doi:10.22100/ijhs.v3i4.286
Original Article

IJHS 2017;3(4):1-6
ijhs.shmu.ac.ir

I J H S
International Journal of Health Studies

Assessment of the Risk of Musculoskeletal Disorders in the Upper -Limb in Greenhouse Workers by the OCRA and ACGIH-HAL Methods

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Received: 29 August 2017
Accepted: 2 October 2017

Abstract

Background: *Greenhouse workers are exposed to a variety of biomechanical risks, repetitive movements, and awkward posture. This study aimed to assess the risk of upper limb injuries in greenhouse workers and its relationship with musculoskeletal disorders (MSDs).*
Methods: *This descriptive, analytic, cross-sectional study was conducted among 50 greenhouse workers. The data related to MSDs were collected using a body map and interview. The OCRA and ACGIH-HAL methods were used to assess the risk factors of the upper limb disorders in six repetitive tasks. The data were analyzed by univariate logistic regression.*
Results: *The results showed that 62% of the workers had MSDs in the upper limbs over the last year. Grafting task had the highest OCRA index and HAL-TLV (8.3 and 0.59). The highest percentage of pain was in the fingers (75%). Univariate regression test showed a significant relationship between the three parts of the upper limb (wrist, palm, and fingers) and the OCRA index (OR=0.30, 95%CI=0.15-0.61; OR=0.26, 95%CI=0.11–0.59; OR=0.21, 95%CI=0.08–0.51; respectively).*
Conclusions: *The prevalence of MSDs was one-third in the wrist. Grafting task was the most dangerous activity, and tasks such as pruning, weeding, and transplanting had a medium risk. Use of ergonomic tools in tasks such as grafting, pruning, and harvesting is recommended. In weeding task, in which repetitive work is done for a long time, management measures such as training, job rotation, and increasing rest time could reduce MSDs.*

Keywords: Greenhouse, OCRA index, ACGIH- HAL, Body map, Musculoskeletal disorders, Upper limb.
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Please cite this paper as: Varmazyar S, Choubdar M. Assessment of the risk of musculoskeletal disorders in the upper -limb in greenhouse workers by the OCRA and ACGIH-HAL methods. Int J Health Stud 2017;3(4):1-6.

Introduction

Musculoskeletal disorders (MSDs) are related to a variety of factors including work-related (posture, force, movement, and vibration), psychosocial, and personal factors; awkward posture and repetitive movements during work are the most important factors.[1,2]The prevalence of work-related MSDs (WMSDs) is 2.5 times higher in workers compared with other people.[3]The highest prevalence of MSDs is reported in unskilled workers such as farmers and building workers.[4]

Around half of the working force in the world is employed in agriculture.[5]In many countries, agriculture is considered as the most dangerous job.[6] Annually, more than 1 million farmers suffer from injuries resulting from strenuous working, awkward posture, and repetitive movements.[7]Some studies have reported WMSDs as the most prevalent injuries in farmers.[8-10]According to the available statistics, 43% of the occupational diseases and injuries in farmers are related to the MSDs.[11]The prevalence of MSDs has been reported to be 76.9% among farmers.[12]Upper Limb WMSDs (UL-WMSDs) constitute a major part of MSDs,[13]which can result from the susceptibility and more use of the upper limbs while performing tasks compared with the lower limbs.[13]The prevalence of upper limb injuries in farmers has been reported to be higher than the mean6; particularly, pain in the shoulders, arms, and hands are the most common symptoms in farmers.[14]

