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Forced Postures in Courgette Greenhouse Workers

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Received: 13 April 2019; Accepted: 17 May 2019; Published: 21 May 2019

Abstract: Occupational health and safety allows the prevention of occupational diseases and accidents. Agriculture is one of the sectors in which it is important to prevent the musculoskeletal disorders that workers usually develop. The objective of this study is the evaluation of postures adopted by courgette farmers in greenhouses of the Almeria-type. OWAS (Ovako Working Posture Assessment System), an ergonomic evaluation method, is used and applied after making observations to the postures adopted by the workers who were previously video recorded. The results concluded that the four risk levels established by OWAS appeared, with 37.14% being the highest rate and belonging to risk level 2, 33.33% to risk level 1, 28.57% to risk level 3, and 0.95% to risk level 4. Therefore, depending on the severity of the postures adopted in each task, the need for changes in a short, medium, or long period of time was concluded.

Keywords: musculoskeletal disorders; OWAS; agriculture; biomechanics

1. Introduction

1.1. Occupational Health and Safety

The concept of occupational health and safety is defined as the "conditions and factors that affect, or could affect, the health and safety of employees or other workers (including temporary workers and contractor personnel), visitors, or any other person in the work area" [1].

Companies implement health and safety management systems for their workers [2]. The implementation of these management systems allows the prevention of occupational diseases and accidents. In addition, it contributes to achieve numerous improvements in companies related to aspects such as competitiveness, the involvement of workers in the company thanks to their motivation, and cost reduction [3].

Musculoskeletal disorders are one of the most common occupational diseases. The prevention of these disorders positively affects companies and the health of workers [4].

1.2. Musculoesqueletal Disorders

Work-related musculoskeletal disorders (MSD) are a serious problem frequently developed in workers of many fields [5].

This type of disorder can appear in different body parts, the most common being the back, shoulders, neck, and upper extremities [4].

Workers are exposed to different risks in their jobs that can contribute to develop these disorders. Some of these risks are, for example, the adoption of forced postures, the performance of repetitive tasks, the handling of loads, the exposure to vibrations, the extreme temperatures in their workplace, etc. [4].

Finally, this type of disorders has numerous consequences [6]:

- For the workers who suffer them, encompassing not only physical, but also mental, aspects, due to not feeling able to continue doing a job.
- For the economy of workers, since they sometimes cannot continue in their jobs due to the type of developed disorders.
- For the economy of companies and countries. In companies, musculoskeletal disorders cause productivity to decrease and sick leave to rise.

1.3. Musculoskeletal Disorders in Southeastern Spain Agriculture

In the agricultural sector, there are a small number of studies dedicated to the investigation of occupational diseases that are common among workers, including musculoskeletal disorders [7]. However, in this area there are numerous risks that farmers are facing during the performance of their tasks and that can contribute to the appearance of these type of disorders [8].

The province of Almeria is characterized by a large area of greenhouses, where different crops are grown, employing approximately 55,000 workers. Several studies conclude that there are numerous musculoskeletal disorder symptoms among workers in these greenhouses [9].

Two research studies have already been carried out on this type of occupational diseases that occur in greenhouse farmers in Almeria. In one study, the Standardized Nordic Questionnaire [10] was used to analyze musculoskeletal disorders in farmers and some variables related to the worker (sex, height, weight, etc.) and to the cultivation (area, type, etc.) were considered. The results concluded a high rate of MSD [9]. Another study was carried out to analyze the MSD in melon cultivation workers. In this, an ergonomic evaluation method called OWAS (Ovako Working Posture Assessment System) [11] was used, which concluded the risks implied by the postures adopted in each task [12].

1.4. Evaluation Methods

There are several ergonomic assessment methods aiming the prevention of occupational musculoskeletal disorders. These methods can be classified intro three types [5]:

- Direct. Based on the use of sensors. An example of this type of method is the HADA Move-Human sensor system [13].
- Semi-quantitative. They use evaluation software and a previous observation of the workers performing tasks. Some examples of these methods are: RULA method [14], REBA (Rapid Entire Body Assessment) method [15], OWAS method [11], Snook and Ciriello tables [16], etc.
- Qualitative. Use of questionnaires. Examples of these methods are the Standardized Nordic Questionnaire [10], the Quick Exposure Check [17], etc.

1.5. Objective

The objective of this study is the evaluation of the adopted postures by farmers during the courgette cultivation in Almeria-type greenhouses.

2. Materials and Methods

2.1. Greenhouse

The greenhouse where the study was conducted is located in the province of Almeria and has the characteristics that are shown in the following table (Table 1).

Table 1. Greenhouse characteristics.

