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Assessment of Postural Load during Melon Cultivation in Mediterranean Greenhouses

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Abstract: Health and safety at work directly influence the development of sustainable agriculture. In the agricultural sector, many farm workers suffer musculoskeletal disorders caused by forced posture. The objective of this research is to assess working postures during melon cultivation in Almería-type greenhouses. The Ovako Working Posture Assessment System (OWAS) has been used with pictures of the tasks. The variables studied by multiple correspondence analysis were as follows: Subtask, Posture code, Back, Arms, Legs, Load, Risk, and Risk combination. The OWAS analysis showed that 47.57% of the postures were assessed as risk category 2, 14.32% as risk category 3, 0.47% as risk category 4, and the rest as risk category 1. Corrective measures should be implemented immediately, as soon as possible, or in the near future, depending on the risks detected.

Keywords: sustainable agriculture; musculoskeletal disorders; work postures; melon; greenhouse; OWAS

1. Introduction

1.1. Sustainability and Occupational Health and Safety (OHS)

In October 1984, the World Commission on Environment and Development met for the first time. A few years later, in April of 1987, its report entitled 'Our Common Future' was published [1]. The report raises the possibility of obtaining economic growth based on sustainability policies.

World agriculture plays a very important role in the sustainability of the planet because it is the primary food source. Sustainable agriculture refers not only to food but also to the way of obtaining this food [2]. Respect for the environment and for the health of farm workers are the fundamental pillars of this type of agriculture (Figure 1).

Occupational diseases and accidents affect the economies of nations; for this reason, governments perpetually promote occupational health and safety (OHS) [3]. OHS refers to "*conditions and factors that affect, or could affect, the health and safety of employees or other workers (including temporary, and contract workers), visitors, or any other person in the workplace*" [4].

Establishing an OHS management system in companies provides numerous improvements for these organisations and their workers. Some of these improvements are: customer and investor relations, cost reduction and management, worker participation, performance increase, social clauses and company reputation [5]. This management system allows for the achievement of OHS policy goals. "*The expected results of the OSH management system are to prevent work-related injury and ill health to workers and to provide safe and healthy workplaces*" [6].

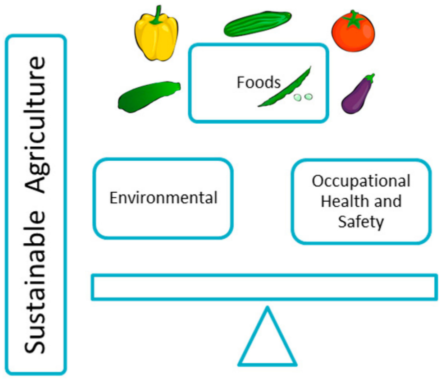


Figure 1. Sustainable Agriculture.

The regulatory framework of this global field is extensive. In Spain, the "Spanish Strategy for Safety and Health at Work 2015–2020" was approved on April 24, 2015 [7].

There are a large number of work areas where researches are being carried out that allow contribution in different ways to Occupational Safety and Health, and everything related to this, such as mining [8–10], construction [11–14], oil refinery [15], other industries [16], firemen [17], ports [18], agriculture [19,20], etc.

1.2. Musculoskeletal Disorders Definition and Standards

According to the European Agency for Safety and Health at Work [21], work-related musculoskeletal disorders (MSDs) are "alterations that affect bodily structures such as muscles, joints, tendons, ligaments, nerves, bones, and the circulatory system, caused or aggravated fundamentally by work and the effects of the environment in which it takes place".

The areas of the body that are usually affected are the elbow and shoulder, hand and wrist, and the back (cervical, dorsal, and lumbar areas). They can appear in workers in any work environment [22], such as construction [23], cleaning [24], cooking [25], nursing [26], administration [27], agriculture [28], driving [29], education [30], and retail [31].

The primary risk factors are due to forced postures, repetitive movements, and manual load handling. However, there are other risk factors of a different nature [32].

According to EU-OSHA, MSDs have the following effects [21,33]:

- Damage human health and can lead to temporary or total work disability.
- Affect the economies of companies and countries.
- Alter work performance.

It is necessary to know and study the risks that cause these MSDs and to rely on the cooperation of workers [32] to implement preventive actions or establish prevention guidelines in companies and during work tasks [34].

Finally, it is important to provide the necessary care and to facilitate a return to work by personnel who have suffered from these disorders [34].

1.3. Relationship with Other Risks

Rohles listed all the factors involved in agricultural work. He called them "*physical factors, organismic factors, and adaptive factors*" (Figure 2) [35].

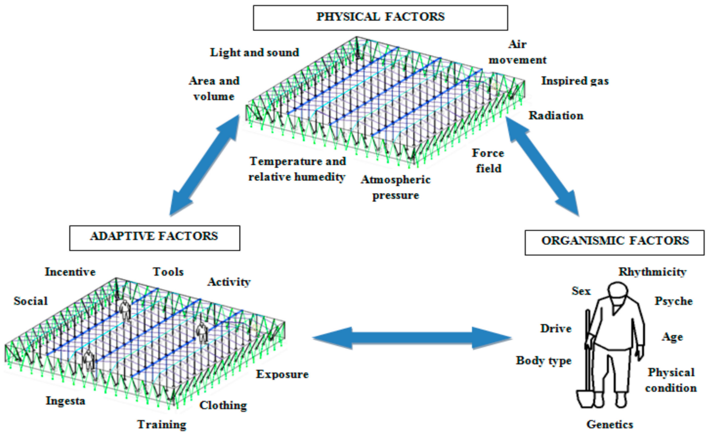


Figure 2. Relationship between factors in greenhouse agriculture (adapted from [35]).

1.4. Musculoskeletal Disorders in Agriculture

At the global level, the most important employment sector after the service sector is agriculture. In farming, there are many conditions, machines, materials, and environments in which work is performed, complicating the prevention task [36]. In addition, a considerable amount of agricultural work is physical, primarily due to the manual nature of many cultivation tasks [37]. Thus, having forced posture when performing tasks with high physical demands is the cause of MSDs [38,39].

In Spain, the greatest physical demands in agriculture are due to the repetitive movements of the arms and hands (67.0%). In addition, more than 50% of farm workers in the agricultural sector suffer from problems in the lower back and 23% in the neck [40], with most sick leave caused by MSDs [41].

Regarding musculoskeletal disorders, it is very important to study measures to prevent or reduce these disorders in farmers. Among these measures, the creation of new tools and equipment, modifications to improve the existing ones, or the adoption of new methods or techniques to carry out the work, in addition to many others, can be considered [42]. Below, there are some examples of studies in which some measures have been implemented, grouped into these two categories:

(a) Creation or improvement of tools and equipment

In rice cultivation, a new design for the threshing machine was made, taking into consideration the relationship between the worker's posture and measurements, and the measurements of the machine [43]. A new tool for planting rice was also carried out, thus avoiding doing this activity manually [44]. Other improvements in this type of crop were the modification of the equipment handles used for the plow, [45] and the mechanization of the tasks of transplantation and start-up in rice cultivation [46].

During the work in vineyards, the use of a robotic suit was proposed, in order to reduce the adoption of harmful work postures for farmers [47].

As a last example, in the cultivation of apples, the use of a belt was proposed to avoid overloading the area of the back when transporting boxes full of fruit [48].

(b) New techniques or work methods

In greenhouse crops where the use of trellises is necessary, a series of recommendations were made to reduce disorders when carrying out the work. For example, the recommended height was set between 1.2 and 1.6 m, and the supported weight should be less than 2 kg. In addition, other measures were a new plann for the working days, and a new practice to avoid injuring postures [49].

Another example is the training courses for pineapple cultivation workers, which proved that musculoskeletal disorders could be reduced [50].

1.5. Previous Studies of Intensive Agriculture in Greenhouses in South-Eastern (SE) Spain

Spain has a total greenhouse area of 65,644 ha. The south-eastern part of the country stands out for having a large proportion of these greenhouses. Almeria is the province with the largest area of greenhouses in Spain, with a total of 31,801 ha and approximately 50,000 farm workers [51], followed by Murcia, with 6230 ha, and Granada, with 5392 ha [52].

The first research studies on OHS to be conducted in greenhouses were related to the effects of pesticides on the physical and psychological health of farm workers [53–56].

