

Prevalence of musculoskeletal disorders, ergonomics risk assessment and implementation of participatory ergonomics program for pistachio farm workers

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ABSTRACT

Background and objectives: Pistachio farmers are exposed to a variety of risk factors for musculoskeletal disorders (MSDs). However, no study has been conducted to investigate MSDs in pistachio workers. Therefore, in the present study, besides investigating the prevalence of MSDs and their ergonomic risk factors, the participatory ergonomics (PE) method is used to provide an intervention program to reduce MSDs in this population in harvesting and processing pistachio. **Methods:** The present study was conducted in two phases. In the first phase 138 workers participated. The prevalence of MSDs was assessed with Nordic Musculoskeletal Questionnaire and the ergonomic risk factors was identified with ManTRA method. In the second phase PE was used to perform ergonomic interventions for reducing MSDs and the effect of the intervention was investigated. Sixty-four workers participated in the second phase (32 in the case group and 32 in the control group). **Results:** The highest prevalence of MSDs was in shoulders (63.7%), followed by the lower back (63%) and wrists/hands (52.1%). The comparison showed that after implementing the PE intervention program, the prevalence of MSDs in the intervention group was not significantly different from that in the control group. However, in the reassessment by the ManTRA method for five tasks that were identified as high risk in the first phase, a decrease in ManTRA final score was observed for all the five tasks. **Conclusions:** MSDs were prevalent in all body regions of workers. After implementing PE interventions exposure to ergonomic risk factors decreased.

INTRODUCTION

Musculoskeletal pain and discomfort are well-known common health problems in almost all occupations and countries, which occur as a consequence of exposure to several work-related stressors such as repetitive movements, awkward

postures, overexertion, and localized mechanical stresses (1, 2). Agriculture is regarded as an occupation with high risks in many countries. Human resources are the most crucial capital and the main production factor in the agriculture industry. Its management is a major determinant for higher productivity (3).

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Farmers are exposed to various diseases such as musculoskeletal disorders (MSDs) (4). Besides significant impact on health, MSDs cause a large financial burden on the employees and industry (5, 6). Moreover, it has been shown that these disorders are the most common occupational injury among farmers. Results of previous studies have also shown that the prevalence of MSD symptoms in these workers has been increasing (7). In Iran, similar to many other developing countries, agriculture is considered a high-risk industry (8).

Pistachio is one of the most important agricultural products from Iran. Iran ranks first in pistachio production in the world (9). In several cities in Iran, a considerable number of people are engaged in pistachio cultivation. Pistachio trees have different morphological characteristics from other trees, so pistachio farmers are exposed to particular ergonomic risk factors (Fig. 1). The pistachio tree grows like a shrub, and the space below or between the branches is not large enough for the worker to easily stand in. The thick and intertwined branches of the pistachio tree prevent the worker from bending the tree branches while picking the pistachios. These features have a negative effect on three cardinal ergonomic constraints including clearance, reach and posture. Gum from trees reduces the efficiency of gloves and even hands when separating pistachio clusters from the tree (more than other trees). Furthermore, in tall trees, due to the inflexibility of the branches, picking pistachios is a difficult task. In most pistachio orchards, the trees are planted in rows and at short intervals, so the load is moved manually. Besides, harvesting takes place in late summer in very hot weather. The process from harvesting up to transferring the dried product to the market also has its own ergonomic risk factors.

Pistachio farmers are exposed to a variety of risk factors for MSDs, which include long hours of activities, such as handling heavy loads, repetitive movements, static and awkward postures, high force exertion, unfavorable weather conditions, and contact stress. In these cases, high rates of MSDs are expected. However, no study has been conducted to assess the ergonomic risks in pistachio orchard workers or to reduce these risks. Therefore, this study aims to reduce MSDs in pistachio orchard workers.

MSDs can be reduced via ergonomic initiatives. One approach to ergonomic interventions is to engage workers in the process of identifying hazards and determining solutions – called participatory ergonomics (10-12). Scientific literature show that PE interventions are effective in reducing MSD outcomes (13-15).

In ergonomic studies, PE is one of the most popular methods for reducing MSDs although this method has been used in a few agricultural ergonomic studies (16, 17). Therefore, in the present study, besides investigating the prevalence of MSDs and their ergonomic risk factors, the PE method is used to provide an ergonomic intervention program to reduce MSDs in the study population. Accordingly, the objectives of this study are as follows:

1. Determining the prevalence of MSDs in pistachio orchard workers.
2. Assessing ergonomic risk factors in harvesting and processing pistachio as well as determining high-risk tasks.
3. Performing ergonomic interventions based on the assessment results and using the PE method.
4. Investigating the effect of ergonomic intervention program on the prevalence of MSDs.

