

Prevalence and risk factors for MSDs in vegetable greenhouse farmers: a cross-sectional survey from Shandong rural area, China

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ABSTRACT

Purpose: *The aim of the research is a cross sectional survey on the prevalence of symptoms related to MSDs in vegetable greenhouse farmers from Shandong rural area and on the risk factors that may influence it.* **Methods:** *This cross-sectional survey was selected 249 farmers working in vegetable greenhouse from different districts of Shandong Province, China. The Questionnaire and the Rapid Upper Limb Assessment (RULA) technique were used to identify ergonomic risks. χ^2 analysis was used to find the relationship between MSDs and various factors. Also, logistic regression methodology was applied to get the most influencing factor for MSDs.* **Results:** *The prevalence of MSDs in farmers working in vegetable greenhouse is 87.5%, and the top 3 prevalent areas of MSDs in various parts of the body are: lower back (47.4%), neck (33.3%), and shoulder (31.7%). The results of Logistic regression analysis showed that age, years working in vegetable greenhouses, keeping their backs in the same position for a long time, and working hours greater than 10 hours per day were the risk factors for MSDs in the farmers. The outcome of the RULA grand score had been found to be higher than 5 in the overwhelming majority of the farmers.* **Conclusions:** *All findings infer that each task of greenhouse vegetable growing inflicts different levels of disorder in a farmers' musculoskeletal structure. Interventions should be increased and reduce the bad ergonomic load level as soon as possible, provided to reduce the impact of such disorders.*

INTRODUCTION

Agriculture is one of the most challenging and dangerous occupations in the world as farmers suffer from various work-related problems of which musculoskeletal disorders (MSDs) are a common problem. Greenhouse vegetable growing, a form of agricultural production, is commonly preferred

among farmers. Greenhouses are widely used in vegetable growing in China, the world's largest producer of greenhouse vegetables. But the operation of greenhouses pose high risks. Working in the hot and humid environment, with high labour intensity, long work hours, and unique working postures required in greenhouse, farmers may be exposed to higher occupational health risk factors resulting in

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the development of MSDs in farmers. These factors can be classified into individual and work-related factors (1,2). The high prevalence of the disease in this occupation is possibly caused by various types of repetitive awkward movements (i.e., frequently working with flexed back, stooping to work, lifting heavy loads, etc.) and bad working postures (i.e., squatting, kneeling, etc.) maintained by farmers for long work hours (3). Literature (4,5) shows that several operations such as planting seedlings and weeding cause excessive physical strain on the musculoskeletal system, which may further promote the development of MSDs among the farmers. MSDs, particularly in the trunk, shoulders, and wrists, have gradually occurred more frequently in Asian producers (6,7). Greenhouse vegetable growing are mostly small-scale family enterprises in China rural area, and vegetable greenhouse farmers are usually neglected in research and policy actions. So far, there are no official statistics of the prevalence of MSDs in vegetable greenhouse farmers, and information about the factors influencing MSDs among the farmers is unknown. Therefore, to prevent MSDs, it is necessary to identify the possible risk factors related to such problems among vegetable greenhouse farmers.

As one of the largest greenhouse bases in China, Shandong Province, with a growing area of about 300,000 ha and over 1,000,000 vegetable greenhouse farmers, produce more than 10 categories of vegetables covering over 150 different kinds. In the rural area of this region, greenhouse vegetable growing is a vital occupation done by farmers. The main activities involve planting seeding, pruning stems and leaves, picking, carrying, shoveling, spraying pesticides, and weeding. In such laborious work, farmers have to repeatedly hold awkward poses (i.e., squatting, kneeling) that cause discomfort in multiple body regions. The aim of the study is a cross sectional survey on the prevalence of symptoms related to MSDs in vegetable greenhouse farmers from Shandong rural area and on the risk factors that may influence it. This study calculates the impact of the main activities on pain in parts of the farmer's body. Once identified risk factors, the most hazardous activities can be intervened at possible scale.