Other studies evaluated the ergonomic and psychosociological conditions of farm workers in different crops using the LEST (Labour Economics and Industrial Sociology) method [57], and they suggested improvements and more specific ergonomic studies [58,59].

Several authors measured the indoor and outdoor climates of greenhouses to uncover the periods in which the onset of thermal stress was more common [60,61]; Pérez-Alonso et al. correlated the accidents that occurred in greenhouse construction workers in SE Spain with the affected anatomical area and the nature of the resulting injury [62]. Psychosocial risks in farmers were subsequently studied using validated questionnaires, and the researchers concluded that the psychosocial risks to which workers were exposed were not serious, although improvements should be made in the medium term [63,64].

Recently, the "Rapid Upper Limb Assessment" (RULA) method [65] was used for the ergonomic assessment of greenhouse tomato-growing farmers. This study focused on analysing and preventing MSDs arising during tomato plant training [49].

1.6. Objective

The objective of the present study is to assess forced postures in farmers who perform melon cultivation tasks in Almería-type greenhouses. This way, injuring postures will be detected.

2. Materials and Methods

2.1. Location

The greenhouse selected for the study is located in SE Spain, specifically in Almeria (Latitude: 36°50′2.569″ North and Longitude: 2°27′49.368″ West).

2.2. Experimental Greenhouse and Crop

The study was conducted in Almería-type greenhouses with an area of 2800 m^2, sandy soil [66], drip irrigation, and cultivation of the "Valverde" melon variety. The melons were transplanted on February 28, 2017, and harvested on May 26, 2017. The planting density was 0.428 plants m^{-2}.

2.3. Cultivation Tasks and Farm Workers

The present article describes all the tasks the workers needed to perform for greenhouse melon cultivation in the Almeria area, as a preliminary study for the assessment of work postures used by farm workers for each task.

Three workers performed melon cultivation tasks, and their characteristics are shown in Table 1.

Table 1. Characteristics of farm workers.

	Worker (1)	Worker (2)	Worker (3)
Sex	Man	Woman	Man
Age	40	38	79
Height	1.75 m	1.52 m	1.65 m
Weight	78 kg	65 kg	77 kg

Regardless of the type of worker, all adopted the same posture during the task, that is, the tasks required for melon cultivation.

A Nikon digital camera manufactured in Indonesia was used to observe each task as it was performed. The model is a COOLPIX S210, with a 3× Zoom-Nikkon lens and 8.0 million effective pixels.

2.4. Method for Assessing the Postural Load

Many methods have been developed for the assessment of musculoskeletal disorders. These methods can be classified into direct, semi-direct and indirect methods [67].

The selected method for postural load assessment was the OWAS method [68], which is classified as a semi-direct method.

Apart from OWAS, there are many other semi-direct methods like the RULA Method [65], OCRA Method [69], REBA Method [70], VIRA Method [71], etc.

2.4.1. Application of the OWAS Method in Agriculture

One of the first studies to evaluate forced postures in agriculture was performed by Vanderschilden [37]. In Finland, NevalaPuranen subsequently used OWAS to confirm the effectiveness of two rehabilitation programmes. The first programme was for women farmers, and the second was for men and women who suffered from lower back pain or shoulder discomfort. The results of both studies showed a reduction in harmful postures by farmers [72,73].

In melon cultivation, musculoskeletal disorders were found to arise in oriental melon-growing farmers according to OWAS, among other methods [74,75].

There is also evidence from two studies conducted in Brazil. This method was used for assessing postures adopted by farm workers in two different crops. One of them focused on farm workers in sugarcane cutting, in which the "Ergonomic Workplace Analysis" method [76] was also used. The other was conducted in a eucalyptus nursery for the tasks of preparing cuttings and mini-cuttings with scissors. Some harmful postures were found in both cases [77,78].

In Japan, a study was conducted on farmers who were dedicated to berry thinning and pruning by assessing postures with OWAS and administering a survey. It was determined that the postures used for both tasks were unfavourable [47].

Abrahao et al. used OWAS to study physical strain in organic horticulture workers [79], whereas Das et al. used it to perform an ergonomic analysis in farm-working children [80].

Finally, farmers dedicated to the harvesting of apples and oil palm fruit were also studied. OWAS and other methods were used to evaluate the physical effort of men and women. The OWAS method elicited postures that were grouped into categories 1, 2, and 3 [81].

2.4.2. The OWAS Method

The OWAS method was developed in the steel industry (OVAKO OY) in Finland. It arose from studies that analysed the workload of workers dedicated to repairing foundry furnaces [68].

This method can be applied in many work sectors [67], including healthcare [82–87], industry [88–93], agriculture and livestock [78–81,94,95], information technologies [96–101], construction [102–106], transport and logistics [107–112], and education [113–116], as well as in other areas, such as supermarkets [117], power line work [118], workers with mental disabilities [119], cooking [120], and electronic or electrical equipment work [121].

The method is based on two fundamental stages, the observation of the posture and the implementation of corrective actions for critical posture positions [68].

The OWAS identifies a total of 252 postures, which result from the combination of the following [122]:

- Four back postures.

- Three arm postures.
- Seven leg postures.
- Three levels of lifted loads.

This combination makes it possible to identify the postures observed while the individuals are working, to assign a posture code to each one (Table A1, see Appendix A). These codes allow researchers to assign a risk category to these postures and to each body part.

These categories are classified according to the risk they pose to the musculoskeletal system (Table 2). Corrective actions are based on making changes in work performance.

Table 2. OWAS risk categories [68].

Risk categories	Postures	Correction	Correction Period
Risk1	Normal	No	-
Risk2	With slight risk	Yes	Not immediate
Risk3	With high risk	Yes	Short term
Risk4	With excessive risk	Yes	Immediate

Several software packages can be used to apply the OWAS method. In the present study, the software was Ergomet 3.0 [123]. The stages for the application of this method were observations taken during 5- to 10-s intervals, the identification of work phases, posture codes (Table A1, see Appendix A), risk categories (from 1 to 4), and relative frequency.

2.5. Data Analysis

The sample data were analysed using SPSS v.23 and XLSTAT software programmes, and thus a descriptive analysis was performed for all the OWAS variables, and a multiple correspondence analysis was performed by adopting the following variables: Subtask, Posture code, Back, Arms, Legs, Load, Risk, and Risk combination (this variable relates the possible combinations that may occur between risks, at 1, 2, 3, and 4). Table A2 (see Appendix A) shows the nomenclature that is used to name each variable category in the multiple correspondence analysis.

Through descriptive analysis, it is possible to statistically describe each of the studied variables using the OWAS method; while with multiple correspondence analysis, we obtain the relationship of the association between these variables, which is an objective of this research. Therefore, carrying out this analysis is justified, since it is a multivariable analysis technique whose objective is to establish relationships between more than two non-metric variables, as happens with the indicated variables. In addition, this technique reveals the degree to which the different values of the variables (categories) contribute to this detected relationship, information that is usually provided in a graphic way (associated values appear nearby, non-associated values appear distant). That is, its objective is the study of the association between the categories of multiple non-metric variables, being able to get a perceptual map revealing this association in a graphic way.

3. Results

3.1. Identified Tasks

Table 3 summarises the tasks identified here and those classified within several work phases (transplanting, manual spraying, tractor spraying, leaf removal, harvesting, and cleaning). Some of the postures adopted by the farm workers are shown.

Table 3. Identified tasks.

Agricultural Tasks	Subtasks	Handling Loads	Repetitive Movements	Forced Postures	Observations	Image
Transplanting	Making holes		√	√	With the help of a weeding hoe or iron bar, the necessary holes are made in the sand.	
	Planting		√	√	The root balls are manually inserted into the previously made holes.	
Spraying treatment	Manual spraying		√	√	The farmer walks between the lines, applying the product to the plants with the help of a hose.	
	Tractor spraying		√	√	Spraying is performed with the help of a tractor with a tank. The farmer drives backwards with the tractor to the end of the greenhouse, down the central corridor. Then, he returns to the door. The tractor pours the mixture over the entire greenhouse crop during both passes.	