Greenhouse	
Type	Almeria-type
Area	8400 m^2
Cultivation	Courgette
Soil	Sandy soil
Irrigation	Drip irrigation
Drip irrigation frame	0.5 m × 1 m
Seedlings from seedbed	60 trays; 150 plants·$tray^{-1}$
Planting density	9000 plants' 8400 m^{-2} = 1 plant·m^{-2}
Transplant date	28 January 2017
Harvest date	31 May 2017
Number of harvesting	40

2.2. Material Used

The material used consists of a PD Pentaxdigital-DPV9000 video camera (Pentax, Tokyo, Japan), with a resolution of 12 megapixels and an 8× digital zoom.

On the other hand, to know the height and weight of the workers, we use:

- An Evel measuring tape (Buenos Aires, Argentina) with a length of 3 m and accuracy of ±0.1 mm.
- A Kern MFB 150K100 scale (Balingen, Germany) with a maximum weighing field of 150 kg and a reproducibility of 0.8 kg.

2.3. Workers

In this crop the work is developed by two workers, a woman of 44 years (height = 1.61 m, weight = 72 kg) and a man of 47 years (height = 1.65 m, weight = 75 kg). Therefore, the sample of workers that has been employed in this study is of two workers belonging to the same greenhouse. This is because the objective of the study was not to investigate the consequences of performing tasks on workers with different characteristics, such as age, sex, etc., but to evaluate the postures that are usually adopted for courgette cultivation.

The postures that are adopted in each one of the courgette cultivation tasks are always very similar in Southeastern Spain, since the tasks carried out are always the same. This study focuses on the evaluation of these positions, regardless of the worker who develops them.

2.4. Evaluation Method

In order to decide which method will be used, five observation methods that could be interesting for this study are described: CORLETT (Posture Targeting) [18], OWAS (Ovako Working Posture Assessment System) [11], REBA (Rapid Entire Body Assessment) [15], VIRA (This method is from National Board of Occupational Safety and Health, Sweden) [19] and ARBAN (Ergonomic Analysis) [20].

- CORLETT: this method evaluates the positions of ten body areas (head, trunk, lower and upper extremities) with respect to a reference position. The method is simple, precise, and reproducible. It is not appropriate for postures that are adopted during short time intervals and that are not repeated. It does not consider the load, the posture's duration, or the frequency with which they are adopted [18,21].
- OWAS: this method allows to evaluate 252 postures. These are the result of combining four positions for the back, three positions for the arms, seven positions for the legs, and three intervals corresponding to the load supported. It is a reliable and frequently used method. In addition, there is a lot of information related to OWAS. It does not evaluate the positions of the neck, wrists, and elbows and does not evaluate the right and left part of the body independently [11,21,22].

- REBA: It allows evaluate the trunk, neck, legs, arms, forearms and wrists. It also considers the load, the grip, and the type of physical activity. It is a simple method and it does not take long in its application. It does not consider the frequency or duration of postures. The right and left hand are analyzed independently [15,21].
- VIRA: This method evaluates the neck and arms. It is a simple method, appropriate for tasks that are repetitive, with a short time interval. It does not evaluate the trunk, hands, and leg postures. It cannot be used when handling important loads. It takes a long time to be applied [19,22].
- ARBAN: This method evaluates neck, trunk, arms, and legs using the Borg scale. It is focused on the evaluation of ergonomic stress. It is easy to understand the results obtained. It does not consider the load and one of its limitations is the time necessary to apply it [20–22].

The VIRA method was the first to be discarded because it only focuses on evaluating two parts of the body: the neck and arms. The second factor considered was the load. OWAS and REBA are the only methods that consider the load. An important difference between these methods is that OWAS is a method that allows a general evaluation of the postures, since these are selected in the observation according to a certain time interval [21,22]. On the contrary, REBA is not used for a general evaluation, but to evaluate the positions considered more harmful or frequent [21]. Therefore, in line with the study objective (the evaluation of the adopted positions), the most appropriate method is OWAS. The REBA method could be used in more specific studies in which it is not intended to evaluate all the postures.

2.5. Ovako Working Posture Assessment System Method

The OWAS method originated in Finland, specifically in the steel industry. Its usefulness is based on the evaluation of the postural load on workers during the performance of their tasks [11].

This method is able to detect a total of 252 different postures by combining the assessed position of each of the three parts of the body, with the weight of the load handled by the worker. The method identifies four positions for the back, three positions for the arms, seven positions for the legs, and three values for the weight of the handled load, thus achieving the 252 possible combinations as mentioned above [11].