METHODS

Study design

The present study was conducted in two phases. The first phase was in September and October 2019 and the second phase in August, September and October 2020 (the yearly harvest and processing of pistachios begin in early September and continue until



Figure 1. Examples of tasks during pistachio harvest

late October). The first phase assessed the prevalence of MSDs and identified the ergonomic risk factors in harvesting and processing pistachio. In the second phase, PE was used to perform ergonomic interventions for reducing MSDs in the study population during pistachio harvest and processing. Furthermore, the effect of PE on reducing the prevalence of MSDs in the control group was investigated. The hypothesis in the second phase was that the prevalence of MSDs in the intervention group (case group) would be lower than the control group.

Participants

In the first phase, a cross-sectional survey was carried out on 138 pistachio growers in one of the districts of Rafsanjan county (in southeastern Iran). The inclusion criteria were having at least 1 year of work experience, having a normal BMI ranging from 18.5 to 30 (18), no smoking and no underlying disease or accident affecting the musculoskeletal system. The workers entered the study voluntarily and filled out a consent form before participating in the study. Sixty-four out of 138 workers who had participated in the first phase were eager to take part in the second phase of the study. Before the start of the second phase, the participants filled out another consent form. Out of 64 participants in the second phase, 32 were selected for the intervention group, and cooperated in compiling and implementing an ergonomic intervention program using the PE method. The other 32 participants were included in the control group (they did not receive the PE intervention).

Demographic data and prevalence of MSDs

The demographic characteristics of the participants and the prevalence of MSDs in the first phase of the study are presented in Table 1. In the first phase, the participants had a mean age (standard deviation) of 35.01 (10.45) years and 68.1% of the participants had more than 5 years of experience. The highest prevalence of MSDs was in shoulders (63.7%), followed by the lower back (63%) and wrists/hands (52.1%).

Data collection tools

Data collection tools and how they were used are described below.

Table 1. Individual characteristics of the agricultural workers (n=138)

Variables	N=138
Demographic characteristics	
Age (Year) Mean (SD)	35.01 (10.45)
Range	18-63
BMI (Kg/m²)	
Mean (SD)	22.6 (3.2)
Marital status (n (%))	
Single	22(15.9)
Married	116(84.1)
Education level (n (%))	
Diploma and lower	77(55.8)
Associate Degree	52(37.7)
Bachelor and higher	9(6.5)
Job experience (More than 5 years) (n (%))	
Yes	94(68.1)
No	44(31.9)
Second job (n (%))	
Yes	87(63)
No	51(37)
Prevalence of MSDs (n (%))	
Neck	63 (45.6)
Shoulders	88 (63.7)
Elbows	24 (17.4)
Wrists/hands	72 (52.1)
Upper back	74 (51.4)
Lower back	87 (63)
Thighs	51 (36.9)
Knees	60 (43.4)
Ankles/feet	63 (45.6)

1. Hierarchical Task Analysis (19): HTA is the most popular task analysis method. HTA involves describing the activity under analysis in terms of a hierarchy of goals, sub-goals, operations and plans. The final result is an exhaustive description of task activity (20).
2. Demographic questionnaire.
3. Nordic Musculoskeletal Questionnaire (NMQ): The general NMQ is used to examine the reported cases of MSD symptoms in different body regions among the study population (21). The validity and reliability of the Persian version of

NMQ were surveyed by Choobineh et al. (22). It should be noted that the reported musculoskeletal symptoms were limited to the past week.

4. **Manual Tasks Risk Assessment (ManTRA):** ManTRA is an ergonomic risk assessment tool that was proposed as a common proposal among University of Queensland, Curtin University of Technology, and Queensland Division of Workplace Health and Safety in 2003 (23). This technique was planned to assess the WMSDs risk level existing in different workplace manual tasks. ManTRA was conceptually based on Strain Index and Quick Exposure Check (QEC). ManTRA is required to assess total exposure of five body regions to: repetition, exertion, awkward postures and vibration. Possible proposed action level thresholds are then presented for exertion only, the combination of exertion and awkwardness, and total exposure only (23). The main advantage of ManTRA can be attributed to providing the simultaneous interactions among different risk factors for each body region. ManTRA provides criteria for manual tasks risk assessment without the need to prior training and can be useful for workplace health and safety inspectors. The most important purpose of ManTRA is to provide an exposure risk assessment to musculoskeletal risk factors of manual tasks in workplaces and industries. Similar to other ergonomic tools, a team work risk assessment comprising the employees performing the manual tasks and the assessors assessing the manual task can be helpful to achieve a correct assessment. Action level thresholds imply the assessors' judgments regarding the need for implementation of control measures (24).
5. **Participatory ergonomics:** Participatory ergonomics (10) is a popular approach to reduce MSDs (15). The involvement of workers in the process is essential as it ensures that the participants take responsibility for and ownership of risk identification, solution development, and implementation of change (25). The PE process encourages workers to be involved in optimizing their own work routines, decreasing work-related risk factors (26), and thereby improving their health (27).