According to the Statistical Center of Iran, agriculture constitutes 19.1% of the employment and production.[15]Among the agricultural activities, greenhouse and under plastic planting are ranked first in employment.[16]Like other farmers, greenhouse workers are at risk of biomechanical injuries, repetitive movements, exertion, awkward posture, and carrying the load by hand2,.[17]Repetitive tasks such as providing soil for plants, planting, grafting, transplanting, irrigation, floriculture, cleaning the environment, and harvesting can create a high workload for the workers.[18,19]Activities such as grafting and cutting plants are associated with the risk of repetitive strain injury and hand disorders.[20]It was found that 50% of the greenhouse workers suffer from musculoskeletal pain, and the incidence of such injuries is common among them.[21]Also, 48.9% of the injuries in the greenhouse workers are related to muscle strain.[11]In a study by the Occupational, Safety and Health Administration (OSHA) from 200 reports of three greenhouses over 1993–1994, 85 cases of musculoskeletal disorders were recorded including 11.8%-48.2%. [11]

Assessment methods of exposure can be used to prevent these disorders and improve productivity and quality of production.[16]The index of occupational repetitive actions (OCRA) is the most comprehensive assessment method, which is recommended by the ISO112283 and EN1005-5 for the assessment of risk, management of repetitive movements and exertion, and preventive measures.[22]According to a study conducted by Colombini et al. on 42 farmers (22 men and 20 women), 33.6% of the workers suffered from upper limb disorders. Tendinitis in the wrist and carpal tunnel syndrome were found in 65.8% and 20.5% of the workers, respectively. The highest score of the OCRA was related to pruning and harvesting.[23]According to other studies, the risk of WMSDs was high in activities such as pruning and planting and moderate in transplanting, irrigation, and spraying.[24]In a study conducted by Colatini et al. on greenhouse workers using the OCRA index, repetitive movements and awkward posture were found to be the main risk factors of grafting in upper limb disorders. The OCRA index obtained was 7.1 and 2.3 for the right and left hands, respectively.[2]In another study, Zimbalatti and Proto examined the risk of repetitive movements using the

OCRA in 180 workers in 35 citrus farms. The score obtained using the checklist was 13.2 for planting (low risk), 10.8 for fertilizing (low risk), 9.9 for spraying (low risk), 19.7 for weeding (moderate risk), and 24.6 for harvesting (high risk). In this study, harvesting of the citrus farms had the highest risk for musculoskeletal injuries due to use of non-ergonomic tools, repetitive movements, and long work.[25]In a study by Rapisrdar et al. on 370 farmers, the repetitive movements of the upper limb and risk of picking up the load manually were examined using the OCRA and National Institute for Occupational Safety and Health (NIOSH). It was found that the risk of low back pain and upper limb injuries such as wrist injury was high. Control measures were suggested, such as teaching and using ergonomic tools to modify the existing situation.[17]Another method for the assessment of upper limb injury is the threshold for Hand Activity Level (HAL). In this method, the HAL and Normalized Peak Force (NFP) are used for the assessment of the risk factors of MSDs in the hand, wrist, and elbow.[26,27]

Given the importance of greenhouse in agricultural production in Iran and the presence of only a few studies regarding the ergonomic assessment of workers in this field, this study aimed to assess the risk of upper limb injury in greenhouse workers using OCRA and ACGIH-HAL and its relationship with MSDs.

Materials and Methods

This descriptive, analytical, cross-sectional study was conducted among 39 employed men and 11 women (census) in a greenhouse 120000 m2 in PishvaVaramin in 2017. In this study, observational method, interview with the subjects and videotaping (for analyzing repetitive tasks), body map questionnaire (for assessing the prevalence of MSDs), OCRA, and ACGIH-HAL (for assessing the risk factors of upper limb injury) were used. The OCRA and ACGIH-HAL.

The ACGIH HAL (American Conference of Governmental Industrial Hygienists, Hand Activity Level)methods are observational methods that are used for the assessment of the ergonomic risk factors in WMSDs.[22,28]

Body Map Questionnaire: This questionnaire has a map in which the different parts of the body are determined. The body map questionnaire has been derived from the Nordic questionnaire in which body images are used instead of questions. Persian version of Nordic questionnaire was validated by Mokhtarinia and colleagues.[29] It has some questions about the demographic characteristics and history of pain in the various body parts over the last year, which determines work-related pain in the body. The questionnaire was completed through an interview with the participants under investigation.[30-33]During the interview, the participants were asked about any history of an accident involving the upper limb. Participants with such a history were excluded from the study.