METHODS

Study setting and population

The current was carried out between August and October 2019 in the form of an epidemiological cross-sectional survey among selected rural area of Shandong Province, where greenhouse vegetable growing is done mostly by farmers. The vegetable greenhouse mainly grows cucumbers, tomatoes, towel gourds, hot peppers, and other vegetables and is 4-6 meters wide, 30-50 meters long, 1.7 meters shoulder high, 3 meters ridge high. Each family is one greenhouse vegetable growing enterprise. According to the principle of randomness, one farmer from each greenhouse vegetable growing family was selected as the study subject. The research was conducted on a total of 253 farmers during on-the-spot investigation. Inclusion criteria: the selected participants were vegetable greenhouse farmers over 18 years old, and had been engaged in greenhouse farming for one year or more. The selected participants were vegetable greenhouse farmers, over 18 years old, having been engaged in greenhouse farming for one year or more, and with one of the following symptoms: (1) having been to a medical unit for treatment and diagnosed with a certain type of MSDs; (2) pain and discomfort in various parts of the body for above 24h; (3) missing work for more than half a day due to pain and discomfort. Exclusion criteria: congenital spinal deformity, musculoskeletal disorders caused by trauma, infectious diseases, malignant tumors and other non-work-related factors. Two hundred fifty-three questionnaires were issued and 253 were taken back among which 249 (145 men/104 women) are valid, according to inclusion and exclusion criteria. The effective rate was 98.4%.

Questionnaires of musculoskeletal disorders

In this study, the information was acquired by distributing questionnaires of the Chinese version of Musculoskeletal Disorders (this questionnaire refers to the Nordic Musculoskeletal Questionnaire and the Dutch Musculoskeletal Questionnaire). Participants were requested to report in the form of 'Yes' or 'No' if they had any trouble in various body

parts (i.e., neck, shoulders, lower arm, wrists, upper back, lower back, legs, knee and ankles) during the last twelve months. The questionnaire was divided into the following two segments.

Individual characteristics: this section of the questionnaire consisted of age, gender, schooling, and smoking habit.

Work-related characteristics: the questionnaire asked about years working in greenhouse, labor load, working postures, repetitive motions, working space, and work-rest, et al.

Rapid Upper Limb Assessment (RULA) for Postural Analysis

In addition to the Musculoskeletal Disorders Questionnaire, RULA sheets were used to check the level of risk involved at each activity of vegetable greenhouse farmers. RULA is a survey method used for ergonomic investigations of musculoskeletal disorders. This method requires no special equipment or tools, only a sheet, pencil, and an observer to assess the postures of the neck, trunk, and upper limbs, along with muscle function and the external loads experienced by the body.

Field investigation and observation: the main activities in greenhouse vegetable growing (planting seeding, pruning stems and leaves, picking, carrying, shoveling, spraying pesticides, weeding and fertilizing) were video recorded.

Video recording requirements: to record the video continuously from the beginning of each work cycle, and select at least five complete work cycles. Each video lasts 2-6 minutes, and should include the following three angles: cross, coronal and sagittal sections. According to RULA score, ergonomic load is divided into four grades shown in Table 1.

Quality Control

Standardization training was conducted on the investigators and action collectors to familiarize them with the methods of field investigation, action collection, observation and evaluation. Investigators were trained before the investigation to unify the investigation methods. Taking a village as a unit, the trained investigators gave out questionnaires to the participants who filled them in by themselves with the help of the investigators. Then investigators checked and collected, replenished, and corrected any incomplete, or inaccurate data on the spot. The study was approved by the ethics research committee of Shandong Academy of Occupational Health and Occupational Medicine and was conducted according to Helsinki guidelines. Each participating village (Guojiaying village, Mafan village, Beiluo village, Qianpuli village, Luoxi village, Liuwang village, and Wangya village) from two districts (Weifang and Dezhou) of Shandong Province approved the conduct of the investigation and all the 253 participants signed informed consent. After familiarizing themselves with the basic situation of greenhouse farming, the investigators selected the main activities for video recording, watched the videos together, and graded the main activities using the RULA tool. And the evaluation criteria were unified after comparison and discussion.

Statistical analysis

The IBM SPSS (version 21.0) was used for statistical analysis. Statistical investigations of the individual, work-related factors and ergonomic risks among the subjects of current study were expressed as a mean \pm standard deviation (SD) and frequencies/rates for different categories of every factor. χ^2 analysis was performed for categorical comparisons between

Table 1. Ergonomic load assessment scale for musculoskeletal Disorders

Load level	RULA Score	Level of MSD risk
Level 1	1-2	Minor risk, no action necessary
Level 2	3-4	Little risk, modification may be desirable
Level 3	5-6	Medium risk, further examination, change soon
Level 4	≥ 7	Very high risk, implement change promptly

factors (individual and work-related characteristics), Significance was checked for $p < 0.05$ and χ^2 value calculated. In the Logistic regression analysis, the odds ratio (OR) of various risk factors was determined and 95% confidence intervals (CI) was computed.