To apply this method in the courgette cultivation, the following stages are settled [11]. First, the observation of the postures performed by workers during the different tasks is carried out. This can be done by recording videos. In this case study, intervals of 5, 10, and 15 s will be used in order to cover most of the postures they perform. For each of these postures, the position of the back, legs and arms and the weight of the load supported is identified, obtaining a four-digit code (Appendix A). The method calculates the risk category corresponding to each posture and to each part of the body (Table 2).

Table 2. OWAS method risk levels [12].

Risk Levels	Postures	Corrective Measures	Correction Period
Risk 1	Normal	No	-
Risk 2	With slight risk	Yes	Not immediate
Risk 3	With high risk	Yes	Short term
Risk 4	With excessive risk	Yes	Immediate

It is possible to use numerous software to apply the OWAS method. In this case the software used is Ergomet 3.0. (MAPFRE ergonomics institute, Madrid, Spain) [23].

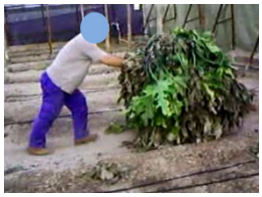
2.6. Identification of Agricultural Tasks during Courgette Cultivation in Almeria-Type Greenhouses

The observation allows to identify all the tasks in the courgette cultivation. A total of 10 tasks were observed. These were divided into 6 work phases. In the selection of the postures of each task, intervals of 5, 10, and 15 s were used. The observation was made in several working days, according to

the day in which the farmers developed each task. The duration of the courgette cultivation was four months (Table 1).

The agricultural tasks (not maintenance or auxiliary) identified in the experimental stage and practiced to the courgette cultivation are shown in Table 3:

Table 3. Identification of tasks in courgette cultivation.

Agricultural Tasks in Courgette Cultivation		
Work Phases	**Agricultural Tasks**	**Description**
Transplanting 	• Removing sand • Making holes • Transplanting • Covering holes	Using a weeding hoe, the sand is removed and a hole is made. In this hole, the root ball is inserted, covered and watered.
Aerating soil 	• Aerating soil	Using a rectangular scraper the layer of the sand surface is broken. After a few days, a fine crust is formed. In this way, the soil is oxygenated, avoiding weeds sprouting.
Spraying 	• Spraying	The worker uses a spraying backpack and walks between the cultivation lines to apply the product on the crop.
Harvesting 	• Harvesting	A manual harvest is carried out. Cutting tools are used to cut courgettes. For the collection, a cart with boxes is used. The boxes are piled up in the greenhouse corridor, being subsequently removed manually or with a tractor. They are also piled on pallets and forklifts are used.
Stringing 	• Stringing	A string is hooked to the grate and to the lower part of the plant.
Plant removal 	• Plant unstringing • Greenhouse plant removal	The previously placed strings are untied manually to unhook the plants, but they are left hooked so that they can be removed by pulling the strings. They are placed in the greenhouse, in the main corridor, then loaded onto a cart and removed from of the greenhouse.

2.7. Data Analysis

In this study two different software packages, SPSS v.23 (International Business Machines Corporation, Armonk, New York) and XLSTAT (2018, Addinsoft, Paris, France), are used in order to analyze the sample data. A descriptive analysis of the different variables corresponding to the OWAS method is carried out. In addition, a multiple correspondence analysis is also performed. The variables used are the following: Posture code (PC), Arms (A), Back (B), Legs (L), Load (Q), Task (T), Risk (R), and Risk combination (RC). This last variable refers to different groupings that may occurs between risk levels 1, 2, 3, and 4. The names that have been established for the different categories of these variables are summarized in Appendix B (Table A1). In the present study, it is interesting to complement the descriptive analysis of the variables with the nominal categorical data analysis technique of the multiple correspondence analysis because it allows the detection and representation of the underlying structures in the dataset. This study allows representing how the different categories of the studied variables are correlated, by means of a two-dimensional model or axes. This will allow to know as a whole, which cultivation task is associated with a certain position or positions of the back, arms, and legs, as well as with the load handled by the worker, and all this associated with the risk provided by the OWAS method and the possible combination of these risks.

3. Results

3.1. Results of the Whole Courgette Cultivation

In the study, 105 observations have been made. To each of these corresponds a posture and to each posture a photographic snapshot. Figure 1 differentiates the risk categories arising when assessing all the postures adopted by the workers during the entire courgette cultivation. The results show that 100% of the postures made during the cultivation are classified in the four risk categories. The highest rate, with a value of 37.14%, belongs to risk level 2. This is followed by 33.33% of the postures with risk level 1. Finally, 28.57% and 0.95% correspond to risk levels 3 and 4, respectively.