The OCRA method aims to analyze tasks, calculate the confrontation index, and determine their risk level. The OCRA index is calculated based on the ratio of the number of real movements of the upper limb in repetitive tasks (Ae) to the number of related recommended movements (Ar). The total number of activities in a working shift can be obtained through the work analysis. The total number of recommended activities in a shift is calculated through the muscle force factor multiplied by the factor of upper limb posture (Fp), factor of additional factors (Fa), factor of repetitive work duration (Dx), and factor of lack of retrieval time (Fr). (n is the number of tasks including upper limb repetitive movements in a working shift, and CF is the stable factor of repetitive movements in minute).

$$A_r = \sum_{i=1}^{n} \left[CF \times \left(F_f \times F_p \times F_a \right) \times D_x \right] \times F_r$$

Table 1 presents the three levels of the OCRA based on the score of the OCRA index (IE: exposure index).[34]

The ACGIH-HAL method consists of three stages. In the first stage, referred to as HAS, the level of the hand activities is classified in a range of 0–10 based on movement, force, and pauses of activities. The second stage is related to the NFP. This stage has a scale of 0–10. The scoring can be performed using three methods including the percentage of maximum voluntary contraction using electromyography, subjective scale (subjective report of force), and Morr-Gargscale (based on the observer’s reports). In the third stage, the point of interception in the first (HAL) and second (NFP) stages on the TLV chart determines the risk level. In the ACGIH-HAL method, if the obtained score is under the action level, it is green (safe), and the job is safe. If the calculated number is between the curve of action level and the TLV, it is yellow (alarm), increasing the risk of the MSDs. Control measures such as supervision should be considered. Finally, if the obtained number is above the TLV curve, it is red (dangerous), and the risk of MSDs is high. Appropriate control measures should be implemented immediately. Also, the level of risk for each person can be determined using the formula [NFP/(10-HAL)] based on Table 1.[22,26,35]

Table 1. Classification of the final scores of OCRA and ACGIH-HAL methods[22,26]

Risk level / Method	Low (Green area)	Medium (Yellow area)	High (Red area)
OCRA index	≤2.2	2.3–3.5	3.5<
ACGIH-HAL	<0.56	0.56–0.78	0.78<

Following the observation and interviewing the employer and videotaping, the six tasks of planting, grafting, transplanting, weeding, pruning, and collecting products were coded and assessed. Each task was analyzed for the related movements, and the OCRA index and HSAL-TLV were calculated for the right and left hands. Given the score of each hand, the risk levels of the factors were finally categorized. The OCRA index was calculated using NEXGEN-ErgoIntelligence software. The activity level of the hands was assessed using checklists related to HAL-TLV and NFP and their combination in the threshold chart.[36]

Logistic univariate regression was used to examine the significance of the impact of the independent variables (risk factors including demographics, occupational information, task type, and assessment methods) on the dependent variables (prevalence of upper limb injuries as occurrence or non-occurrence) with 95% confidence intervals. The odds ratio statistic was used to interpret the relationships between the dependent and independent variables, in which each dependent variable (MSDs) shows a change in the odds ratio of the event occurrence to its non-occurrence. To examine the effect of the independent variables on dependent variables, the 95% confidence intervals for the odds ratios were used in addition to the significance level p-value. If this interval includes the number 1 (equal to the odds ratio of the event occurrence to its non-occurrence), it confirms the null hypothesis, which means non-significance of the independent variable. Otherwise, the null hypothesis is rejected, and the effect of the independent variable on the dependent variable is considered meaningful.[37] Data analysis was done using SPSS version 20. In this study, the task of planting was considered as a basic activity based on the primary observations and lower risk factors, and the other tasks were compared with it. Based on the Kolmogorov–Smirnov test, only BMI, age, and prevalence of MSDs (P>0.2) had a normal distribution.