RESULTS

MSDs and investigating factors

The study investigated the subjects between ages 31 and 68, with an average age of 50.9 ± 8.2 yr, average BMI of 24.8 ± 8.1 , and average years working in greenhouses of 17.1 ± 12.6 yr. Most of them (77.5%) had an educational level of junior high school or below, 14.9% of them graduated from senior high school. Almost half of the subjects complained about lower back pain, while lower arm pain was least prevalent with the respondents (4.8%) complaining about it (Fig. 1).

Individual characteristics of vegetable greenhouse farmers are listed in Table 2. On average, the farmers were older and started working at an early age. Further analysis showed that age was correlated with years working in vegetable greenhouse ($\chi^2 = 22.46$, $P < 0.01$), which increased with age. Table 2 shows that 45.8% of the subjects had been working for 10–30 yrs, 14.9% of them over 30 yrs. According to χ^2 analysis statistically significant rela-

tion was found that prevalence of MSDs with individual characteristics except for Smoking.

It was observed that the most common operation environment is relatively narrow in greenhouses which prevents the use of mechanized tools. Therefore, the basic operation in the greenhouses is manual in nature. 44.2% of the farmers had worked in the greenhouse for ten hours or more every day, and there was only one break during the whole workday: a two-hour lunch break. Table 3 shows that according to χ^2 analysis statistically significant relation was found that prevalence of MSDs with work-related factors except for repeated the same action at the waist.

Association of risk factors with MSDs : regression analysis

Table 4 shows that the risk factors of MSDs for vegetable greenhouse farmers are age (OR=4.86, 95% CI: 1.54-16.31, $p < 0.01$), years working in greenhouses (OR=1.93, 95% CI: 1.41-11.47, $p < 0.01$), keeping the back in the same position for a long time (OR=2.44, 95% CI: 1.09-5.48, $p < 0.05$), and working hours per day ≥ 10 h (OR=4.83, 95% CI: 1.91-12.17, $p < 0.01$).

Table 5 shows that the associations of MSDs in three body parts with the highest frequency of MSDS with individual and work-related factors. Age (OR=4.17, 95% CI: 1.29-13.83, $p < 0.01$), years

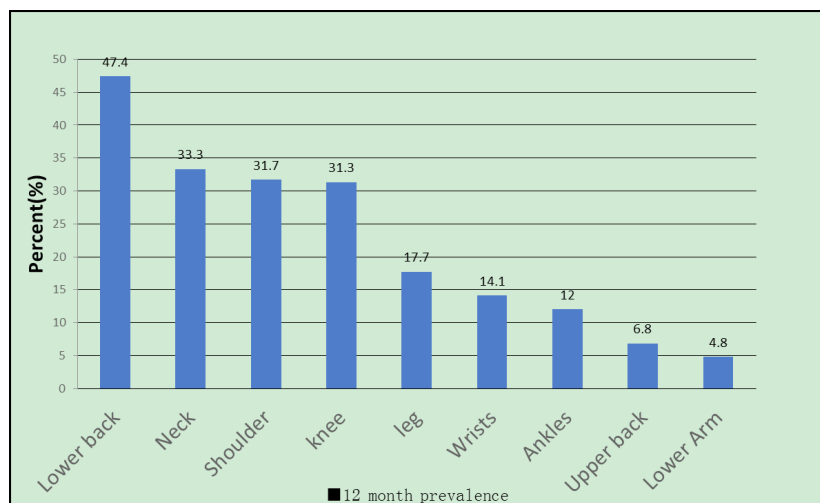


Figure 1. Prevalence of MSDs by different anatomical regions

Table 2. Individual characteristics and their association with musculoskeletal disorders (N=249)

Independent factor (n ^a)	Musculoskeletal Disorders		χ^2	P
	With MSDs% ^b (215)	Without MSDs% ^b (34)		
Age (yr)				
<50 (108)	79.6	20.4	5.0	0.025
≥50 (141)	91.5	8.5		
Years working in vegetable greenhouse				
<10 (129)	55.8	44.2	39.6	0.00
10~30 (94)	83.0	17.0		
>30 (26)	92.3	7.7		
BMI				
<18.5(48)	91.7	8.3	7.14	0.28
18.5~25.0 (143)	87.4	12.6		
>25.0 (58)	79.3	20.7		
Gender				
Male (145)	91.0	9.0	4.9	0.027
Female (104)	79.8	20.2		
Schooling				
Junior high school or below (193)	87.6	12.4	42.9	0.000
Senior high school (37)	91.9	8.1		
Bachelor and above (19)	63.2	36.8		
Smoking				
Yes (77)	80.5	19.5	3.0	0.084
No (172)	89.0	11.0		