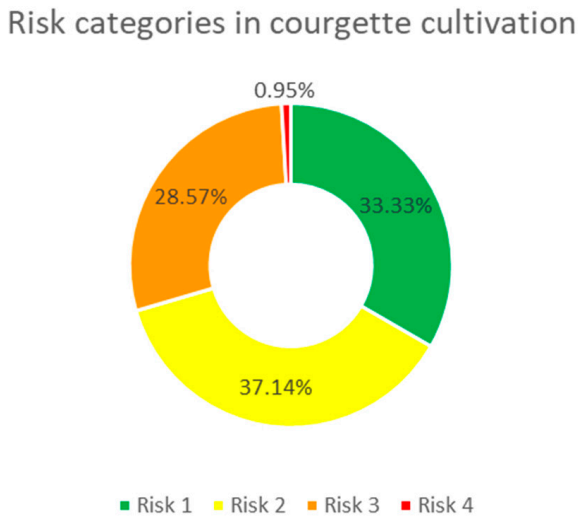


Figure 1. Risk categories in the postures adopted during courgette cultivation.

3.2. Results according to the Courgette Cultivation Tasks

Of the 105 observations taken, nine are from "Removing sand", 6 from "Making holes", 10 from "Transplanting", seven from "Covering holes", eight from "Aerating soil", six from "Spraying", 19 from "Harvesting", 15 from "Stringing", 10 from "Plant unstringing", and 15 from "Greenhouse plant removal".

Below, the results obtained for these observations are shown depending on agricultural tasks (Table 4). The table shows the codes for the postures adopted by the workers, the repetition rate of these, and risk level to which they belong represented in colors. The meaning of posture codes can be found in Appendix A.

Table 4. Posture codes, repetition rates and risk levels according to agriculture tasks.

Work Phases	Agricultural Tasks	Posture Codes	Repetition Rates (%)	Risk Levels
Transplanting	Removing sand	2121	55.56	
		2171	33.33	
		2141	11.11	
	Making holes	1171	33.33	
		2121	33.33	
		2221	33.33	
	Transplanting	2171	40.00	
		2131	20.00	
		2151	20.00	
		2141	10.00	
		2121	10.00	
	Covering holes	2171	42.86	
		2341	28.57	
		2241	14.29	
		2141	14.29	
Aerating soil	Aerating soil	3131	12.50	
		2131	25.00	
		2121	25.00	
		2171	37.50	
Spraying	Spraying	1172	100.00	
Harvesting	Harvesting	4141	5.26	
		2141	5.26	
		2131	5.26	
		2122	5.26	
		2341	5.26	
		1171	10.53	
		2351	10.53	
		2121	10.53	
		1122	10.53	
		2151	15.79	
		2171	15.79	
Stringing	Stringing	1271	13.33	
		1321	40.00	
		2341	46.67	
Plant removal	Plant unstringing	1172	30.00	
		1231	30.00	
		1122	20.00	
		1221	10.00	
		1131	10.00	
	Greenhouse plant removal	2141	26.67	
		2173	20.00	
		1321	20.00	
		2131	13.33	
		1152	6.67	
		2233	6.67	
		1123	6.67	

■ Risk 1 ■ Risk 2 ■ Risk 3 ■ Risk 4

As shown (Table 4), the highest risk level (level 4) is identified only in a position of all those evaluated. Therefore, the most damaging posture that the worker performs is with the bent and twisted back, arms below shoulder level, standing or squatting two bent legs, and load less than 10 kg (4141), with a repetition rate of 5.26%. This posture is adopted in the "Harvesting" task.

Other harmful postures identified in this cultivation belong to risk level 3. It consists of 14 postures that appear in 6 cultivation tasks. Some of those that present a higher repetition rate in the tasks are:

- The bent back, arms at or above shoulder level, standing or squatting two bent legs, and load less than 10 kg (2341), with a rate of 28.57%, in the "Covering holes" task.
- The bent back, arms at or above shoulder level, standing or squatting two bent legs, and load less than 10 kg (2341), with a rate of 46.67%, in the "Stringing" task.
- The bent back, arms below shoulder level, standing or squatting two bent legs, and load less than 10 kg (2141), with a rate of 26.67%, in the "Greenhouse plant removal" task.

The positions belonging to risk level 2 are not as damaging as the previous ones. The research shows that the predominant risk is risk level 2. For example, this risk appears in the posture with the bent back, arms below shoulder level, standing on two straight legs and load less than 10 kg (2121), with rate of 55.56%, in the "Removing sand" task.

Finally, the postures that correspond to a risk category 1 are normal positions, they are not harmful to the worker.