Results

The analysis showed that the mean age of the 50 workers was 35.2±11.54 years. The demographic and occupational information is presented in Table 2. Sixty-two percent of the workers had signs of MSDs in one of the upper limbs in the last year. Since 92% of the study participants were right-handed, the right-hand pain information has been presented. The highest percentage of injury in the right hand was reported in the wrist.

The percentages of the upper limb injuries in the different tasks are presented in Table 3. Most of the injuries were reported for tasks of grafting (fingers) and planting seeds (shoulder). The mean scores of the OCRA and HAL-TLV for the right hand and six tasks are presented in Figure 1. The highest OCRA score was for grafting and pruning. Also, transplanting and pruning had the highest HAL-TLV score. The assessments of the individuals and work-related risk factors are presented in Table 4. There were significant relationships between weight and shoulder disorders; extra working and shoulder and arm injuries; the OCRSA score and wrist, palm, and finger injuries.

Table 2. Demographics, occupational data, and the prevalence of upper extremity musculoskeletal disorders in the study subjects (N=50)

Type of demographics and occupational data	Mean±S.D	Pain in the upper extremity	
		Upper extremity	Percent (%)
Weight (Kg)	71.9±7.32	Arm	12
Height (Cm)	173.06±8.59	Shoulder	22
BMI (Kg/m^2)	24±1.82	Elbow	16
Work time (h)	9.22±1.88	Wrist	32
Work history(year)	10.5±9.21	Palm	28
Overtime (h)	1.46±9.21	Fingers	30

Table 3. Distribution of upper extremity musculoskeletal disorders frequency according to the task type

Upper extremity / Task type	Shoulder Percent	Arm Percent	Elbow Percent	Wrist Percent	Palm Percent	Fingers Percent
Grafting	0	0	12.5	37.5	37.5	75
Planting seeds	60	40	40	20	20	0
Transplanting	30	10	10	40	40	30
Weeding	9.1	9	0	54.5	36.4	27.3
Pruning	28.6	14.3	14.3	28.6	28.6	28.6
Harvesting	22.2	11.11	33.3	0	0	11.1

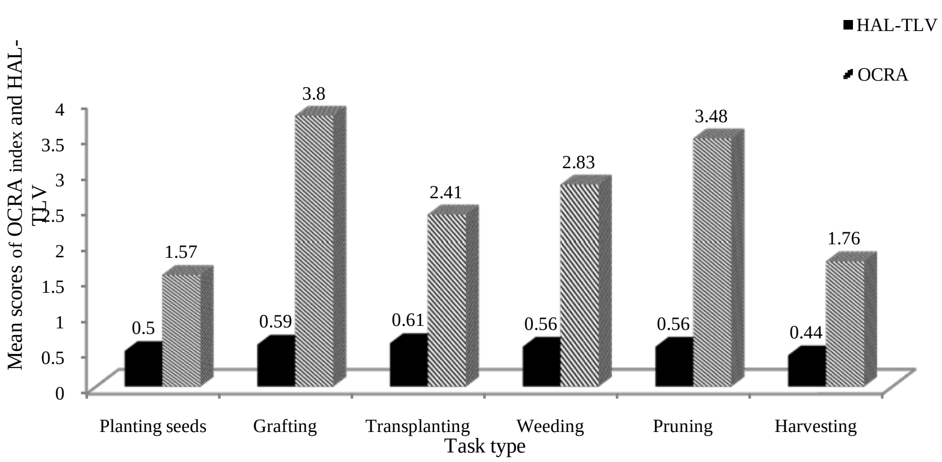

Figure 1. Mean scores of the OCRA index and HAL-TLV according to the task type

Table 4. Prevalence (95% CI) of upper extremity musculoskeletal disorders according to the risk factors determined by the univariate logistic regression test