Implementation of the study

The first phase of the study was conducted during the harvest time in 2019. The workers were interviewed and all tasks were analyzed using the HTA method. Ergonomic evaluation was then performed using the ManTRA method for different subtasks. Additionally, 20 days after the harvest and processing, the Nordic questionnaires were completed by the participants. At this stage, the prevalence of MSDs, high-risk tasks and the body regions with ergonomic risk factors were determined.

The second phase of the study began a month before harvest in 2020 and continued for 20 days. Half of the participants in this phase were working in a 25-hectare pistachio orchard, which were selected for the PE intervention program. To evaluate the effectiveness of the interventions and control their implementation, according to the research facilities, the workers had to be selected from a single orchard and farm. There were 37 workers in this farm, 32 of whom were enrolled in the study.

The control group included 32 participants who were working in a similar farm for pistachio harvesting and processing. During the implementation of the PE program, two researchers guided the process. Initially, the participants in the intervention group were trained in two one-hour ergonomic sessions by an ergonomist; the training included basic ergonomic knowledge on how to carry loads correctly and to avoid inappropriate postures or spending a long time in a posture. At this stage, it was attempted to transfer the general ergonomic knowledge to the orchard workers and increase their understanding of the complications due to MSDs.

Then, the results of ergonomic assessments were then explained to all. These results included the prevalence of MSDs in various body parts and identified high-risk tasks using the ManTRA method. These results were supposed to increase the participants' knowledge of ergonomic risk factors in their job tasks (harvesting and processing) and promote common understanding of work-related issues, facilitate communication and prepare for better cooperation to achieve common objectives. In these sessions, the workers learned how to analyze ergonomic risk factors in their tasks. Moreover, the summary of training and a form were given to the workers.

The workers were asked to write down their suggestions on the form. After a week, a two-hour workshop was held. In this workshop, the high-risk tasks were introduced and the risk factors in these subtasks were determined; the participants were then asked to declare their suggestions for implementing the principles of ergonomics in harvest/processing pistachio and improving the existing conditions. The suggestions of the participants were recorded by the ergonomist. Those suggestions that could reduce the existing ergonomic risk factors in the process were selected by ergonomists and their feasibility was discussed in the next session.

At the end of the feasibility-proving session, those suggestions that could be cost-effectively implemented by the orchard owners were concluded and tabulated as the measures to reduce the prevalence of MSDs in the workers. Therefore, according to the identified risk factors and the PE method, an ergonomic intervention program was developed two weeks after the first PE session. To implement ergonomic interventions before harvesting, the necessary tools were provided for the participants. These tools included pliers, gloves, new carrying bags, lighter shovels, long-handled rectangular slabs to flatten the pistachios, platforms to reduce the height for easier loading and unloading, light portable travel seats and sit-stand chairs.

Moreover, one week before harvest, the participants in groups of 4 to 5 were trained for 1 hour to perform corrective exercises every 15 minutes, and they were asked to activate the alarms of their mobile phone every 18 minutes as a reminder for the corrective exercises. Actually, the participants were asked to stop working for 2 to 3 minutes every 15 minutes and perform corrective exercises or sit on a chair and rest those body parts that are at risk of repetitive movements or static work postures. This schedule was inspired by the review paper of Miedema et al. who studied maximum holding times (MHT) for the prevention of discomfort and classified different postures in different categories. These authors determined the value of MHT for each category of postures, and recommended the workers to hold a posture for at most 20% of the MHT (28). Using their classification for the task of harvesting pistachio, a maximum time of 10 to 15 minutes was

obtained, and 15 minutes was chosen according to the suggestions of the participants.

Up to 20 days after harvest, one of the ergonomists on the PE team reminded every participant on a daily basis to perform the intended interventions. However, due to the existing limitations, it was not possible to fully monitor the implementation of interventions. After 20 days of the interventions, the Nordic questionnaires were completed by both the intervention and control groups and subsequently compared. Additionally, the participants in the intervention group were asked to express their satisfaction with the interventions as a percentage.

Statistical analysis

Data were analyzed using Statistical Package for Social Sciences, version 16 (SPSS Inc., Chicago, IL, USA). Descriptive statistics and frequency distribution of the demographic data and the prevalence of MSDs were presented through number (percentage), range, and mean [Standard Deviation]. T-test and chi-square tests were used to compare demographic characteristics and the results of MSDs prevalence in the intervention and control groups.