Table 3. *Cont.*

Agricultural Tasks	Subtasks	Handling Loads	Repetitive Movements	Forced Postures	Observations	Image
Bee pollination	Bee pollination				This task consists of the installation of beehives for pollination during melon cultivation. This task was not performed by the farmer, but by an external company. For this reason, it will not be evaluated.	
Leaf removal	Leaf removal	√	√	√	The purpose of this task is to allow the sun to reach the melons directly. This task is repeated several times during crop cultivation. It is performed by dragging a horizontal pipe over the plants in each zone of the greenhouse.	
Harvesting	Melon picking		√	√	During this task, the melons are picked with the help of cutting tools or shears.	
	Melon harvesting (1)	√	√	√	This task is performed by a single farm worker who does all the tasks consecutively.	
	Melon harvesting (2)	√	√	√	This task is performed by a chain of several farm workers. One worker picks the melon from the ground, the worker passes the melon to another worker, and the last worker deposits it in the container.	

Table 3. *Cont.*

Agricultural Tasks	Subtasks	Handling Loads	Repetitive Movements	Forced Postures	Observations	Image
	Transporting containers		√	√	When the agricultural containers are full, they are removed from the greenhouse with the help of a wheelbarrow.	
Greenhouse sweeping	Plant removal	√	√	√	The plants are removed and accumulated in the central corridor.	
	Greenhouse plant removal		√	√	The plants are removed and accumulated in the central corridor of the greenhouse and collected with a tractor.	
	Greenhouse sweeping		√	√	The greenhouse is swept for final cleaning.	

3.2. Results According to the Posture and Risk Categories

Table 4 summarises the codes for the postures adopted during each subtask that were performed during melon cultivation. For each agricultural task, a different number of observations were made, depending on the task duration.

Regarding the "Transplanting" phase, the subtask with a higher posture code repetition rate is "Making holes". This code is 2121, risk category 2, which has a value of 34.05%. However, other postures in both subtasks belong to a higher risk category, particularly category 3.

In "Spraying treatment", the highest frequency is found for "Tractor spraying". In 60.00% of the occasions, the workers adopt posture 3111, which belongs to risk category 2.

In the third task, "Leaf removal", code 2171 (risk category 2) represents the most frequently adopted posture, with 87 repetitions. By contrast, the highest risk category of all the tasks involves posture 2151 (risk category 3).

In the "Harvesting" phase, in which there are a total of four tasks, the highest repetition rate (47.06%) is found for "Transporting containers". This task appears in posture 1121, which corresponds to risk category 1. The highest risk (level 4) observed here appears in postures 4141 and 4151 of "melon picking" and 4141 of "Melon harvesting (2)".

Finally, in the last task performed here ("Greenhouse sweeping"), the posture with the highest rate (54.84%) is "Greenhouse plant removal". This is posture 3111, which belongs to risk category 1. The highest level of risk (4) is observed in posture 4141 of "Greenhouse sweeping", and it is only adopted on one occasion.

However, Table 4 also presents the risk categories of each complete subtask.

Risk category 4, which is classified as the most harmful, only appears in three of the 12 subtasks that make up the cultivation process. The highest rate of adopted postures with this risk is observed in "Melon harvesting (2)", with 2.50%, and the lowest was in "Greenhouse sweeping", with 0.54%.

Regarding risk category 3, it is assigned to 8 of the 12 subtasks. The highest rate is 68.39% for "Plant removal". The lowest is observed for "Making holes", with 1.08%.

Risk category 2 can be observed for all farming tasks, with rates higher than 50.00% in half of the tasks. In "Making holes", it is observed in 84.86%, for the highest rate compared to the rest of the subtasks. The lowest is found for "Manual Spraying", with 1.08%.

Finally, risk category 1 appears in the 12 tasks, reaching almost 100% in "Manual spraying", and the lowest rate is observed for "Planting", with 12.97%.

Table 4. Codes of posture and risks.

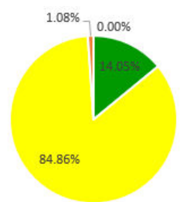
Agricultural Tasks	Subtasks	Codes of Posture	Risk	Frequency	Rate	Total
Transplanting	Making holes	2121		63	34.05	
		2131		8	4.32	
		2171		12	6.49	
		4121		47	25.41	
		4171		7	3.78	
		1121		23	12.43	
		1221		1	0.54	
		4131		9	4.86	
		4271		6	3.24	
		2271		4	2.16	
		4231		2	1.08	
		1131		2	1.08	
		2221		1	0.54	

Table 4. *Cont.*

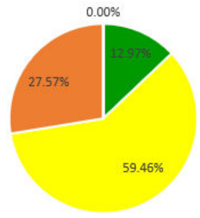
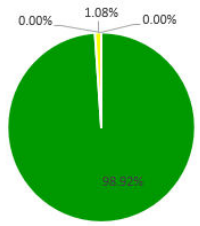
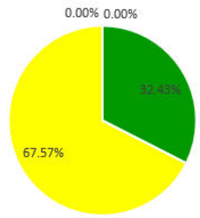
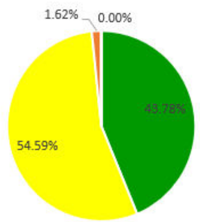
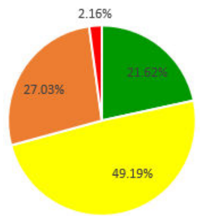
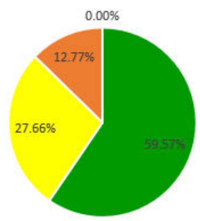
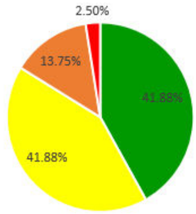
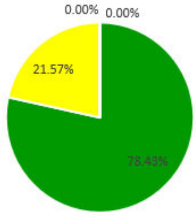
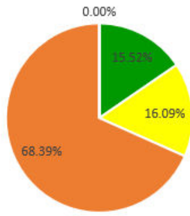
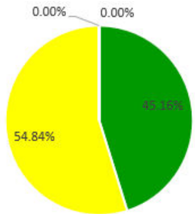
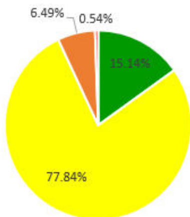
Agricultural Tasks	Subtasks	Codes of Posture	Risk	Frequency	Rate	Total
	Planting	2121		43	23.24	
		1121		7	3.78	
		2131		57	30.81	
		2141		30	16.22	
		2151		21	11.35	
		2171		10	5.41	
		1171		12	6.49	
		1131		5	2.70	
Spraying treatment	Manual spraying	1171		56	30.27	
		1131		19	10.27	
		1121		93	50.27	
		3171		10	5.41	
		2121		1	0.54	
		4171		1	0.54	
		3121		5	2.70	
	Tractor spraying	3111		111	60.00	
		1111		60	32.43	
		4111		13	7.03	
		2111		1	0.54	
Leaf removal	Leaf removal	1171		64	34.59	
		2171		87	47.03	
		2151		3	1.62	
		1121		15	8.11	
		2131		14	7.57	
		3131		1	0.54	
		3171		1	0.54	
Harvesting	Melon picking	2171		17	9.19	
		1121		17	9.19	
		2121		57	30.81	
		2151		13	7.03	
		1171		17	9.19	
		2131		16	8.65	
		3141		1	0.54	
		2141		36	19.46	
		4141		1	0.54	
		4151		3	1.62	
		1131		6	3.24	
		4121		1	0.54	
	Melon harvesting (1)	1171		34	24.11	
		1121		27	19.15	
		2121		29	20.57	
		2141		18	12.77	
		1131		5	3.55	
		1371		1	0.71	
		1321		2	1.42	
		3231		1	0.71	
		2131		7	4.96	
		3131		3	2.13	
		1231		1	0.71	
		1221		1	0.71	
		1172		7	4.96	
		2171		3	2.13	
		3171		1	0.71	
		1132		1	0.71	

Table 4. *Cont.*

Agricultural Tasks	Subtasks	Codes of Posture	Risk	Frequency	Rate	Total
	Melon harvesting (2)	2131		11	6.88	
		1171		8	5.00	
		1131		3	1.88	
		2121		17	10.63	
		2141		18	11.25	
		1121		26	16.25	
		1221		1	0.63	
		4131		20	12.50	
		2161		8	5.00	
		2261		1	0.63	
		2151		3	1.88	
		3131		17	10.63	
		2171		3	1.88	
		3121		12	7.50	
		4141		4	2.50	
		4121		8	2.00	
	Transporting containers	1121		48	47.06	
		2131		10	9.80	
		1131		29	28.43	
		4131		1	0.98	
		3121		1	0.98	
		2171		1	0.98	
		2121		5	4.90	
		4171		5	4.90	
		3171		1	0.98	
		3131		1	0.98	
Greenhouse sweeping	Plant removal	2151		26	14.94	
		2141		30	17.24	
		2171		25	14.37	
		2142		26	14.94	
		2172		37	21.26	
		1171		18	10.34	
		2121		3	1.72	
		1131		3	1.72	
		1121		5	2.87	
		1111		1	0.57	
	Greenhouse plant removal	3111		34	54.84	
		1111		28	45.16	
	Greenhouse sweeping	2231		3	1.62	
		4131		48	25.95	
		2131		36	19.46	
		2121		22	11.89	
		1131		8	4.32	
		4121		24	12.97	
		1171		6	3.24	
		2141		5	2.70	
		1271		5	2.70	
		4231		7	3.78	
		4171		4	2.16	
		1231		5	2.70	
		2171		4	2.16	
		3121		2	1.08	
		2221		3	1.62	
		1121		2	1.08	
		4141		1	0.54	

■ Risk 1 ■ Risk 2 ■ Risk 3 ■ Risk 4

3.3. Results According to Body Area

OWAS also allows researchers to obtain the frequency and repetition rate of the posture of each body area and the level of risk for each one (Table 5).