Scale or Category	Prevalence					
Risk factor	Shoulder	Arm	Elbow	Wrist	Hand	Fingers
Age (year)	1(0.94–1.06)	1.01(0.93–1.09)	1(0.93–1.07)	0.99(0.94–1.04)	1(0.95–1.05)	0.97(0.93–1.02)
Gender (Man and woman)	0.29(0.03–2.56)	0.68(0.07–6.51)	1	2.12(0.53–8.40)	1.66(40–6.88)	1.45(0.35–5.97)
Weight (kg)	0.88(0.78–0.98)*	0.97(0.84–1.11)	0.87(0.75–1.01)	1.04(0.94–1.14)	1.03(0.94–1.14)	1.08(0.98–1.19)
Height (cm)	0.91(0.8–1.03)	0.92(0.81–1.05)	0.90(0.79–1.01)	1.01(0.93–1.09)	1.03(0.95–1.12)	1.07(0.98–1.17)
BMI (Kg/m2)	0.76(0.52–1.12)	0.78(0.50–1.22)	0.87(0.59–1.32)	0.89(0.64–1.24)	1.03(0.73–1.46)	1.13(0.79–1.60)
Work time (hour)	0.72(0.51–1.03)	0.78(0.53–1.14)	0.74(0.52–1.07)	1.14(0.80–1.62)	1.10 (0.77–1.57)	0.98(0.71–1.35)
Work history (year)	0.97(0.90–1.03)	0.97(0.89–1.049)	0.95(0.89–1.02)	1.04(0.96–1.12)	1.04(0.95–1.13)	0.96(0.90–1.02)
Overtime (hour)	0.54(0.31–0.96)*	0.48(0.24–0.96)*	0.88(0.48–1.61)	1.44(0.83–2.47)	1.10(0.66–1.85)	1.06(0.64–1.75)
Task type						
- Planting seeds	1	1	1	1	1	1
- Harvesting	5.25(0.48–56.80)	5.33(0.34–82.83)	1.33(0.14–12.82)	0	0	0
- Transplanting	3.50(0.37–32.97)	6.00(0.39–92.28)	6.00(0.39–92.28)	0.37(0.03–4.71)	0.38(0.03–4.71)	0
- Weeding	15(0.98–228.90)	6.66(0.44–101.73)	0	0.21(0.2–2.52)	0.44(0.03–5.40)	0
- Pruning	3.75(0.33–42.47)	4.00(0.25–63.95)	4.00(0.25–63.95)	0.62(0.04–9.65)	0.62(0.04–9.65)	0
- Grafting	0	0	4.66(0.30–73.38)	0.42(0.03–5.71)	0.42(0.03–5.71)	0
OCRA Index	1.11(0.65–1.88)	1.11(0.56–2.18)	1.21(0.66–2.22)	0.30(0.15–0.615)*	0.26(0.12–0.59)*	0.21(0.09–0.52)*
ACGIH-HAL	0.68(0.03–15.10)	0.59(0.01–30.84)	1.62(0.05–52.57)	3.81(0.23–62.98)	1.91(0.11–33.31)	0.11(0.005–2.22)