RESULTS

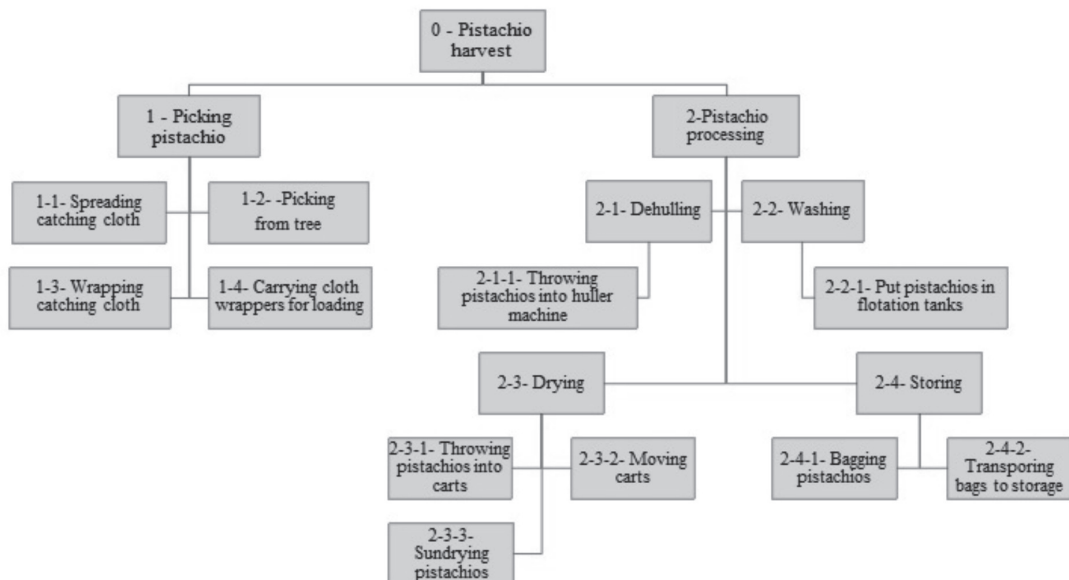
The demographic characteristics of the participants and the prevalence of MSDs in the second phase for the control and intervention groups are shown in Table 2. The participants in the second phase in the control and intervention groups had a mean age (standard deviation) of 35.41 (8.86) and 34.69 (9.44), respectively. There was no statistically significant difference between the prevalence of MSDs in any body part in the intervention and control groups. In the intervention group, the prevalence in the neck and wrists/hands was, respectively, 21% and 12% less than those in the control group, while in other regions such as lower back and ankles/feet the prevalence was, respectively, 16% and 12% higher than those in the control group.

Tasks description and analysis

The HTA task analysis results are shown in Fig. 2. According to the analysis, this job includes 2 tasks and 11 subtasks. Harvest and processing of

Table 2. Demographic characteristics and MSDs among case and control groups

Variables	Control group (n=32)	Case group (n=32)	P- value
Demographic characteristics			
Age (Year) Mean (SD)	35.41 (8.86)	34.69 (9.44)	0.755
BMI (Kg/m²)			
Mean (SD)	22.26 (2.94)	21.85 (2.59)	0.56
Marital status (n (%))			
Single	12 (37.5)	9 (28.1)	0.424 chi – square
Married	20 (62.5)	23 (71.8)	
Education level (n (%))			
Diploma and lower	15 (46.8)	15 (46.8)	0.753 chi - square
Associate Degree	13 (40.6)	11 (34.3)	
Bachelor and higher	4 (12.5)	6 (18.7)	
Second job (n (%))			
Yes	14 (43.7)	15 (46.8)	0.802 chi - square
No	18 (56.2)	17 (53.1)	
Prevalence of MSDs (n (%))			
Neck	15 (46.8)	8 (25)	0.068 chi - square
Shoulders	13 (40.6)	11 (34.3)	0.606 chi - square
Elbows	11(34.3)	10 (31.2)	0.79 chi - square
Wrists/hands	8 (25)	12 (37.5)	0.281 chi - square
Upper back	18 (56.2)	13 (40.6)	0.211 chi - square
Lower back	17 (53.1)	21 (65.6)	0.309 chi - square
Thighs	6 (18.7)	5 (15.6)	0.74 chi - square
Knees	12 (37.5)	17 (53.1)	0.209 chi - square
Ankles/feet	15 (46.8)	20 (62.5)	0.209 chi - square

**Figure 2.** Hierarchical Task Analysis of harvesting Pistachio

pistachio takes between 25 to 45 days. Every day, some workers go to the orchard to pick pistachios and some work in the hulling/drying facility, while others are responsible for transporting pistachios from the orchard to the processing facility. The hulling/drying facility is equipped with devices for dehulling, washing and drying pistachios and has a large area for spreading pistachios (which have been semi-dried in the dryer machine) under the sun. Workers pick pistachios from 6 a.m. to 2 p.m. (i.e., 8 hours, including 45 minutes for breakfast between 9 and 10 a.m. The following cycle is repeated during pistachio picking process: the workers spread a catching cloth/fabric under the tree and start picking pistachio clusters. In this activity, the upper limb is at risk of repetitive work, and after 9 p.m., the temperature rise is also considered as a cause of discomfort. After picking, someone wraps the catching cloth and another worker carries and unloads it to a transport truck dedicated to fresh in-hull pistachios.