MSDs: musculoskeletal disorders;

n^a: quantities in braces demonstrates the total count in that variable in the first column;^b percentage computed for each category of all factors with MSDs and without MSDs.**Table 3.** work-related characteristics and their association with musculoskeletal disorders (N = 249)

Independent factor(n ^a)	Musculoskeletal Disorders		χ^2	P
	With MSDs% ^b (215)	Without MSDs% ^b (34)		
Prolonged standing				
Seldom (17)	76.5	23.5	53.7	0.000
Sometimes (26)	53.8	46.2		
Often (100)	90.0	10.0		
Frequently (106)	92.4	7.6		
Lifting heavy weights >20Kg				
Seldom (49)	77.6	22.4	9.4	0.024
Sometimes (84)	88.1	19.9		
Often (104)	88.5	11.5		
Frequently (12)	91.7	8.3		
Repeating actions several times per minute				
Seldom (20)	75.0	25.0	12.0	0.008

(continued)

Independent factor(n ^a)	Musculoskeletal Disorders		χ^2	P
	With MSDs% ^b (215)	Without MSDs% ^b (34)		
Sometimes (66)	81.8	18.2		
Often (116)	91.4	8.6		
Frequently (47)	89.4	10.6		
Working hours per day				
≥10(110)	94.5	5.5	8.8	0.003
<10(139)	79.9	20.1		
Enough rest time				
Yes (66)	72.7	27.3	11.0	0.001
No (183)	91.3	8.7		
Repeating the same action at the waist				
Yes (136)	89.2	10.8	1.5	0.221
No (113)	83.2	16.8		
Keeping the back in the same position for a long time				
Yes (197)	89.3	10.7	6.6	0.01
No (52)	75.0	25.0		
Keeping the neck in the same position for a long time				
Yes (159)	89.9	10.1	3.9	0.048
No (90)	80.0	20.0		
When working, it is necessary to hold things tight by hand				
Yes (180)	89.4	10.6	4.4	0.036
No (69)	78.3	21.7		
Years working in vegetable greenhouse				
<10 (98)	74.5	25.5	28.2	0.000
10~30 (114)	93.0	7.0		
>30 (37)	96.7	3.3		
Squatting for a long time				
Yes (130)	91.5	8.5	4.3	0.039
No (119)	80.7	19.3		

MSDs: musculoskeletal disorders;

^a quantities in braces demonstrates the total count in that variable in the first column;

^bpercentage computed for each category of all factors with MSDs and without MSDs.

Table 4. Binary Logistic Regression Analysis of MSDs for farmers working in vegetable greenhouse

Factor	OR	95%CI	P
Age	4.86	1.54-16.31	<0.01
Years working in vegetable greenhouse	1.93	1.41-11.47	<0.01
Keeping the back in the same position for a long time	2.44	1.09-5.48	<0.05
working hours per day ≥10 h	4.83	1.91-12.17	<0.01

OR: odds ratio; P: significance value; 95% CI: 95% confidence interval.

Table 5. Binary Logistic Regression Analysis of the various sites of MSDs for greenhouse vegetable farmers

MSDs	Factor	OR	95%CI	P
Lower back	Age	4.17	1.29-13.83	<0.01
	years working in vegetable greenhouse	2.11	2.07-12.26	<0.01
	Keeping the back in the same position for a long time	6.32	1.42-25.94	<0.05
Neck	Age	5.34	1.72-20.85	<0.01
	years working in vegetable greenhouse	1.66	1.19-9.14	<0.01
	working hours per day ≥ 10 h	4.96	1.52-16.11	<0.05
Shoulder	Age	4.35	1.46-14.26	<0.01
	working hours per day ≥ 10 h	2.66	1.26-15.02	<0.05
	Lifting heavy weights >20 Kg	7.06	1.67-28.62	<0.05

OR: odds ratio; P: significance value; 95% CI: 95% confidence interval.