* Significant effect of the independent variable on dependent variable

Discussion

In a greenhouse, repetitive tasks are performed in awkward postures, with high intensity, and for a long duration. In this study, an analysis of six repetitive tasks using the OCRA method showed that the tasks including grafting, weeding, pruning, and transplanting have moderate to high risk of causing injuries in the upper limb, which is consistent with the results of a study by Camillieri and colleagues.[19] A low mean score of the HAL-TLV compared with the OCRA could be due to the use of less force during the performance of the task. According to Hoen's study, the HAL-TLV method can present different results due to its limitation and different definitions of repetitive movements. This method is limited to the assessment of stress on the hand and does not consider other risk factors such as work posture, touch tension, vibration, and temperature. It only considers repetitions and force in manual work.[38] Abad et al. reported a moderate level of congruence between the OCRA and HAL-TAL methods.[39] This can be explained by the difference in the study population and the small sample size. The significant relationship between the risk level of the OCRA and prevalence of disorders in the wrist, palm, and fingers ($P<0.001$) suggests that a higher level of exposure results in more frequent hand injuries. The logistic regression analysis showed that there was a significant relationship between the risk factor of weight and prevalence of injuries in the shoulder. In many studies, the relationship between personal factors and prevalence of MSDs has been confirmed. In a study conducted in the USA, it was found that a higher weight increase the different risk factors that contribute to the severity of MSDs.[40] There was a significant relationship between extra work and pain in the shoulder and arm in the last year. People who worked more than 8 hours per day had a higher rate of such disorders. This can be explained by fatigue and lack of rest, which can result in more stress on the muscles. Grafting, with an OCRA score of 3.8, was the most dangerous task and associated with the highest prevalence of injury, as shown in Figure 1. These results are similar to that of Colatoni et al. who showed the risk level of the OCRA index in the red zone.[2,40]

The most important risk factor in grafting was the number of movements, awkward posture, and the high frequency (in 50% of work duration), which resulted from the long duration of use of small scissors to cut the young stems without rest. Over 80% of the time, while performing this task, the workers' elbow is in a 60 degree position.[41] The univariate analysis showed that the prevalence of elbow disorders in those involved in grafting is four times higher than in those involved in planting. Also, the score of the HAL-TLV was at the moderate level, which can be due to the low force used during grafting. During each grafting using a knife, 15 movements are performed by the right hand over 20–30 seconds. Therefore, 120 grafts are performed over an hour of continuous work, and 960 grafts during an 8-hour shift, which exerts a high biomechanical load on the fingers and wrist, and the right hand is at risk of MSDs due to the greater usage compared with the left hand.[2] It seems that increasing the number of workers in grafting not only results in a decrease in the prevalence of the disorders but also an increase in the number of people involved in the risk of confrontation. Therefore, the use ergonomic knives appropriate to the type of task, required force, and dimensions of the hand is recommended.[42] Also, short-term pauses during work can decrease fatigue and injury in the workers.[2]

The task of pruning has a moderate risk based on the two methods (HAL-TLV, 0.56; IE, 3.48), which is similar to the results of previous studies which showed the moderate to high risk of pruning of fruits such as kiwi, peach, apricot, citrus, and grape.[24,25,36] But there is a difference in the pruning of bushes and trees. In this study, a lesser force and involvement of both the upper limbs were observed due to the shorter bushes (at most 90 cm) and thinner branches compared with the fruit trees. Therefore, the prevalence of the disorders was equal in most of the parts of the upper limb (Table 3). Although no significant relationship was found between the prevalence of upper limb disorders and the task of pruning, the prevalence of shoulder, arm, and elbow disorders in pruning was four times higher than that in planting. During each pruning, three movements of the dominant hand are performed in 3 minutes; 100 cucumber bushes are pruned over 15 minutes of continuous work. In the greenhouse, pruning of cucumber and tomato bushes were performed manually, and one-branch flowers were not pruned. The use of gardening knives and scissors with ergonomic handle and blade is recommended for pruning of the fruit bushes. These tools enable normal wrist movement and decrease pressure on the wrist and palm; consequently, the muscle activities of the users are decreased.

Harvesting is one of the most important agricultural activity.[25] Although a failure in any activity from planting to harvesting can result in decreased performance and income, lack of attention during harvesting can result in most damage[43] as the duration and method of collecting products has a direct relationship with the quality and quantity.[25] In this study, the scores related to the OCRA and HAL-TLV for harvesting were suggestive of low risk. In contrast, the study conducted by Zimbalatti and Proto showed that the OCRA checklist score for olive harvesting was indicative of high risk, and the reason for the difference was the types of plants. In the manual and mechanical methods of olive harvesting, handles 2–3 m long are used. The shaking and placing of such handles on the tress can result in an awkward posture, with the hands above the shoulders.[25] But the greenhouse products are collected at a lower height.