The back posture adopted with a high repetition rate is the straight back, with 90.81% in the "Manual spraying" task, in risk category 1. This posture is followed by the twisted back posture, with 87.03% in "Planting", in risk category 3. The postures that imply a greater risk are bent back, bent and twisted back, and twisted back.

Regarding the arms, eight tasks are identified in which both arms are placed below the shoulders in 100% of the observations. Raising both arms at or above shoulder level is practically not done, except for in "Melon harvesting (1)", when it appears with a repetition rate of 2.13%. All the arm postures are in risk category 1.

Regarding the legs, there are two subtasks in which the farmer remains seated throughout their performance and is assigned to risk category 2. These are "Tractor spraying" and "Greenhouse plant removal". The highest repetition rate after the previous case is 82.16%. This task occurs when the farmer is walking. It occurs during the "Leaf removal" task, in risk category 2. The highest risk category is reached when the farm worker is standing with bent legs, adopting this posture on 56 occasions during "Plant removal".

Finally, in 10 of the 12 subtasks, the load is less than 10 kg in 100% of the postures. In the other two, the highest rates are also reached for this case.

Table 5. Risks by body parts.

		Transplanting		Spraying Treatment		Leaf Removal	Harvesting				Greenhouse Sweeping		
		Making Holes	Planting	Manual Spraying	Tractor Spraying	Leaf Removal	Melon Picking	Melon Harvesting (1)	Melon Harvesting (2)	Transporting Containers	Plant Removal	Greenhouse Plant Removal	Greenhouse Sweeping
BACK	**Straight**												
	Rate	14.05	12.97	90.81	32.43	42.70	21.62	56.03	23.75	75.49	15.52	45.16	14.05
	Frequency	26	24	168	60	79	40	79	38	77	27	28	26
	Bent												
	Rate	47.57	87.03	0.54	0.54	56.22	75.14	40.43	38.13	15.69	84.48	0.00	39.46
	Frequency	88	161	1	1	104	139	57	61	16	147	0	73
	Twisted												
	Rate	0.00	0.00	8.11	60.00	1.08	0.54	3.55	18.13	2.94	0.00	58.48	1.08
	Frequency	0	0	15	111	2	1	5	29	3	0	34	2
	Bent and twisted												
	Rate	38.38	0.00	0.54	7.03	0.00	2.70	0.00	20.00	5.88	0.00	0.00	45.41
	Frequency	71	0	1	13	0	5	0	32	6	0	0	84
ARMS	**Both arms below shoulder level**												
	Rate	92.43	100.0	100.00	100.00	100.00	100.00	95.74	98.75	100.00	100.00	100.00	87.57
	Frequency	171	185	185	185	185	185	135	158	102	174	62	162
	One arm at or above shoulder level												
	Rate	7.57	0.00	0.00	0.00	0.00	0.00	2.13	1.25	0.00	0.00	0.00	12.43
	Frequency	14	0	0	0	0	0	3	2	0	0	0	23

Table 5. *Cont.*

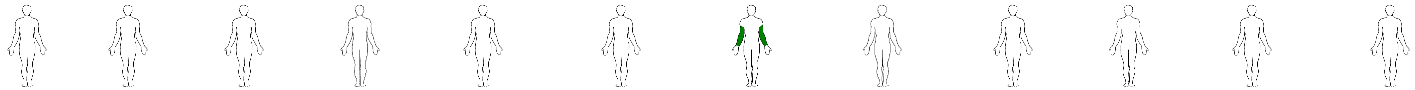
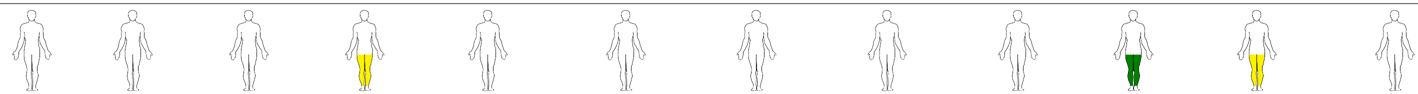
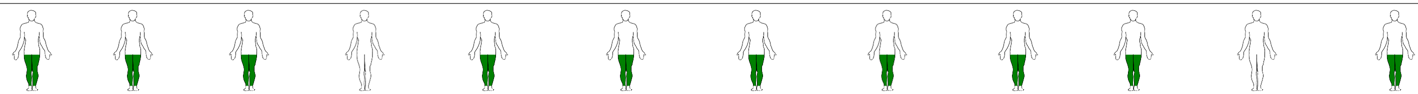
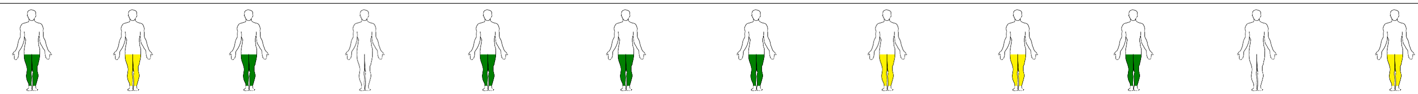
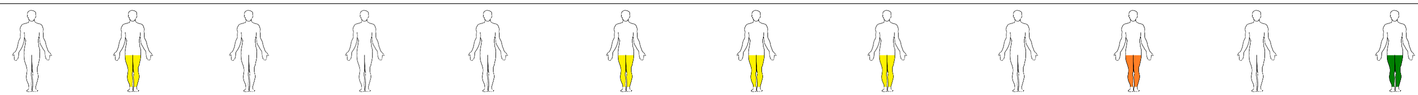
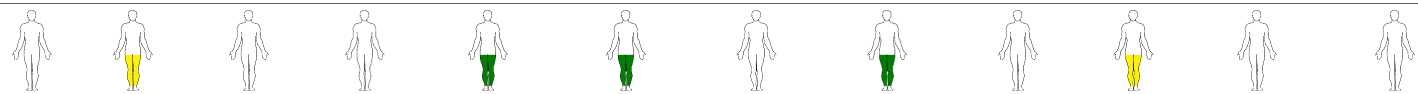
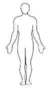
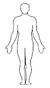
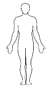
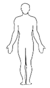
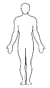
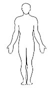
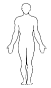
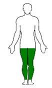
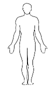
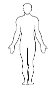
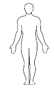
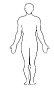
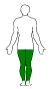
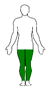
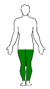
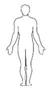
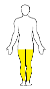
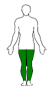
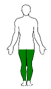
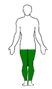
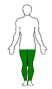
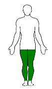
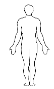
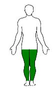
		Transplanting		Spraying Treatment		Leaf Removal	Harvesting				Greenhouse Sweeping		
		Making Holes	**Planting**	**Manual Spraying**	**Tractor Spraying**	**Leaf Removal**	**Melon Picking**	**Melon Harvesting (1)**	**Melon Harvesting (2)**	**Transporting Containers**	**Plant Removal**	**Greenhouse Plant Removal**	**Greenhouse Sweeping**
	Both arms at or above shoulder level												
	Rate	0.00	0.00	0.00	0.00	0.00	0.00	2.13	0.00	0.00	0.00	0.00	0.00
	Frequency	0	0	0	0	0	0	3	0	0	0	0	0
LEGS	**Sitting**												
	Rate	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.57	100.00	0.00
	Frequency	0	0	0	185	0	0	0	0	0	1	62	0
	Standing on two straight legs												
	Rate	72.97	27.03	53.51	0.00	8.11	40.54	41.84	40.00	52.49	4.60	0.00	28.65
	Frequency	135	50	99	0	15	75	59	64	54	8	0	53
	Standing on one straight leg												
	Rate	11.35	33.51	10.27	0.00	8.11	11.89	12.77	31.88	40.20	1.72	0.00	57.84
	Frequency	21	62	19	0	15	22	18	51	41	3	0	107
	Standing or squatting on two bent legs												
	Rate	0.00	16.22	0.00	0.00	0.00	20.54	12.77	13.75	0.00	32.18	0.00	3.24
	Frequency	0	30	0	0	0	38	18	22	0	56	0	6
	Standing or squatting on one bent leg												
	Rate	0.00	11.35	0.00	0.00	1.62	8.65	0.00	1.88	0.00	14.94	0.00	0.00
	Frequency	0	21	0	0	3	16	0	3	0	26	0	0