On the other hand, Table 5 shows the total rates and the relative frequencies of each risk according to the task.

Table 5. Risks in each task.

	Risk 1		Risk 2		Risk 3		Risk 4	
	Frequency	**Rate**	**Frequency**	**Rate**	**Frequency**	**Rate**	**Frequency**	**Rate**
Removing sand	0	0	8	88.89	1	11.11	0	0
Making holes	2	33.33	4	66.66	0	0	0	0
Transplanting	0	0	7	70	3	30	0	0
Covering holes	0	0	3	42.86	4	57.14	0	0
Aerating soil	1	12.50	7	87.50	0	0	0	0
Spraying	6	100	0	0	0	0	0	0
Harvesting	4	21.05	7	36.84	7	36.84	1	5.26
Stringing	8	53.30	0	0	7	46.67	0	0
Plant unstringing	10	100	0	0	0	0	0	0
Greenhouse plant removal	4	26.67	3	20	8	53.33	0	0

Risk level 1 is presented in seven of the 10 tasks, identifying the highest rates in the tasks of "Spraying" and "Plant unstringing" with 100% in both. Risk category 2, also differ in seven of the 10 tasks. For this, the highest rates of postures are found in "Removing sand" and "Aerating soil", with 88.89% and 87.50%, respectively. Risk level 3, appears in 6 of the 10 tasks evaluated, being in a greater rate in "Covering holes", specifically with a rate of 57.14%. Finally, risk level 4 only occurs in a task of the studied ones ("Harvesting"), with 5.26%.

3.3. Results according to Body Parts and Weight of the Handled Load for the Entire Courgette Cultivation

Using the OWAS method it is also possible to obtain the results of relative frequency or repetition rate and risk level for each body parts.

For the entire courgette cultivation a total of 105 postures are observed. The results show that the most harmful postures adopted (risk level 2) were for the bent back and standing or squatting on two bent legs, with a repetition rate of 64.76% and 19.05%, respectively (Table 6).

Finally, the load weights less than 10 kg in most of the adopted positions (80.95%).

Table 6. Risk level and repetition rate of the position of each body part and of the weight of the handled load for the entire courgette cultivation.

	Body Parts	Repetition Rates (%)	Risk Levels
Back	Straight	33.33	
	Bent	64.76	
	Twisted	0.95	
	Bent and twisted	0.95	
Arms	Both arms below shoulder level	70.48	
	One arm at or above shoulder level	9.52	
	Both arms at or above shoulder level	20.00	
Legs	Sitting	0	-
	Standing on two straight leg	28.57	
	Standing on one straight leg	12.38	
	Standing or squatting on two bent legs	19.05	
	Standing or squatting on one bent leg	7.62	
	Kneeling or squatting	0	-
	Walking	32.38	
Charge	<10 (kg)	80.95	-
	10–20 (kg)	14.29	-
	>20 (kg)	4.76	-
	Risk 1 Risk 2 Risk 3 Risk 4		

3.4. Results according to Body Parts and Weight of the Handled Load Based on the Courgette Cultivation Tasks

Next, the results are presented for each body part, but in this case according to the agricultural task (Table 7).

The greatest risk for the back is when it is bent. This happens in four tasks, "Removing sand", "Transplanting", "Covering holes", and "Aerating soil", all with a repetition rate of 100%, except for the last one with an 87.50%. The rest of the back positions present lower risk categories, with levels 2 and 1.

In the case of the arms, the highest risk level is also 3, found in the task of "Stringing" when both arms are above shoulder level, and with a repetition rate of 86.67%.

For the last part of the body evaluated, the legs, the highest risk level is 3, as in the two previous cases. This category appears in the position of bent knees, in two particular tasks, "Covering holes" and "Stringing" with repetition rates of 57.14% and 44.67%, respectively.

Finally, in six of the 10 tasks the load weighs less than 10 kg for the 100% of the cases. The other higher rate, also a 100%, is observed in the "Spraying" task with the load weight included in the range between 10 and 20 kg. For the third range, in which the load weighs more than 20 kg, there is a repetition rate of 33.33% in the "Greenhouse plant removal" task.

Table 7. Repetition rate and risk category of the position of each body part and of the weight of the handled load.

