed. All participants were familiarized with their cooperation in this study and were instructed to carry out their related work task in a normal routine time. Participants were entirely full consent to take part in this study.

Operation

This study was conducted in Iran as one of the Asian countries whereby sesame cultivation is common. Manual sesame seed harvest is performed during October and entirely carried out using manual works in Iran. This operation consisted of three main work tasks of mowing, tying and shaking (Figure 1). At the maturity of the crop, worker mows the stem of sesame using a sickle, put it down on the ground and prepares sheaf by gathering the mowed stems in straight legs position, and then walks to mow the rest stems (work task of mowing). In the next work task, the worker walks in order to gather three or four prepared sheaves, squats and ties them with some sesame stems or by a tie (work task of tying). The sesame

sheaves are put under the sunlight about 20 days for drying. In the third work task, the worker walks toward sheaf, squats, lifts and shakes it in order to extract seeds from their capsules in a standing position (work task of shaking). Work task of "putting the sheaves under sunlight" was negligible because cycle time of this work was negligible in comparison with other tasks. Cycle times taken to complete each work task were measured using a digital stopwatch and were presented as the times equaled to treating one sheaf (Table 1).

Mowing Tying Shaking

Figure 1 Work tasks in manual sesame seed harvest

Table 1 Cycle times of work tasks in manual sesame seed harvest, time in seconds (percentage of the total cycle time)

Work tasks	Cycle time (second (%))
1 Mowing	16.8 (43.8)
2 Tying	11.1 (28.9)
3 Shaking	10.5 (27.3)
All works tasks (Total)	38.4 (100)

2.2 Methods and procedure

An observational basic method Ovako Working posture Analysis System (OWAS) was used for postural analysis. This method identifies four work postures for the back, three for arms and seven for legs. In addition, this method considers three classes for the force. So, OWAS has 252 (4×3×7×3) basic combinations of code levels. Finally, works are classified into four action categories (ACs) using combinations of postures and forces showing the level of postural workload severity according to the potential harmfulness of the postures. Therefore, these categories help to identify onerous activities of manual sesame seed harvest. ACs consists of: AC1 indicates normal postures, AC2, AC3, and AC4 represent harmful postures that will require the remedial action (Karhu et al., 1977; Mattila et al., 1993).

Work tasks were recorded by a camera. A skilled observer analyzed the videos in an observational way (Figure 2). Each second divided into four parts in order to increase the precision of analysis. The total number of observations for postural analysis was 480. So, we had 160 (480/3) observations for each work task. Similar to some studies in the field of ergonomics (Hwang et al., 2010; Hayati et al., 2015b), the results of the present study have been presented as means without statistical comparison.

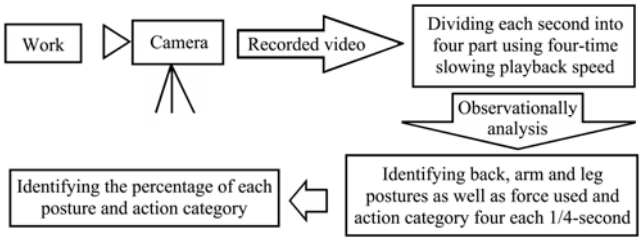

Figure 2 A schematic of the posture measurement system

3 Results

Considering Table 2, the most common work postures in mowing work task were bending forward back and standing with both legs associated with the use of forces less than 10 kg. Postures of bending forward back, both arms below shoulder level and squatting with both legs bent associated with the use of forces less than 10 kg were the most common in the work task of tying. In this work task, corrective measures were needed as soon as possible. About the work task of shaking, the most common posture for the back was straight, for arms was locating below shoulder level and for legs was standing with both legs straight. This work task resulted in the frequent need of forces from 10 kg to 20 kg (Table 2).

In the general viewpoint, as shown in the column related to "Average" in Table 2, worker was often observed in bent forward back posture (61%), both arms

below shoulder level (56%), standing with both legs straight (55%) and use of forces less than 10 kg (93%). Corrective measures in the near future (65%) were the most common actions required in manual sesame seed harvest.

Table 2 Distribution of postures (%) of work tasks in manual sesame seed harvest

	Variable	Mowing (%)	Tying (%)	Shaking (%)	Average* (%)
	Back				
1	Straight	7	10	40	17
2	Bent forward, backward	76	79	17	61
3	Twisted or bent sideways	0	0	41	11
4	Bent and twisted	17	11	2	11
	Arms				
1	Both arms below shoulder level	38	80	59	56
2	One arm at or above shoulder level	32	15	35	28
3	Both arms at or above shoulder level	30	5	5	16
	Legs				
1	Sitting	0	0	0	0
2	Standing with both legs straight	62	26	73	55
3	Standing with one leg straight	0	0	0	0
4	Standing or squatting with both legs bent	0	52	15	19
5	Standing or squatting with one leg bent	0	0	0	0
6	Kneeling on one or both knees	0	0	0	0
7	Walking or moving	37	22	12	26
	Load/use of force				
1	Less than 10 kg (100 N)	100	100	74	93
2	10-20 kg (100-200 N)	0	0	26	7
3	Over 20 kg (200 N)	0	0	0	0
	Action categories				
1	No corrective measures	4	13	63	23
2	Corrective measures in the near future	96	62	17	65
3	Corrective measures as soon as possible	0	24	18	12
4	Corrective measures immediately	0	0	0	0

Note: * Refer to the weighted arithmetic mean of three work tasks (weight of each work task was its percentage of time cycle (Table 1)).