Table 5. *Cont.*

		Transplanting		Spraying Treatment		Leaf Removal	Harvesting				Greenhouse Sweeping		
		Making Holes	**Planting**	**Manual Spraying**	**Tractor Spraying**	**Leaf Removal**	**Melon Picking**	**Melon Harvesting (1)**	**Melon Harvesting (2)**	**Transporting Containers**	**Plant Removal**	**Greenhouse Plant Removal**	**Greenhouse Sweeping**
	Kneeling or squatting												
	Rate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.63	0.00	0.00	0.00	0.00
	Frequency	0	0	0	0	0	0	0	9	0	0	0	0
	Walking												
	Rate	15.68	11.89	36.22	0.00	82.16	18.38	32.62	6.88	6.86	45.98	0.00	10.27
	Frequency	29	22	67	0	152	34	46	11	7	80	0	19
CARGA							**<10 kg**						
	Rate	100.00	100.00	100.00	100.00	100.00	100.00	94.33	100.00	100.00	63.79	100.00	100.00
	Frequency	185	185	185	185	185	185	133	160	102	111	62	185
							10–20 kg						
	Rate	0.00	0.00	0.00	0.00	0.00	0.00	5.67	0.00	0.00	36.21	0.00	0.00
	Frequency	0	0	0	0	0	0	8	0	0	63	0	0
							>20 kg						
	Rate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Frequency	0	0	0	0	0	0	0	0	0	0	0	0

Risk 1 Risk 2 Risk 3 Risk 4

3.4. Results for the Entire melon Cultivation Process

The results for all the tasks performed for melon cultivation are shown.

Figure 3 shows the levels of risk that arise. A total of 1934 postures were observed during the entire cultivation process. Of these, 920 correspond to risk category 2. This frequency represents approximately half of the postures adopted here, at 47.57%.

Another large part of these observations shows that 37.64% fall into risk category 1, with a total of 728 postures.

Risk categories 3 and 4 represent a lower percentage compared to the other two, being a 14.32% for risk category 3 and a 0.47% for risk category 4, respectively.

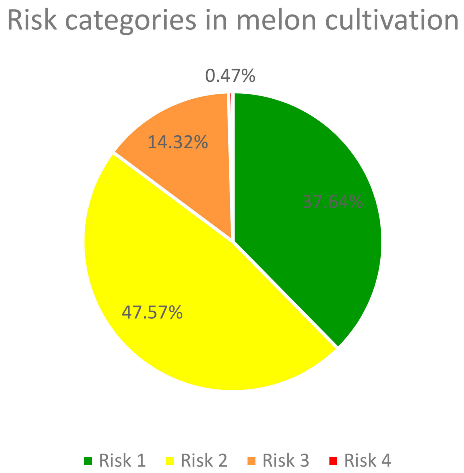


Figure 3. Risk categories in melon cultivation.

In analysing the repetition frequency by body area (Table 6), the bent back is the posture that is most frequently adopted, with 848 repetitions (43.85%).

For the arms, holding both arms below shoulder level stands out from the others with 1889 repetitions (97.37%).

For leg postures, the most common one is standing on two straight legs, with 612 occasions (31.64%).

Finally, regarding the load, most of the work is performed with less than 10 kg.

Table 6. Frequency and rate of postures per body area.

Body Parts	Posture	Frequency	Rate
Back	Straight	672	34.75
	Bent	848	43.85
	Twisted	202	10.44
	Bent and twisted	212	10.96
Arms	Both arms below shoulder level	1889	97.67
	One arm at or above shoulder level	42	2.17
	Both arms at or above shoulder level	3	0.16
Legs	Sitting	248	12.82
	Standing on two straight legs	612	31.64
	Standing on one straight leg	359	18.56
	Standing or squatting on two bent legs	170	8.79
	Standing or squatting on one bent leg	69	3.57
	Kneeling or squatting	9	0.47
	Walking	467	24.15
Load	<10 kg	1863	96.33
	10–20 kg	71	3.67
	>20 kg	0	0.00

3.5. Multiple Correspondence Analysis

The result of the multiple correspondence analysis performed here provides a model that allows us to identify the correlations of variable categories as well as of the variables themselves. The model obtained after this analysis has two significant dimensions. The first one explains 47.097% of the variance with a Cronbach's α coefficient of 0.840 and an eigenvalue of 3.768, and the second dimension explains 41.784% of the variance with a Cronbach's α coefficient of 0.801 and an eigenvalue of 3.343, so that for the factorial model, the mean variance is 44.441%, the mean Cronbach's α coefficient 0.821, and the mean eigenvalue 3.555, and thus the model reliability is good.

Table 7 shows the variable discrimination measures for each of the two model dimensions and the mean; as shown, the leading variable in the ranking of variance explanatory variables for the homogeniser model is PC (0.921), because it has the highest discrimination, followed in descending order of explanation by the variables T (0.616), L (0.577), R (0.507), RC (0.404), B (0.394), and A (0.095), and the least explanatory variable is Q (0.041). Regarding the discrimination in both dimensions, the first dimension shows very large discriminations with the variables PC (0.931), R (0.723), and L (0.685), and the second dimension shows large discriminations with the variables PC (0.912) and T (0.726).

Table 7. Discrimination measures of the variables.

Variable	Dimension 1	Dimension 2	Model mean
Subtask	0.506	0.726	0.616
Posture code	0.931	0.912	0.921
Back	0.499	0.289	0.394
Arms	0.033	0.158	0.950
Legs	0.685	0.468	0.577
Load	0.002	0.081	0.041
Risk	0.723	0.291	0.507
Risk combination	0.390	0.418	0.404
Total	**3.768**	**3.343**	**3.555**
% variance	**47.097**	**41.784**	**44.441**

Each discrimination measure coincides with the coordinate variance on every dimension of the modalities of each variable, so that the variables whose modalities have coordinates on a dimension different from one another will be presented on said dimension's high discrimination measures. In addition, similar variable discrimination measures in the two dimensions reflect the difficulties of allocating one variable to a given dimension (as with the variable PC, which has virtually the same discrimination in dimensions 1 in 2). Ideally, a variable should have a high value in only one dimension and a low value in another, as occurs only with a variable R that is more correlated with Dimension 1, and therefore, this dimension discriminates among the categories of this variable better. Variable T is more highly correlated with Dimension 2, because it is the only one that has greater discrimination in Dimension 2 than in 1 with a certain level of significance, which is why this dimension discriminates among the categories of this variable better.

The multiple correspondence analysis model used here allows for the identification of the categories of each variable with a better discrimination of the objects (sample unit) and, therefore, the most important consideration for this objective are the quantifications of the variables that are represented in a factorial plane in which the axes are the 2 model dimensions (Figure 4). The quantifications of the categories are the average of the scores for same-category objects. In addition, to know which category of each variable shows the best contribution to each dimension, the model calculates the contributions of the dimension to the inertia of the point for each of the variables, which are shown below in terms of the most significant variables of the model as expressed in percentages.