working in greenhouses (OR=2.11, 95% CI: 2.07-12.26, $p<0.01$), and keeping the back in the same position for a long time (OR=6.32, 95% CI: 1.42-25.94, $p<0.05$) was associated with the occurrence of pain in lower back. The associations of neck are age (OR=5.34, 95% CI: 1.72-20.85, $p<0.01$), years working in greenhouses (OR=1.66, 95% CI: 1.19-9.14, $p<0.01$), and working hours per day greater than 10 h (OR=4.96, 95% CI: 1.52-16.11, $p<0.05$). The associations of shoulder are age (OR=4.35, 95% CI: 1.46-14.26, $p<0.01$), working hours per day ≥ 10 h (OR=2.66, 95% CI: 1.26-15.02, $p<0.05$), and lifting heavy weights ≥ 20 Kg (OR=7.06, 95% CI: 1.67-28.62, $p<0.05$).

Evaluation of each activity using RULA

Postural analysis of all farmers occupied with each activity was carried out by RULA sheet and results are compiled in Table 6. RULA score results show that the RULA scores of greenhouse vegetable growing are all above 5 points.

DISCUSSION

About half of the world's labor force is engaged in agricultural work, and MSDs are the most com-

mon injuries among farmers (8). The results of the review done by Osborne et al. (9) in 2012 showed that MSDs prevalence rate was 77.0%. After 2012, various researches have also determined the MSDs prevalence rate. In Malaysian farmers MSDs prevalence among manual working farmers is 43.4% (10), and other study of Trinidad farmers found the overall MSDs prevalence 61% (11). The results of this study show that 86.3% of the subjects reported pain in at least one body part which indicates that MSDs are prevalent among vegetable greenhouse farmers. This MSDs prevalence rate is higher than that among traditional agricultural workers. MSDs are related to a variety of occupational factors involving hard physical work, lifting heavy weights, bad working postures, repetitive motions, mechanical vibration, etc. (12). In the main activities of the farmers, these factors coexist with each other and greater harms might be caused. At the same time, prevalence of MSDs in various parts of the body was within the range of 4.8%–47.4%. The lower back pain (47.4%) was the most seriously affected part among the farmers. The farmers suffer from such problems due to adopting forward bending and squat sitting postures for long periods of time during work. Lower back pain was followed by neck pain (33.3%) because of working hours per day ≥ 10 h. In the course

Table 6. The RULA score for different activity in farmers working in vegetable greenhouse

Activity	Number	RULA score		
		A Scores	B Scores	grand Scores
planting seedling	19	4.9±0.7	5.4±0.5	5.9±0.6
pruning stems and leaves	66	5.5±1.1	6.4±1.2	6.1±0.7
picking	78	5.9±1.4	7.4±1.1	6.4±0.5
carrying	47	10.1±1.4	7.0±1.3	7
shoveling	28	6.6±0.5	5.2±0.8	6.5±0.5
spraying pesticides	33	4.5±0.5	6.3±1.1	6.1±0.8
weeding	41	4.8±0.8	7.8±1.0	6.3±0.6

A Score: combination of Score A, muscle use and force scores for group A.

B Score: combination of Score B, muscle use and force scores for group B.

of working long hours, farmers were compelled to twist their neck frequently to observe the plants, the frequent rotation of the cervical spine may strain the muscles. Shoulder pain (31.7%) came in third. The main reason is that the operation space of greenhouses is relatively narrow which prevents the use of mechanized tools. In addition to the narrow space, farmers had to repeatedly heaving weights over a significant period of time. These results are similar to what were found in the Greenhouse Survey being conducted in China. It was found through literature retrieval that there are no relevant studies on greenhouse farmers from other geographical areas. The findings of this study have instructive significance for the prevention of MSDs in greenhouse farmers all over the world.

In accordance with χ^2 outcomes, individual factors including gender, age, and schooling were associated with the prevalence of MSDs. At the same time, MSDs were also associated to work-related factors like prolonged standing, lifting heavy weights $\geq 20\text{Kg}$, not enough rest time, and kneeling down for a long time. Additionally, the results of this study indicated that farmers with a higher schooling (Bachelor and above) were less likely to report MSDs than others. Therefore, it is likely that farmers with lower schooling are less aware of ergonomic philosophies and appropriate methods of working compared to farmers with higher schooling. This outcome suggests that it is necessary to provide relevant education and training for vegetable greenhouse farmers

in order to help them have a better understanding about the effects of various awkward postures during the work.