Body Parts	Posture	Repetition Rates (%) and Risk Categories according to Body Parts and Load									
		Removing Sand	Making Holes	Transplanting	Covering Holes	Aerating Soil	Spraying	Harvesting	Stringing	Plant Unstringing	Greenhouse Plant Removal
Back	Straight	0	33.33	0	0	0	100	21.05	53.33	100.00	33.33
	Bent	100	66.67	100	100	87.50	0	73.68	46.67	0	66.67
	Twisted	0	0	0	0	12.50	0	0	0	0	0.00
	Bent and twisted	0	0	0	0	0	0	5.26	0	0	0.00
Arms	Both arms below shoulder level	100	66.67	100	57.14	100	100	84.21	0	60.00	73.33
	One arm at or above shoulder level	0	33.33	0	14.29	0	0	0	13.33	40.00	6.67
	Both arms at or above shoulder level	0	0	0	28.57	0	0	15.79	86.67	0	20.00
Legs	Sitting	0	0	0	0	0	0	0	0	0	0.00
	Standing on two straight leg	55.56	66.67	10.00	0	25.00	0	26.32	40.00	30.00	26.67
	Standing on one straight leg	0	0	20.00	0	37.50	0	5.26	0	40.00	20.00
	Standing or squatting on two bent legs	11.11	0	10.00	57.14	0	0	15.79	46.67	0	26.67
	Standing or squatting on one bent leg	0	0	20.00	0	0	0	26.32	0.00	0	6.67
	Kneeling or squatting	0	0	0.00	0	0	0	0	0.00	0	0.00
	Walking	33.33	33.33	40.00	42.86	37.50	100	26.32	13.33	30.00	20.00
Charge	<10 (kg)	100	100	100	100	100	0	84.21	100	50.00	60.00
	10–20 (kg)	0	0	0	0	0	100	15.79	0	50.00	6.67
	>20 (kg)	0	0	0	0	0	0	0	0	0.00	33.33

■ Risk 1 ■ Risk 2 ■ Risk 3 ■ Risk 4

3.5. Workdays Related to the Courgette Cultivation

Based on the observation of the videos recorded during the courgette cultivation, the seconds that the worker spends performing a cycle for every task can be obtained. Some tasks, such as harvesting and plant removal, are divided into two parts (Table 8).

Table 8. Time in seconds of one cycle for each agricultural task.

Agricultural Task		One Cycle
Transplanting		17 s·plant^{-1}
Aerating soil		7 s·m^{-2}
Spraying		2 s·m^{-2}
Harvesting	Plant harvesting	6 s·plant^{-1}·harvesting^{-1}
	Downloading cart boxes	2 s·harvesting^{-1}·box^{-1}
Stringing		14 s·plant^{-1}
Plant removal	Plant unstringing	23 s·4^{-1}·plants^{-1}
	Greenhouse plant removal	126.6 s·2^{-1}·m^{-2}

The results of the total workdays and hours (Table 9) that a worker spends on each task for courgette cultivation are shown below. These results are obtained from Tables 1 and 8. In addition, a correction factor (fc = 1.20) is considered for each agricultural task, which considers time relative to breaks, preparation of tools, etc.

Table 9. Hours destined for each task and totals. Workdays total.

Agricultural Task		Time (hours)
Transplanting		51
Aerating soil		19.6
Spraying		5.6
Harvesting	Plant harvesting	720
	Downloading cart boxes *	12.6
Stringing		42
Plant removal	Plant unstringing	17.25
	Greenhouse plant removal	177.24
Total hours		1045.29 h
Total workdays (1 day = 8 h)		130.66 workdays

* For the task "Downloading cart boxes" from the harvesting task, additional data are considered: 15 kg·box^{-1}, 1 courgette·0.4^{-1}·kg^{-1}, 1 plant (cut)·2^{-1}·courgettes^{-1}.

3.6. Multiple Correspondence Analysis

By performing multiple correspondence analysis, it is possible to obtain the correlations of the categories of the variables. The model that has been obtained after this analysis presents two significant dimensions (Table 10). In this table the values of the variance, the Cronbach's coefficient (α), and the eigenvalue are shown. Since the Cronbach's coefficient is 0.878 and the mean eigenvalue is 4.314, the reliability of the model is considered good. Each of the two dimensions represents a factorial axis that gives information about the original study variables that are most associated with each other. This is quantified by the discrimination measures of each variable. Table 10 also shows the discrimination measures. Regarding the model mean, the variable with the highest value is PC (0.948), followed by T (0.749), RC (0.710), R (0.669), B (0.515), L (0.341), and A (0.233), and ending with the least explanatory one, which is Q (0.150). It is also observed in Table 10 that in dimension 1 the maximum value is that of variable PC (0.974) and the minimum value is that of variable A (0.080), and for dimension 2, the maximum and minimum values are for variables PC (0.922) and Q (0.018), respectively. Dimension 1

(horizontal axis) can discriminate with a gradient of values from more positive to more negative in the categories of the variables PC, R, and B as represented in Figure 2. Dimension 2 (vertical axis) better discriminates the referred gradient of values, but on the vertical axis, in the categories of variables PC and T.