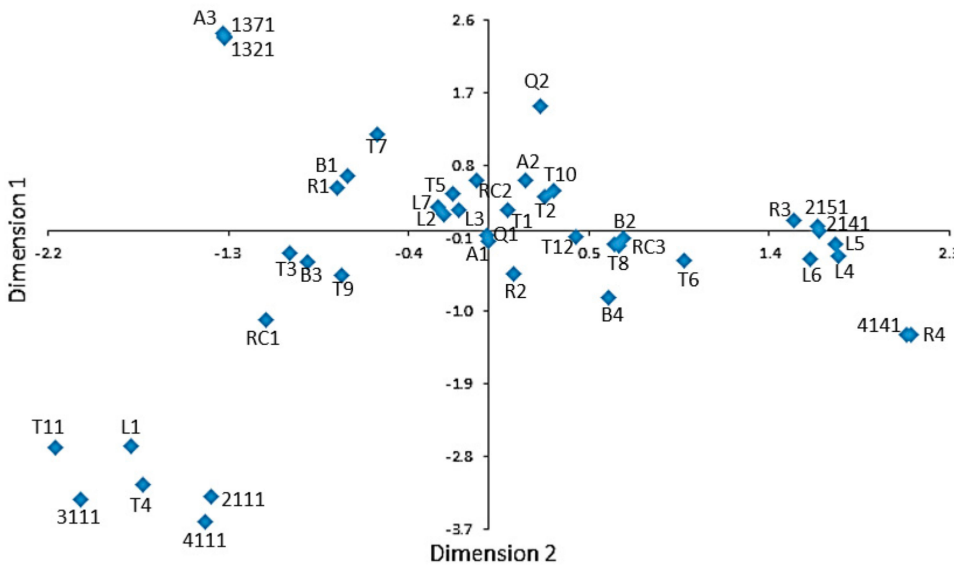


Figure 4. Factorial Plane of the Multiple Correspondence Analysis Model (the nomenclature of the categories is shown in Table A2, see Appendix A).

For variable PC, the category that best explains the positive value of dimension 1 is code 2141 (14.1%), followed by 2151 (11.5%) and 4141 (11.0%), and for the negative value, it is code 3111 (6.9%). For dimension 2, it is code 1371 (4.9%) followed by 1321 (4.7%) for positive values, and code 3111 (18.4%) followed by 4111 (10.8%) and 2111 (9.0%) for the negative values, because this dimension presents the contributions of the dimension to the inertia of the largest point. For variable T, the category that best explains the positive values of dimension 1 is T6 (10.4%) followed by T8 (5.9%), and for negative values, it is T11 (7.8%) followed by T9 (4.9%). For the positive values of dimension 2, it is T7 (21.5%), and for the negative values, it is T4 (33.4%) followed by T11 (12.1%). Regarding variable L, the category that best explains the positive values of dimension 1 are L4 (30.2%) and L5 (15.5%), and for negative values, it is L1 (19.5%); for positive values of dimension 2, it is L7 (3.1%), and for negative values, it is L1 (43%). For variable R, the categories that best explain the positive values of dimension 1 are R3 (37.4%) and R4 (15.1%), while for negative values, it is R1 (44.0%). For positive values of dimension 2, it is R1 (22.1%), and for negative values, it is R2 (18.1%).

For variable RC, the category that best explains the positive values of dimension 1 is RC3 (24.5%), with RC1 (28.8%) for negative values; and for positive values of dimension 2, it is RC2 (31.2%), and for negative values, it is RC1 (28.5%). For variable B, the category that best explains the positive values of dimension 1 is B2 (27.0%), while for the negative values, they are B1 (24.4%) and B3 (12.3%). For positive values of dimension 2, it is B1 (22.9%), and it is B4 for negative values (13.4%). For variable A, the category that best explains the positive values of dimension 1 is A2 (0.4%), and for negative values, it is A3 (2.9%). For positive values of dimension 2, it is A3 (9.7%), and it is A1 for negative values (11.1%). Variable Q is the least explanatory of the model, and thus, the category that best explains the positive values of dimension 1 is Q2 (0.2%), and for negative values, it is Q1 (0.2%). For positive values of dimension 2, it is Q2 (8.1%), and for negative values, it is Q1 (8.1%).

4. Discussion

This section will discuss the results obtained using the OWAS method, the descriptive analysis of the variables, and the multiple correspondence analysis.

4.1. Descriptive Analysis of the Variables Assessed Using the OWAS Method

In the results obtained here, the four risk categories of the OWAS method are identified. The first includes normal postures, which do not affect the musculoskeletal system. The fourth, by contrast, assumes a serious risk to the musculoskeletal system [68].

For the 12 tasks identified during melon cultivation, risk category 2 appears to a greater or lesser extent in all the tasks performed here. The postures in this level can cause negative effects on the musculoskeletal system. Corrective actions should be taken in the near future. The melon cultivation task that includes a greater rate of postures with this level of risk is making holes, with 84.86% of them (Table 4).

Category 3 appears in 8 of the 12 tasks. Plant removal has the highest rate, at 68.39% (Table 4). Therefore, the postures adopted in this task are quite detrimental to the musculoskeletal system, requiring corrective actions as soon as possible.

Category 4 includes postures that cause serious damage to the musculoskeletal system. During melon cultivation, this level of risk is rare. There are only three tasks that present it, with melon harvesting (2) reaching the highest rate, at 2.50% (Table 4, see Section 4.2). This result coincides with a study conducted on oriental melon-growing farmers, in which the harvesting task was also one that presented a high level of risk [74,75].

In other fruit crops, such as apples, the harvesting task was classified into categories 1 and 2, presenting lower risk than in the case of melons [81].

However, the risk associated with the task of melon picking is the one that follows Harvesting, representing a rate of 2.16% in category 4 (see Section 4.2).

In other types of crops, such as berries, sugarcane, and eucalyptus, negative results were also obtained for picking tasks, according to the OWAS method. In all three cases, this task involved harmful postures that contributed to the onset of musculoskeletal disorders [47,77,78].

Even so, in the 12 tasks, some postures are considered normal; that is, they do not cause damage. Manual spraying (Table 4) is performed in such a way that 98.92% of the postures are considered normal. Therefore, for the method used for spraying, corrective measures should only be taken in the remaining rate belonging to level 2. In melon harvesting (1) and transporting containers (Table 4), more than half of the postures do not present a risk either.

For the melon harvesting task, two working methods are identified. The results obtained for both show that the second method is more damaging to the farm worker (see Section 4.2). In this regard, a greater number of postures cause risks to the musculoskeletal system. In the first case (Table 4), more than half of the postures (59.57%) are normal, level 1, and the remaining percentage are levels 2 and 3. By contrast, in the second case (Table 4), non-harmful postures make up a lower percentage (41.88%). The remaining percentage belong to categories 2, 3 and 4, with categories 2 and 3 having the highest rates of damaging postures compared to the other type of harvesting. Engaging in detrimental postures during the harvesting task has also been shown in other crops. In the case of harvesting oil palm fruit, OWAS was used with the help of a questionnaire. In this case, the high rate of uncomfortable postures adopted along with other risk factors led to the development of musculoskeletal disorders [124].

Of all the combinations of postures adopted, the most uncomfortable or harmful ones that give rise to a more serious risk to the musculoskeletal system are 4141 and 4151. These postures should be corrected immediately, even though they very rarely occur. Risk category 3 includes combinations of 4231, 2141, 2151, 3141, 2261, 2142, and 2172 (see Section 4.2). These postures require corrective measures as soon as possible.

It is also important to highlight that the areas of the body most affected during these tasks are the back and legs, because in each of these cases, postures are adopted that present or may present some risk (see Section 4.2). This finding coincides, in part, with the results obtained in previous studies, in which musculoskeletal disorders were caused in oriental melon-growing farmers primarily in the lower back, knees, and shoulders [74,75].

The most important postures that have been identified for the back are those that belong to risk category 3. These are the postures of bent back, twisted, or bent and twisted, presenting each of these postures during two different tasks. The tasks in which the twisted back involves risk are tractor spraying and greenhouse plant removal. For the bent back, they are planting and plant removal. Finally, for bent and twisted back, making holes and greenhouse sweeping are the most common tasks (Table 5, see Section 4.2). The highest rate of repetition is found for the bent back posture in the planting task, at 87.03%. There is also a risk category 2 in some tasks for bent back postures, and only in the task of melon harvesting (2) for bent and twisted back postures (Table 5).