There were various significant outcomes concerning the relation of individual and work-related factors to MSDs. According to the logistic regression outcomes, it is clear that age and years working in greenhouse are related to the incidence of MSDs. This may be because the longer the years working in greenhouses, the more exposure a farmer has to its microclimate and the harmful occupational environment. Studies have suggested tissue degeneration is a precipitating factor for musculoskeletal disorders that comes with aging (13). Furthermore, with increasing age, physical workload and the destruction of work ability balance can cause chronic overload in elderly workers. Research on age and years working in greenhouse as risk factors also showed similar results among other workers (14, 15).

It is very difficult to work year-round in the greenhouse environment which the farmers are exposed to. The work involves planting seeding, pruning stems and leaves, picking, carrying, shoveling, spraying pesticides and weeding. In addition, they also have to ventilate the greenhouse regularly, to prevent diseases and pests, and ensure stable temperature and humidity in the greenhouse. Therefore, the farmers are expected to work long hours all days of the week in the greenhouse. This long duration of exposure may lead to the development of musculoskeletal discomfort/pain among the farmers

which is corroborated with the outcomes of regression analysis of relationship between working hours per day ≥ 10 h and MSDs. This result is also consistent with the related research results abroad (16). Furthermore, Binary Logistic Regression Analysis of MSDs also revealed keeping the backs in the same position for a long time was an important risk factor for MSDs in vegetable greenhouse farmers. By observation, farmers were required to work in squatting or kneeling posture for a long time during the planting seedling periods, twisting their trunk for a long time which increases the risk of MSDs. This outcome highlights the significance of biomechanical risk factors for vegetable greenhouse farmers. It is also observed in the current study that the farmers were engaged in labor-intensive work in a narrow space, bending frequently to lift and carry heavy loads, which is bound to increase strain on lower back muscles. Therefore, vegetable greenhouse farmers may be advised to take consistent rest breaks and be equipped with waist protection equipment to minimize risk of MSDs.

In this study, RULA was used for the first time to study the ergonomic load levels on vegetable greenhouse farmers in China. It was observed that the farmers' production activities involved long-term or repeated neck bending, neck rotation, shoulder abduction, trunk movements forward or bending, and long-term squatting or kneeling. Such bad working postures could easily place the body in a state of fatigue, which, if recovery was poor, will increase the risk of MSDs. Correlation analysis showed that keeping the back/ neck in the same position for a long time, and working ≥ 10 h hours per day were correlated with MSDs incidence ($r = 0.736, 0.748$ and 0.562 , respectively). The results of this study show that men have a higher incidence of MSDs than women. A possible cause is that men are necessary for most of the labor-intensive work like shoveling, lifting and carrying heavy loads, and weeding, which has the highest scores in RULA. Since the RULA scores of vegetable greenhouse farmers are all above 5 points, the work needs to be further examined and changed soon to reduce ergonomic load level according to the RULA load level intervention principle.

LIMITATIONS

The current study has an advantage that observer error was managed utilizing two qualified assessors in contrast to investigations in which there were single observers for each situation. However, the study still has some limitations, owing to the smaller sample size, lower representation, and the poorer precision in estimating population. Several farmers were reluctant to share their miseries or they were unable to explain the place and frequency of pain. Although the inference of the results is limited to some degree, the results can reflect the epidemic trend of musculoskeletal disorders among vegetable greenhouse farmers. In future investigations, a larger sample needs to be studied to reduce errors. The judgment criteria of MSDs in this current study were given by the researchers, and judged by the farmers themselves, which might cause overestimation of the prevalence rate of MSDs. In addition, RULA, focusing more on the assessment of postural load, is more accurate in the assessment of workload of upper limbs and trunk, but does not evaluation of manual handling of loads. The simultaneous use of other ergonomic tools should be considered in future studies to remedy these deficiencies.

CONCLUSION

To conclude, factors such as age, years working in vegetable greenhouse, keeping the back in the same position for a long time, and working ≥ 10 h hours per day, demonstrate that greenhouse vegetable growing is related to MSDs. The outcomes emphasize the significance of both individual and work-related factors of greenhouse vegetable growing related to MSDs, and highlight the necessity for the need to objectively evaluate both health conditions and risk factors in vegetable greenhouse farmers and to develop solutions. Our findings are important for awareness raising and initiation of a program for improvement of health and safety in greenhouse vegetable farmers in the Shandong rural area, which may be provides reference basis for implemented policy actions later in the entire greenhouse sector in China.

CONFLICT OF INTEREST: The authors have no conflicts of interest to declare.

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