According to the workers, the weight of the cloth wrappers is usually between 30 and 50 kilograms. After transporting the in-hull pistachios to the drying facility (between 7 and 8 in the morning), the workers shovel the pistachios into the hulling machine (the upper limbs are at risk of repetitive work and lower limbs of prolonged standing). The dehulled pistachios are washed and dried by drying machines. Then, for the final drying stage under the sun, the product is transferred to transport carts and spread on the ground by the workers. The dry product is bagged in packages of 65 to 70 kg and transported by the workers to the storage. Improper working postures and load handling are the major ergonomic hazards in this process, which usually lasts until 3 to 5 p.m. It is worth mentioning that in this study, the pistachios were washed using special machinery, while in some facilities this is done traditionally by manual effort, which causes more ergonomic hazards.

Manual tasks risk assessment

The results of assessing subtasks in ManTRA are shown in Table 3. According to the ManTRA method, action may be indicated if, for any region, the exertion risk factor is 5, the sum of exertion and awkwardness is 8 or greater, or the cumulative risk is

15 or greater. These results show that five harvesting and processing subtasks required corrective actions according to the scores of the ManTRA method. These subtasks were picking pistachios from the tree, carrying in-hull pistachios for loading, shoveling them into the hulling machine, shoveling the hulls for disposal and transporting pistachio bags to storage. For the subtask of picking pistachios from trees, the final and overall scores of force exertion and posture for the arm, wrist and hand exceeded the acceptable range. Both subtasks of carrying fresh and dry pistachio bags had high scores

for different body regions, especially the upper limbs and back. Shoveling pistachios into the hulling machine and shoveling the hulls into the disposal truck also had higher final score for the four body regions.

Table 4 illustrates the results of ManTRA [assessment/approach which was conducted] after applying participative ergonomics interventions. In the task of picking pistachios from trees, results denote that posture code and frequency [/posture and frequency codes] decreased for various parts of the body which has reduced the total ManTRA score for this [specific] task. For the task of carrying cloth wrappers for loading, posture code and force exertion in the back and upper body [limb] have improved. In the task of washing pistachios, neck and upper body codes diminished however, the overall score indicates that corrective measures are [still] required for this task. Also, reducing load weight has decreased the scoring in the task of transferring bags to storehouse.

Participatory ergonomics

The suggestions that could be cost-effectively implemented by the orchard owners and the participants agreed to do them are listed in Table 4.

Table 4. Results of ergonomic evaluation by ManTRA method, after implementing the PE intervention program

The results of the prevalence of MSDs were compared between the intervention and control groups (Table 2). The comparison showed that after implementing the PE intervention program, the prevalence of MSDs in the intervention group was not significantly different from that in the control

Table 3. Results of ergonomic evaluation by ManTRA method

Task	Subtasks	Body region	Total time of task	Repetition	Force exertion	Posture	Vibration	Overall score of force exertion and posture	Cumulative risk score
Picking pistachio	Spreading catching cloth under trees	Lower limbs	4	1	1	5	1	6	12
		Back	4	1	1	5	1	6	12
		Neck/shoulder	4	1	1	3	1	4	10
	Picking pistachios from trees	Arm/wrist/hand	4	1	2	4	1	6	12
		Lower limbs	4	4	1	3	1	4	13
		Back	4	4	1	4	1	5	14
		Neck/shoulder	4	4	2	5	1	7	16
		Arm/wrist/hand	4	4	3	5	1	8	17
		Lower limbs	4	1	1	5	1	6	12
	Wrapping the catching cloth	Back	4	1	1	5	1	6	12
		Neck/shoulder	4	1	1	5	1	6	12
		Arm/wrist/hand	4	1	3	4	1	7	13
		Lower limbs	4	1	3	4	1	7	13
	Carrying cloth wrappers for loading	Back	4	1	4	5	1	9	15
		Neck/shoulder	4	1	3	2	1	5	11
		Arm/wrist/hand	4	1	5	4	1	9	15
		Lower limbs	5	5	1	2	1	3	14
	Shoveling in-hull pistachios into hulling machine	Back	5	5	1	4	1	5	16
		Neck/shoulder	5	5	2	2	1	4	15
		Arm/wrist/hand	5	5	4	4	1	8	19
		Lower limbs	5	3	2	2	1	4	13
	Washing pistachio	Back	5	3	2	2	1	4	13
		Neck/shoulder	5	3	2	4	1	6	15
		Arm/wrist/hand	5	3	3	5	1	8	17
		Lower limbs	5	1	1	2	1	3	10
	Putting dehulled pistachios in carts	Back	5	1	1	3	1	4	11
Neck/shoulder		5	1	1	3	1	4	11	
Arm/wrist/hand		5	1	1	2	1	3	10	
Lower limbs		5	1	3	2	1	5	12	
Back		5	1	2	3	1	5	12	
Neck/shoulder		5	1	2	4	1	6	13	
Moving carts	Arm/wrist/hand	5	1	2	3	1	5	12	
	Lower limbs	5	1	1	4	1	5	12	
	Back	5	1	1	3	1	4	11	
	Neck/shoulder	5	1	1	2	1	3	10	
Spreading for sun drying	Arm/wrist/hand	5	1	1	2	1	3	10	
	Lower limbs	2	2	2	2	1	4	9	
	Back	2	2	1	3	1	4	9	
Bagging pistachios	Neck/shoulder	2	2	1	3	1	4	9	
	Arm/wrist/hand	2	2	3	2	1	5	10	
	Lower limbs	2	1	4	5	1	9	13	
Transferring bags to storehouse	Back	2	1	4	5	1	9	13	
	Neck/shoulder	2	1	4	5	1	9	13	
	Arm/wrist/hand	2	1	5	5	1	10	14	