Table 10. Discrimination measures of the variables.

Variable	Dimension 1	Dimension 2	Model Mean
Task (T)	0.780	0.718	0.749
Posture code (PC)	0.974	0.922	0.948
Back (B)	0.799	0.232	0.515
Arms (A)	0.080	0.386	0.233
Legs (L)	0.341	0.340	0.341
Load (Q)	0.281	0.018	0.150
Risk (R)	0.807	0.530	0.669
Risk combination (RC)	0.773	0.646	0.710
Total	4.836	3.792	4.314
% variance	60.5	47.4	53.9
Cronbach's coefficient (α)	0.907	0.841	0.878

From Table 10 it can be deduced that the value of each dimension discriminates more the closer it is to the value 1. The multiple correspondence model made allows the identification of the categories of each variable that discriminates the objects (sample unit) and, therefore, the quantifications of the variables are obtained. Graphically, this fact can be observed in Figure 2.

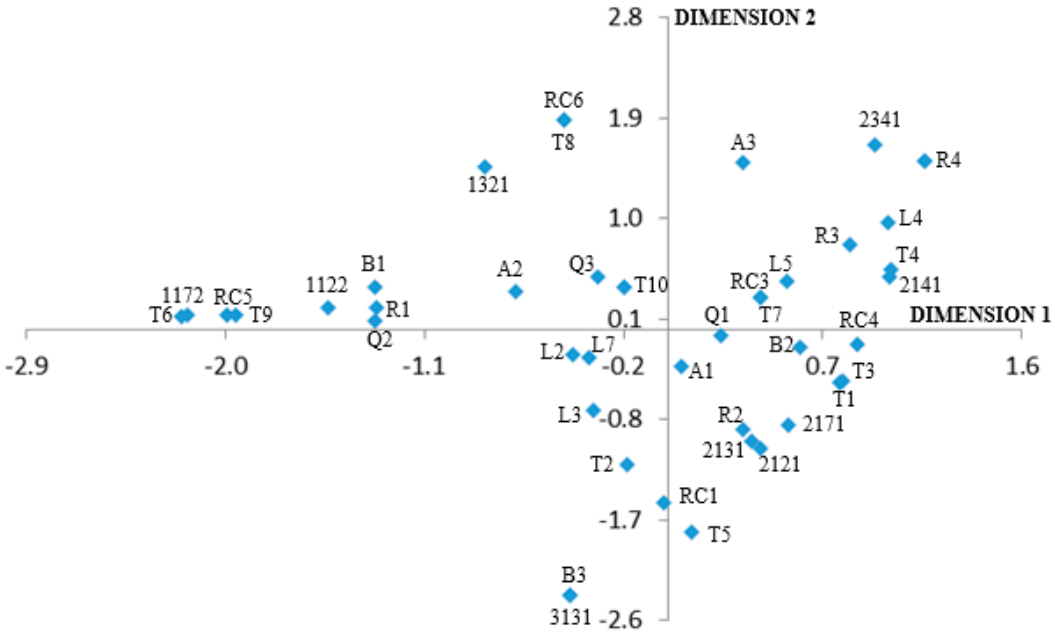


Figure 2. Factorial plane of the multiple correspondence analysis (the nomenclature of the categories is shown in Table A1, see Appendix B).

Next, Table 11 shows the quantifications of the most representative categories that best explain the positive and negative values in each dimension, for each of the variables.

Table 11. Quantifications of the most representative categories of the variables.

	Dimension 1		Dimension 2	
Variables	**Positive Values**	**Negative Values**	**Positive Values**	**Negative Values**
PC	2141 (12.2%)	1172 (21.4%); 1122 (10.7%)	2341 (19.1%)	2121 (13.8%); 3131 (12.5%)
T	T4 (9.7%); T3 (7.6%)	T9 (46.6%); T6 (10.7%)	T8 (24.8%)	T5 (31.1%); T2 (10.1%)
L	L4 (27.5%)	L2 (7.2%)	L4 (26.0%)	L3 (11.0%)
R	R3 (29.6%)	R1 (76.0%)	R3 (25.7%)	R2 (45.9%)
RC	RC4 (26.0%)	RC5 (59.7%)	RC6 (24.8%)	RC1 (43.2%)
B	B2 (66.3%)	B1 (76.9%)	B1 (6.4%)	B3 (12.5%)
A	A3 (1.7%)	A2 (7.1%)	A3 (33.6%)	A1 (29.9%)
Q	Q1 (23.7%)	Q2 (26.3%)	Q2 (0.1%)	Q1 (1.1%)

4. Discussion

4.1. Discussion about the OWAS Method Results

The results indicate that farmers adopt postures distributed mainly among the first 3 levels or risk (Table 4). This coincides with another research made about melon cultivation in Almería within greenhouses with "backbone" structures [12]. Obviously, these facts require actions (see Appendix C) aimed at minimizing musculoskeletal risk [9].