According to Villar-Fernández, musculoskeletal disorders usually appear in different areas, with one of the primary areas being the back, which occurs in this case, because back postures are those with the highest risk [22].

In the leg area, the farm worker also adopts postures that can lead to the onset of musculoskeletal disorders. Risk category 3 appears only in the task of plant removal (Table 5) for the posture of standing or squatting on two bent legs (32.18%). There are also risk 2 levels in other tasks for this same posture and for standing or squatting on one straight or bent leg, when the farm worker is walking, and when he is sitting (see Section 4.2).

As noted, the areas where there is a greater risk are the back and the legs. According to Almodóvar-Molina et al., in agriculture, livestock, forestry, and fishing, 50.9% of farm workers suffer from musculoskeletal disorders in the lower back area, 20.3% in the upper area, and 13.2% in the legs [40].

Finally, it should be noted that during the analysis of the entire melon cultivation process, only 37.64% of the postures are not harmful, with the remaining percentage being distributed into risk categories 2, 3 and 4. Most of these postures correspond to level 2 at 47.57%. The lowest value, at 0.47%, corresponds to category 4 (Figure 3). Therefore, 62.36% of postures will require corrective actions.

4.2. Multiple Correspondence Analysis

From the interpretation of the factorial plane of Figure 4 and from the contributions of the dimension to the inertia of the point for each variable, the correspondence between the categories of the variables can be observed. Thus, the categories of the variables that are associated with more positive values of dimension 1 are as follows: For the agricultural subtask variable, melon picking (T6) and melon harvesting (2) (T8); for the variable Back, Bent back posture (B2); for the variable Arms, One arm at or above shoulder level (A2); for the variable Legs, Bent legs (L4) and Standing or squatting on one bent leg (L5); for the variable Load, between 10 and 20 kg (Q2), although there is no clear trend; for the variable Risk, Risk 3 (R3) and Risk 4 (R4); and finally, for the variable Risk combination, when the four risks are combined simultaneously (RC3). The findings associated with more negative values of dimension 1 are as follows: For the variable agricultural subtask, Greenhouse plant removal (T11), Tractor spraying (T4), and Manual spraying (T3); for the variable Back, Straight back posture (B1), and Twisted back posture (B3); for the variable Arms, Both arms at or above shoulder level (A3); for the variable Legs, Sitting (L1); for the variable Load, less than 10 kg (Q1), although there is no clear trend; for the variable Risk, Risk 1 (R1); and finally, for the variable Risk combination, when risks 1 and 2 are simultaneously combined (RC1). Notably, the categories of the variables that are associated with more positive values of dimension 2 are as follows: For the variable of agricultural subtask, melon harvesting (1) (T7); for the variable Back, Straight back posture (B1); for the variable Arms, Both arms at or above shoulder level (A3); for the variable Legs, Walking (L7); for the variable Load, between 10 and 20 kg (Q2), although there is no clear trend; for the variable Risk, Risk 1 (R1); and finally, for the variable Risk combination, when the three risks 1, 2 and 3 are combined simultaneously (RC2). The postures associated with the more negative values of dimension 2 are as follows: For the variable agricultural subtask, Tractor spraying (T4) and Greenhouse plant removal (T11); for the variable Back, Bent and twisted back posture (B4); for the variable Arms, Both arms below shoulder level (A1); for the variable Legs, Sitting (L1); for the variable Load, less than 10 kg (Q1), although without a clear trend;

for the variable Risk, Risk 2 (R2); and finally, for the variable Risk combination, when the two risks 1 and 2 are simultaneously combined (RC1).

Therefore, it is observed that Dimension 1 discriminates among the types of risk and its combinations well, and thus the more positive the value of Dimension 1, the more serious the risk and the greater the number of risk combinations, and vice versa. The more negative the value of Dimension 1, the lower the risk and its combinations. Higher risk categories such as 3 and 4 as well as the combination of more unfavorable risks (1 + 2 + 3 + 4) are correlated with the tasks of melon picking and melon harvesting (2) as well as with a back bent posture with one arm at or above shoulder level, and the postures of standing or squatting on two bent legs, and standing or squatting on one bent leg. The postures associated with more positive values of Dimension 1, and therefore with greater risk, are 2141 (Bent back, both arms below shoulder level, standing or squatting on two bent legs, and load less than 10 kg), 2151 (Bent back, one arm below shoulder level, standing or squatting on one bent leg, and load less than 10 kg), and 4141 (Bent and twisted back, arms below shoulder level, standing or squatting on two bent legs, and load less than 10 kg). However, negative values of Dimension 1 are correlated with risk 1 and a combination of less unfavorable risks (1 + 2), including a straight back or twisted posture, both arms at or above shoulder level, sitting, and performing the tractor spraying tasks, transporting containers, and greenhouse plant removal. Likewise, at negative values of Dimension 1, and therefore with less risk, the 3111 posture is correlated (Twisted back, arms below shoulder level, sitting, and load less than 10 kg).

Dimension 2 is good at correlating the subtask performed with the posture adopted and, to a lesser extent, with the workload. Thus, positive values of the same variable are associated with handling loads between 10 and 20 kg (for very positive values; for less positive values, the trend is not clearly associated), and tasks T1 (Making holes), T2 (Planting), T5 (Leaf removal), T7 (Melon harvesting (1), and T10 (Plant removal), and with postures 1371 (Straight back, both arms at or above shoulder level, walking, and load less than 10 kg) and 1321 (Straight back, both arms at or above shoulder level, standing on two straight legs, and load less than 10 kg). Negative values of dimension 2 are not clearly associated with handling loads, while they are correlated with tasks T3 (Manual spraying), T4 (Tractor spraying), T6 (Melon picking), T9 (Transporting containers), T11 (Greenhouse plant removal), and T12 (Greenhouse sweeping), and with postures 2111 (Bent back, arms below shoulder level, sitting, and load less than 10 kg), 3111 (Twisted back, arms below shoulder level, sitting, and load less than 10 kg), 4111 (Bent and twisted back, arms below shoulder level, sitting, and load less than 10 kg), and 4141 (Bent and twisted back, arms below shoulder level, standing or squatting on two bent legs, and load less than 10 kg). Finally, it should be noted that Figure 4 clearly shows how working postures 1371 and 1321 are associated with both arms at or above shoulder level with risk 1, and postures 2151 and 2141 are associated with risk 3, and posture 4141 with risk 4.

4.3. Strengths and Limitations

After discussing the more relevant results, the strengths and limitations of this study are exposed.

- Strengths

The main strength of this study is the identification of forced postures that may cause musculoskeletal disorders, as well as the correlation of these postures with the cultivation subtask, back, arms and legs injuries, managed load, risk produced and risk combination, carrying out the assessment in a way that does not disturb worker's common tasks, as it is only based on observation. It is the first semi-direct method applied on a cultivation carried out in a greenhouse.

- Limitations

During the observation period, it is not possible to make a video recording of an entire task continuously. While the workers are performing the tasks, there are interruptions such as worker breaks and stops to drink water. For this reason, some observations are not consecutive.

Breaks are not considered as part of the worker's tasks, as during these periods workers go out of their working place. Because the objective is the assessment of the adopted postures when performing cultivation tasks, observations were not carried out during these breaks.

Melon cultivation tasks are short, and farm workers change posture continuously. They spend just a few seconds in changing from one posture to the other (depending on the task), but frequently the more tired they are, the longer these seconds last. This means that it is not possible to use constant intervals of time to get the observations that are going to be encoded. Therefore, short time intervals were used for the observation, with the intervals lasting between 5 and 10 s. The OWAS method suggests a higher interval of time, but this has been shortened to increase the assessment accuracy.

Finally, the sample of workers used in this research is made of three people and no more. This is justified because melon cultivation tasks are very similar in SE Spain. Melon cultivation is made the same way in every greenhouse, this is, tasks are constant and carried out the same way, and therefore, repetitive for the workers. What was fundamental according to this assessment research objective was to get a big number of observations for every task posture, and this was achieved.

4.4. Recommendations

Lastly, a number of recommendations are provided in order to avoid the adoption of forced postures by farmers, which may cause musculoskeletal disorders [125].