Table 4. Results of ergonomic evaluation by ManTRA method, after implementing the PE intervention pro-gram

Task	Subtasks	Body region	Total time of task	Repetition	Force exertion	Posture	Vibration	Overall score of force exertion and posture	Cumulative risk score
Pistachio processing	Picking pistachios from trees	Lower limbs	4	3	1	2	1	3	11
		Back	4	3	1	3	1	4	12
		Neck/shoulder	4	3	1	3	1	4	12
		Arm/wrist/hand	4	3	2	4	1	6	14
	Carrying cloth wrappers for loading	Lower limbs	4	1	3	4	1	7	13
		Back	4	1	2	4	1	6	12
		Neck/shoulder	4	1	3	2	1	5	11
		Arm/wrist/hand	4	1	4	3	1	7	13
	Shoveling in-hull pistachios into hulling machine	Lower limbs	5	5	1	2	1	3	14
		Back	5	5	1	4	1	5	16
		Neck/shoulder	5	5	2	2	1	4	15
		Arm/wrist/hand	5	5	3	2	1	5	16
	Washing pistachio	Lower limbs	5	3	2	2	1	4	13
		Back	5	3	2	2	1	4	13
		Neck/shoulder	5	3	2	3	1	5	14
		Arm/wrist/hand	5	3	3	4	1	7	16
	Transferring bags to storehouse	Lower limbs	2	1	2	5	1	7	11
		Back	2	1	2	5	1	7	11
Neck/shoulder		2	1	2	5	1	7	11	
Arm/wrist/hand		2	1	3	5	1	8	12	

group. However, in the reassessment by the ManTRA method for five tasks that were identified as high risk in the previous stage, a decrease in ManTRA final score was observed for all the five tasks (Table 5). Moreover, the participants, on average, considered 73% of the total interventions as satisfactory.

DISCUSSION

First phase: Ergonomic evaluation of pistachio harvesting tasks before implementing PE intervention

Manual harvesting and processing is one of the various tasks of farmers that exposes the workers to high physical workload and various ergonomic risk factors due to time limitation and special features of the products (29, 30). In the first phase of the study, the results of the Nordic questionnaire showed that the prevalence of MSDs was common among par-

ticipants for all body regions. The highest prevalence of MSDs was also observed in shoulders and back. Many studies on ergonomic evaluation in harvesting and processing of other agricultural products have also observed a high prevalence of MSDs (3, 31). The prevalence of MSD symptoms among pistachio orchard workers during harvest was higher compared to other occupational groups in Iran, including furniture workshop workers (16), restaurant workers (17), office workers (19, 32), health care workers (33) and automotive assembly workers (34).