The high prevalence of shoulder, arm, and elbow injuries based on the univariate regression in pruning and harvesting tasks compared with planting could be explained by increased involvement of these parts and static and long activities, as the planting of seeds takes 3 weeks while harvesting takes over 3–4 months of continuous activity. Modern gardening scissors and mechanical methods can be used to decrease the risk of upper limb injuries while collecting fruits and pruning. While working with such equipment, the level of touch with the tool increases due to the adaptation of the hand to the handle; consequently, the pressure on the hands is decreased. Based on scores of the OCRA and HAL-TLV, the task of weeding has a moderate risk of causing injuries (HAL-TLV, 0.56; IE, 2.83). Unlike pruning and harvesting, each weeding is performed using three movements of the dominant hand over 3 seconds in a sitting position. The results of the logistic regression showed that the prevalence of arm and shoulder injuries during weeding compared with planting was 6 and 15 times higher, respectively (Table 4). Also, the prevalence of wrist injuries was higher in people who weeded compared with other parts of the body due to the more use of the wrist.

The scores based on the two methods for the task of transplanting showed a moderate risk (IE, 2.41; HAL-TLV, 0.61). Transplanting is transferring and planting in the main place. It is usually performed using five movements of the dominant hand over 5–10 minutes. It involves the hands more than the other parts of the body; therefore, disorders of the wrist and palm are more common. The univariate analysis revealed a 3–6 times higher risk of shoulder, arm, and elbow injury in this task compared with planting (Table 4). Ergonomic tools cannot be used for weeding and transplanting as these activities involve direct handling of the young plants and need manual work by experienced people. Therefore, it is suggested to teach workers about MSDs and the preventive measures. In tasks such as weeding and transplanting, in which the number of activities is high (it constitutes around 50% of the work shift), some measures should be used such as employing more staff for the task allocation and increasing the rest time to restore the muscles to the normal state. In addition to decreasing MSDs, such measures could decrease work-related fatigue and increase productivity.[36] It is recommended to teach the workers to do stretching exercises during rest time as such exercises can increase the muscle strength, decrease musculoskeletal injuries, and increase productivity.[44] Given that the work is performed in the standing (48%) and sitting positions (32%) for most tasks, the workers should rotate between these tasks. Thus, the parts of the body involved can be changed, and all the work pressures are not put in one point.[13]

The results of this study revealed that the grafting task was the most dangerous activity. Pruning, weeding, and transplanting tasks involved moderate risk. The prevalence of MSDs in the upper limb in greenhouse workers could be related to weight, extra working hours, the number of movements, awkward posture, higher frequency, more involvement of the upper limb, and static and long activities. In addition to teaching and increasing the awareness of the risk factors of UL-WMSDs in workers, appropriate modification measures should be used. The suggested modification measures include increasing the staff to allocate the tasks; using appropriate cycles of work-rest and standing-sitting; stretch exercise particularly during repetitive tasks performed for a long duration such as weeding and transplanting; regular health examination for early diagnosis of MSDs in workers, and using ergonomic scissors and knives for tasks such as grafting, pruning, and harvesting.

One of the limitations of this study was the small sample size; therefore, it is suggested to investigate more greenhouse workers in the future. This is the first study conducted in Iran. Further research on ergonomics in agriculture, particularly greenhouse, may provide effective suggestions and measures to improve health, productivity, and working condition.

Acknowledgement

The authors would like to extend thanks to the greenhouse workers who so generously contributed to the work presented in this study.

Conflict of Interest

The authors declared that they have no conflict of interest.

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