According to the observation of the adopted postures in every identified subtask, and the results obtained, the recommendations [126–128] that could be applied in the greenhouse melon cultivation are:

(a) For "Making holes", the use of a tool with an extendible handle, so that it can be adjusted to the height of each farmer, allowing the workers to keep their backs as straight as possible.
(b) Some tasks such as planting or picking melons are done at ground level, this implies that most of the postures are made with the back bent and with a bad position for the legs. One recommendation would be to use carts that allow people to move around, and performing some tasks in a sitting position to avoid the adoption of forced postures. In order for the cars to circulate, there must be an adequate space between the lines.
(c) In the task of "Melon harvesting", using carts during the whole task. This way, it is possible to avoid loading the boxes manually up to the containers where the melons are finally deposited.
(d) Lifting the boxes up properly as they are located at a low level or on the ground. To do this, keep your back straight, bend your legs, bend your hips and stick the load to your body.
(e) To cut the melons use knives with handles that are not as short as the ones usually used and that can cut optimally so that efforts are reduced.
(f) In the tasks performed with a tractor, avoid the back posture rotated as far as possible, use a seat that allows an adequate position.
(g) In some subtasks such as "Melon harvesting", there are several different actions and therefore several postures adopted, it would be advisable to alternate these tasks.

Other more general recommendations [127–130] that can be applied to all subtasks carried out would be:

(a) Avoiding performing the whole work in an individual way and promoting to make shifts between at least two people, carrying the task out alternatively.
(b) The farmer should change his or her posture after a short period of time, approximately every 2 minutes.
(c) Placing in areas nearby the working place all the elements requested to carry out the task, in order to avoid making sudden and wide movements.
(d) Avoiding static postures during long intervals of time, alternating the type of postures
(e) Ergonomic training courses for farmers.

5. Conclusions

The results obtained here indicate that during melon cultivation, farm workers adopt uncomfortable postures that are harmful to their health and can damage their musculoskeletal systems. Therefore, corrective actions should be taken immediately, as soon as possible, or in the near future, depending on the severity.

It can be concluded that more than half of the postures adopted by farmers present some type of risk (excessive, high or slight) to the musculoskeletal system. The rest of the postures are classified as normal, which indicates that they are not harmful to workers and that they do not need correction.

0.47% of the postures are classified as the most harmful, as seen in the results. These present an excessive risk. For this reason, it is concluded that they should be corrected immediately. 14.32% are high risk. These must also be modified, but in this case, they can count on short period of time to arrive to a solution. 47.57% do not have as harmful effects on the musculoskeletal system as the previous ones, but they are also harmful. These present a slight risk, which indicates that they can be corrected in a longer period than in the other cases. The remaining percentage of postures (37.64%) can continue to be carried out as usual due to the fact that these are normal postures.

Another conclusion reached with the study is that the correction of postures in the 12 subtasks of the cultivation is necessary due to there being several postures in every subtask that imply any of the three risks. The development of these tasks should be reviewed, adopting new postures, qualified as normal, which cannot cause musculoskeletal disorders. Of these 12 subtasks, the "Manual spraying" is developed almost correctly, and requires the correction of only 1.08% of the postures involving a slight risk.

Finally, with respect to each part of the body, the farmers do not see their arms affected in any of the postures they adopt, so they can continue to perform the same arm postures in their tasks.

For back postures, a straight posture is not a problem, since it does not involve any risk. The rest of the postures of the back, suppose a high or slight risk in several of the 12 subtasks. Therefore, they should be corrected in a short time when the risk is high and later if it is slight.

For the legs, the most harmful posture they perform is when they bend their knees, specifically in the task of "Plant removal" with a high risk, which will have to be modified in a short period of time.

None of the postures of the different parts of the body present an excessive risk for any of the 12 subtasks involved in the melon cultivation.

For all the above, it is necessary to develop preventive measures and recommendations that allow these tasks to be performed safely, preventing or diminishing these risks. Some preventive actions could be based on technological developments to perform tasks in a less repetitive and more automated fashion.

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Appendix A

Table A1. OWAS codes.

			CODES OF POSTURE													
			1. BACK													
			1			**2**			**3**			**4**				
			Straight			**Bent**			**Twisted**			**Bent and Twisted**				
3.LEGS	**1**	Sitting	1111	1211	1311	2111	2211	2311	3111	3211	3311	4111	4211	4311	<10 kg	**1**
			1112	1212	1312	2112	2212	2312	3112	3212	3312	4112	4212	4312	10–20 kg	**2**
			1113	1213	1313	2113	2213	2313	3113	3213	3313	4113	4213	4313	>20 kg	**3**
	2	Standing on two straight legs	1121	1221	1321	2121	2221	2321	3121	3221	3321	4121	4221	4321	<10 kg	**1**
			1122	1222	1322	2122	2222	2322	3122	3222	3322	4122	4222	4322	10–20 kg	**2**
			1123	1223	1323	2123	2223	2323	3123	3223	3323	4123	4223	4323	>20 kg	**3**
	3	Standing on one straight leg	1131	1231	1331	2131	2231	2331	3131	3231	3331	4131	4231	4331	<10 kg	**1**
			1132	1232	1332	2132	2232	2332	3132	3232	3332	4132	4232	4332	10–20 kg	**2**
			1133	1233	1333	2133	2233	2333	3133	3233	3333	4133	4233	4333	>20 kg	**3**
	4	Standing or squatting on two bent legs	1141	1241	1341	2141	2241	2341	3141	3241	3341	4141	4241	4341	<10 kg	**1**
			1142	1242	1342	2142	2242	2342	3142	3242	3342	4142	4242	4342	10–20 kg	**2**
			1143	1243	1343	2143	2243	2343	3143	3243	3343	4143	4243	4343	>20 kg	**3**
	5	Standing or squatting on one bent leg	1151	1251	1351	2151	2251	2351	3151	3251	3351	4151	4251	4351	<10 kg	**1**
			1152	1252	1352	2152	2252	2352	3152	3252	3352	4152	4252	4352	10–20 kg	**2**
			1153	1253	1353	2153	2253	2353	3153	3253	3353	4153	4253	4353	>20 kg	**3**
	6	Kneeling or squatting	1161	1261	1361	2161	2261	2361	3161	3261	3361	4161	4261	4361	<10 kg	**1**
			1162	1262	1362	2162	2262	2362	3162	3262	3362	4162	4262	4362	10–20 kg	**2**
			1163	1263	1363	2163	2263	2363	3163	3263	3363	4163	4263	4363	>20 kg	**3**
	7	Walking	1171	1271	1371	2171	2271	2371	3171	3271	3371	4171	4271	4371	<10 kg	**1**
			1172	1272	1372	2172	2272	2372	3172	3272	3372	4172	4272	4372	10–20 kg	**2**
			1173	1273	1373	2173	2273	2373	3173	3273	3373	4173	4273	4373	>20 kg	**3**
			Both arms below shoulde level	One arm at or above shoulde level	Both arms at or above shoulde level	Both arms below shoulde level	One arm at or above shoulde level	Both arms at or above shoulde level	Both arms below shoulde level	One arm at or above shoulde level	Both arms at or above shoulde level	Both arms below shoulde level	One arm at or above shoulde level	Both arms at or above shoulder level		**4.LOAD**
			1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**		
			2. ARMS													

Table A2. Variable category coding for Multiple Correspondence Analysis.

Variables	Categories	Codes
Cultivation subtask (T)	Making holes	T1
	Planting	T2
	Manual spraying	T3
	Tractor spraying	T4
	Leaf removal	T5
	Melon picking	T6
	Melon harvesting (1)	T7
	Melon harvesting (2)	T8
	Transporting containers	T9
	Plant removal	T10
	Greenhouse plant removal	T11
	Greenhouse sweeping	T12
Posture code (PC)	See Table A1, Appendix A	
Back (B)	Straight	B1
	Bent	B2
	Twisted	B3
	Bent and twisted	B4
Arms (A)	Both arms below shoulder level	A1
	One arm at or above shoulder level	A2
	Both arms at or above shoulder level	A3
Legs (L)	Sitting	L1
	Standing on two straight legs	L2
	Standing on one straight leg	L3
	Standing or squatting on two bent legs	L4
	Standing or squatting on one bent leg	L5
	Kneeling or squatting	L6
	Walking	L7
Load (Q)	<10 kg	Q1
	10–20 kg	Q2
	>20 kg	Q3
Risk (R)	Risk1	R1
	Risk2	R2
	Risk3	R3
	Risk4	R4
Risk combination (RC)	1 + 2	RC1
	1 + 2 + 3	RC2
	1 + 2 + 3 + 4	RC3

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