The results of ManTRA assessment showed that the back and upper limbs are more at risk of MSDs than other body parts. Ergonomic risk factors that cause MSDs, such as repetitive motion, excessive force, awkward and/or sustained postures, prolonged sitting and standing, which are frequently seen in pistachio harvest, were the reasons behind the increase in ManTRA final score in the assess-

Table 5. Suggested interventions resulted from implementing PE

High-risk tasks identified by ManTRA method	Final suggestions resulted from implementing PE
Picking pistachios from trees	<ul style="list-style-type: none"> - Using pliers for easily reaching high tree branches to reduce overstretching of shoulders - Using gloves for better grip (tree branches are rough, so there is always a fear of injury to the skin of hand, and the grip is often weaker with fingers and vulnerable muscles) - Using lightweight portable chairs to rest while picking pistachios to prevent prolonged standing and lower limbs damage - Dividing the picking time into two time periods from 6 to 11:30 a.m. and from 2 to 4:30 p.m. - Performing a few short corrective exercises while picking pistachios (every 10 to 15 minutes)
Transferring pistachios for loading	<ul style="list-style-type: none"> - Reducing the size of bags to a maximum capacity of 20 kg - Reducing the carry distance by nearing the vehicles - Using portable platforms to reduce loading height for easier lifting or lowering
Shoveling (by snow shovel) pistachios into hulling machine	<ul style="list-style-type: none"> - Reducing the height of transferring pistachios to the hulling machine by installing a conveyor belt - Using thinner handles for better shovel grip - Using lightweight shovels - Using sit-stand chairs
Spreading for sun drying	<ul style="list-style-type: none"> - Using a tool for spreading the pistachios in standing position instead of squatting position.
Carrying bags to storehouse	<ul style="list-style-type: none"> - Reducing the size of bags to a maximum capacity of 20 kg (existing common bags have a capacity of 70 kg, which is a very harmful risk factor) - Using handles for bags for easier grip - Using a cart for carrying bags

ment of the five tasks. Moreover, for the five tasks that comprise much of the harvesting time, the corrective exercises were necessary to reduce the risk factors.

The results of this study are in agreement with the results of other studies on the ergonomic evaluation of the harvest of other agricultural products. A study on blueberry harvesting by the RULA method found that the final RULA score was high level and an immediate corrective action was required (35). Additionally, in a study on using the OWAS method for ergonomically evaluating rice harvesting, the level of risk for different tasks was different and some tasks had the highest risk. In this study, back showed the highest prevalence of MSDs (36). In a study for assessing the harvesting of different products, the risk assessed by the RULA method was at the highest level (30). In two other studies on assessing the ergonomic hazards in apple harvesting using the PATH and REBA methods, the risk level was also high and immediate corrective actions were

required to prevent workers from suffering MSDs (3, 31).

Second phase: Implementing PE intervention

In the second phase of the study, PE was used to prevent MSDs, and workers (farmers) were asked to carefully analyze the tasks that were identified as critical in the first phase. The exploration of workers and the guide provided by the ergonomist helped the workers to analyze the risk factors based on the need for interventions. The workers' good cooperation facilitated the implementation of the project in this phase. The first step in implementing the PE method was to train the participants about the principles of ergonomics and the ergonomic risk factors in their tasks. Many tasks with ergonomic risk factors in pistachio harvest, such as prolonged picking of pistachios without stop and carrying heavy loads, have been done in the same way for many years due to the unawareness of their complications.

For example, according to pistachios growers, bags for transporting dry pistachios with a capacity of about 70 kg have been commonly used for more than 40 years, and all growers have used the same bags to store and sell the product. Many of the suggestions could be easily implemented, and some ergonomic risk factors could be eliminated using very simple tools. No ergonomic assessments or training has been provided for these workers to remind them of the importance of these simple interventions. The results of the study of Rasmussen et al. on childcare workers and that of Capodaglio et al. on maintenance workers using the PE method also showed the positive effect of ergonomics training on the better implementation of the PE method and the better cooperation of participants (26, 37). General ergonomic knowledge on the activities under study is an important factor that motivates workers to identify the most appropriate solutions using their awareness of the work situation (10, 38). In the present study, the preliminary ergonomics training was also effective in increasing the participants' motivation to cooperate for finding ergonomic solutions and implementing interventions (39).

The results of ManTRA assessment for the five tasks in the first phase showed the need for corrective actions. After implementing PE interventions, it was found that the final score of the five tasks decreased to less than 15 and the risk level of exposure to ergonomic risk factors decreased. After the interventions during 20 days of the harvest, the results of assessing the prevalence rates of MSDs in the control and intervention groups showed no significant difference. The prevalence of MSDs in the intervention group was lower than it was in the control group for the back, knee, and shoulder areas, but that was a little higher in the wrist and neck areas. However, the hypothesis of the second phase of the study was that by implementing the PE intervention program, the prevalence of MSDs (for different body parts, especially the upper limbs) in the intervention group would be lower than the control group. In a study on the effect of participatory action-oriented training intervention approach among harvesters in oil palm plantation, the prevalence rates of MSDs in the control and intervention groups were not significantly different. Furthermore,

the results showed that instead of a reduction, there was an increase in the prevalence of MSDs in the intervention group compared to the control group. However, in another study on reducing MSDs through ergonomics training by using a participatory approach, a decrease in MSDs was observed for some body parts two months after the intervention (40). In other studies, similar results have been found (41, 42).