4 Discussion

OWAS method proved to be well suited for analyzing working postures in agricultural activities (Das et al., 2013; Nevala-Puranen, 1996). Therefore, this study evaluated the working postures in manual sesame seed harvest using this method. This method made it possible to classify the work tasks based on intensity and extensity of awkward postures.

The sesame was planted in the on-bed planting system. Worker placed in the furrow which was at a lower height in comparison with sesame stem. The worker had to adjust his body in bent forward back with both legs straight standing posture to mow the stems. This posture is called stooped posture which is common in the manual harvest of agricultural crops and is strongly associated with high incidence of low back disorders and pains (Fathallah et al., 2004). Sustained shoulder abduction (both arms at or above shoulder level, 30% (Table 2)) during work task of mowing, as a static work posture and one of physical risk factors at work (Burdorf and Sorock, 1997), may increase the muscle pain at shoulders' region (Roquelaure et al., 2009).

Sesame farm is usually sparse and it let the worker to rapidly mow the stems. This condition did not let the worker squat or sit beside the crop stems but encouraged him to stand with both legs straight and walk. It could be ergonomically improved, until future mechanization interference, if the worker occasionally squats in-furrow or on the bed in order to break the stooped posture by dividing it into the stooped posture and squatting posture instead of pure stooped posture. This action causes to decrease physical strains on the particular body parts. Posture rotation is a potential way to prorate the physical workloads (Das et al., 2013).

In the work task of tying, the worker was highly observed with postures of bent forward back, both arms below shoulder level, squatting with both legs bent (52%) and standing (26%). These postures could be explained by the fact that worker gathered sheaves in a stooped posture and then tied them in a squatting posture. These two awkward postures are common risk factors for low back musculoskeletal disorders in the agricultural sector (Fathallah et al., 2004). In addition, kneeling during squatting to work at ground level in this work task could increase knee discomfort risks (van Dieen et al., 1997). Bent forward back posture could relatively be avoided if worker straightens occasionally his upper and lower body during walking toward sheaves as a rest time. Increasing rest time during work cycle should be considered when designing an appropriate job rotation scheme (Keir et al., 211). This action may expand a time, but it can help to improve the worker health and decrease low back risk factors because of posture rotation (Raina and Dickerson, 2009). It should be remarked that due to performing the work task of tying immediately after the work task of

mowing and frequent bent forward postures in these two work tasks, risk of low back disorders could more highly increase with exposure to awkward back postures and increasing duration of this exposure (Sbriccoli et al., 2004).

During work task of the shaking, the worker was observed with postures of bent and twisted back and one arm above shoulder level using a 10-20 kg force in order to shake the sheaves. This awkward posture may cause low back disorder and pain due to heavy lifting (Bernard, 1997) and shoulder musculoskeletal disorders due to heavy physical activities of shoulders (Roquelaure et al., 2009). The act of shaking was not avoidable in this work task, whether posture rotation is introduced or not. It seems that only way to avoid the shoulder heavy activity is the utilization of manual or powered machines for shaking, whilst rest durations could be suggested. Whereas corrective measures required in this work task was not the highest among all of the manual sesame seed harvest work tasks, due to non-avoidably of shoulder heavy activities using potential work rotation, this work task seems to be most critical onerous activity in the present study.

Worker participation in developing ergonomic interventions for stooped and squatting work provides the feedback on efficiency, comfort, and social and cultural issues that are necessary to improve worker acceptance and understand barriers to adoption (Fathallah et al., 2004). Therefore, further studies would be conducted to evaluate the effectiveness of some simple ergonomic interventions, for example, posture rotation or simple tools in manual sesame seed harvest.

Limitations

This study was only performed with considering to the male gender. The scarcity of female workers in manual sesame seed harvest area caused difficulty to prepare the conditions for participation and evaluation them.

5 Conclusions

Stooped and squatting postures were the most common awkward postures in manual sesame seed harvest similar to other agricultural activities, whereas the nature of activities of the present study was different from them. Some ergonomic recommendations including posture rotation could be implemented where the mechanization and technology are still not entered. Moreover, some onerous work tasks (i.e. shaking) may not be mitigated but by introducing a manual or motorized tool. Overall, further studies would be undertaken to investigate the effects of some simple ergonomic interventions and manual or mechanized tools in manual sesame seed harvest.

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