When an intervention shows no effect on the results, it is important to examine whether this is due to a theory or a failure in implementing (43, 44). Since the implementation of all intervention measures was successful, it is possible that the sample size in the second phase ($n = 32$) was not large enough to investigate the effect of the interventions on the prevalence of MSDs. In other words, if the interventions were performed on a larger population, a different outcome would be observed. However, the sample size of the intervention group was comparable to other ergonomic interventions among farmers (45-47). Moreover, due to the short harvest period, the evaluation time was 20 days after the interventions, so the participants may not have conformed to the new tools and work plans. One of the reasons of the rejection of the study hypothesis in the second phase may be due to the way the participatory interventions were assessed (43). Musculoskeletal disorders are affected by many other factors (for example, individual factors) (48), so one of the reasons for no reduction in the prevalence of MSDs in the intervention group can be other influencing factors that concealed the effects of interventions on MSDs. An additional reason of concern is that about half of both cases and controls had a second job. It cannot be excluded that this additional activity (whose level of risk for musculoskeletal disorders cannot be defined) may have contributed significantly to the symptoms detected with the Nordic Musculoskeletal Questionnaire. The paper openly analyzes the presence of musculoskeletal disorders, not diseases. Therefore, the survey carried out was based solely on the symptoms reported by the workers and did not involve a clinical or instrumental examination. Although certainly useful for a guidance assessment of the ergonomic risks of the work studied, this approach obviously leads to a possibly inaccurate as-

assessment (as it is based solely on subjectivity) of the effects on workers due to the risk analysed that could be affected by psychosocial factors. In fact, the Nordic Questionnaire is a useful tool but not without limits, like other similar tools based solely on subjectivity.

However, it is unclear that whether these cases prevented the effects of interventions or other mechanisms had a role. Therefore, this should be investigated by further analyzing the data from the assessment of the study procedure. Furthermore, it should be remembered that in the scientific literature there is no really conclusive evidence that ergonomic improvement measures lead unequivocally to an improvement in related disorders and diseases. In particular, there are conflicting data on participatory ergonomics.

The main characteristic of our PE intervention was the design and implementation of interventions that were feasible and cost-effective for pistachio growers/orchard workers in a short time with no interference with their main tasks. This is due to the fact that given the low labor cost, these interventions can be introduced as a model to other pistachio growers in the region only if this characteristic exists. It has been emphasized in other studies that simple and practical interventions have to be implemented with no interference with the tasks of individuals (2, 26).

Although the prevalence of musculoskeletal disorders did not decrease after the intervention, this could not be a reason why other positive results such as reduced ergonomic risk factors and musculoskeletal discomforts were not achieved. Studies have shown that musculoskeletal discomforts can lead to musculoskeletal disorders after a long time (49), but absence of pain is not an indicator of absence of musculoskeletal discomforts during the task performance. Therefore, workers' satisfaction with the implementation of interventions can be high despite not reducing the prevalence of musculoskeletal disorders. However, if the prevalence of musculoskeletal disorders decreased, it was likely to increase.

In most agricultural jobs, the physical workload is high during the harvest and implementing simple interventions can ease the job and reduce musculo-

skeletal pain while performing the tasks. However, since these difficult tasks are performed in a limited time [period], results are seldom emerged in the form of reduced suffering from musculoskeletal disorders even after implementing interventions that improve the work situation. In fact, limited time of workers in facing the risk factors has made ergonomics risk factors less visible, and employers usually give up performing the simple interventions. This study demonstrated that although the impact of simple interventions in the form of reducing musculoskeletal pain are not visible, high workers satisfaction and improved work situation were observed in the ergonomic [/ergonomics] aspects of work environment which can likely result in the improvement of work ability and workers productivity. Based on the results of this research, the authors recommend the study of the impact of simple ergonomic interventions on factors such as feeling discomfort, work ability index, etc. in the future studies.

Limitations

In this study, the time period of interventions was limited due to limited harvest time. Moreover, due to the limited resources for the study, it was not possible to perform interventions with a larger sample size. Using a larger sample size or other assessment tools in future studies can more clearly show the impact of PE interventions.

CONCLUSION

Musculoskeletal disorders were prevalent in all body regions of pistachio orchard workers during pistachio harvest and processing. The highest prevalence rates of MSDs were observed for the back and shoulders. The back and upper limbs were more at risk of MSDs than other body regions, so corrective actions were required to reduce the risk factors in five tasks that made a large portion of the time spent for pistachio harvest and processing. After implementing PE interventions, the results of ergonomic evaluation of the five tasks in the first phase showed that for all the five tasks, the risk level of exposure to ergonomic risk factors decreased. However, the prevalence rates of MSDs in the control and intervention groups showed no significant difference.

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