By work phases, in "Transplanting" (Table 4) forced postures are performed (level 3), which also coincides with other studies [12,24]. In "Aerating soil" (bent back; Table 7), "Stringing" (both arms at or above shoulder level and standing or squatting on two bent legs; Table 7), "Harvesting" (bent back, standing or squatting on two bent legs, and standing or squatting on one bent leg; Table 7) and "Plant removal" (bent back and standing or squatting on two bent legs; Table 7) something similar happens, but with risk levels between 2 and 3. These disorders and other incorrect postures of the trunk, wrist, and neck have also been described by other authors [12,25–30].

4.2. Discussion about Results Related to Workdays

In Almeria (SE Spain) an agricultural work unit is equivalent to 320 workdays/hectare for nine months of cultivation [31].

According to the previous data, the theoretical data that would be obtained for the present study with a courgette cultivation area of 8400 m^2, would be 268.8 workdays for nine9 months. Therefore, workdays for four months would be 119.5.

If this theoretical value of 119.5 workdays is compared with the real one of 130.66 workdays obtained in the results statement (point 3.5), it can be deduced that they are close values. The difference between both values could be due to periods dedicated to irrigation, arrangements, etc.

During all the time the workers are performing some of the tasks described these workers will be exposed to risk levels between one and four, which highlights one of the limitations of the OWAS method. This method does not consider the total exposure time per evaluated task [5].

4.3. Multiple Correspondence Analysis

Figure 2 shows how certain courgette cultivation tasks are associated with a certain risk level of suffering musculoskeletal risks, as well as the position of the back, arms, and legs, as occurs with melon cultivation in greenhouses in Almería [12]. Thus, for positive values of both dimensions, it is observed how the tasks "Covering holes" and "Harvesting" of courgettes are associated with a high risk level, up to type 3 in the first case and up to type 4 in the second case, which is due to the fact that a posture is adopted with knees and legs flexed, as has been described for other crops, such as melon [12,29,30], tomato [27,28], and pepper [27]. Likewise, for positive values of dimension 1 and negative values of 2, it is observed, as well as for courgette, that the tasks "Transplanting" and "Removing sand" are associated with postures, such as the bent back (forced) and both arms below shoulder level, with a combination of risks 2 and 3. Although for melon cultivation in Almeria [12] the

task "Transplanting" was associated only with risk 2, that is, a lower risk than for courgettes. For rice cultivation [24], musculoskeletal disorders associated with the "Transplanting" task have also been identified. On the other hand, for negative values in both dimensions in courgette, it is observed that the task "Making holes" is associated with a posture of standing on two straight legs, as has been observed for melon [12], pepper, and tomato [27] cultivation, which also involves a combination of risk 1 and 2 in courgette. Finally, the tasks of "Spraying" and "Plant unstringing" are associated with a straight back posture and risk level 1.

4.4. Strengths and Limitations of the Study

The OWAS method allows carrying out an assessment by observation, not requiring the use of sensors or other means that could disturb, distract or make workers waste their time during the performance of their tasks. Regarding the limitations, the OWAS method establishes that observations must be done in periods of time between 30 and 60 s. In this case, observations are made on periods of 5, 10, and 15 s, because different postures are adopted continuously in these tasks. It does not consider the worker's total exposure time in each task.

5. Conclusions

The findings discovered in this study show that farmers growing courgettes are exposed to musculoskeletal disorders because during the tasks they perform, many of the postures they adopt are injuring.

Therefore, since these postures that need to be corrected have been identified, corrective and preventive measures should be established to reduce or even prevent the appearance of these types of occupational diseases that are so common in the agricultural sector.

The main measures can be based on the use of tools that can replace or help the work made manually, and the reorganization of tasks, looking for solutions to carry them out in a healthy and safe way.

Author Contributions: All authors contributed equally to the manuscript and have approved the final manuscript.

Acknowledgments: Laboratory-Observatory Andalusian Working Conditions in the Agricultural Sector (LASA; C.G. 401251) and to Research Own Plan of the University of Almería.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The following are the posture codes established by the OWAS method. This method codes the back, arms and legs positions, and the load held by workers, forming a 4-digit code [11].

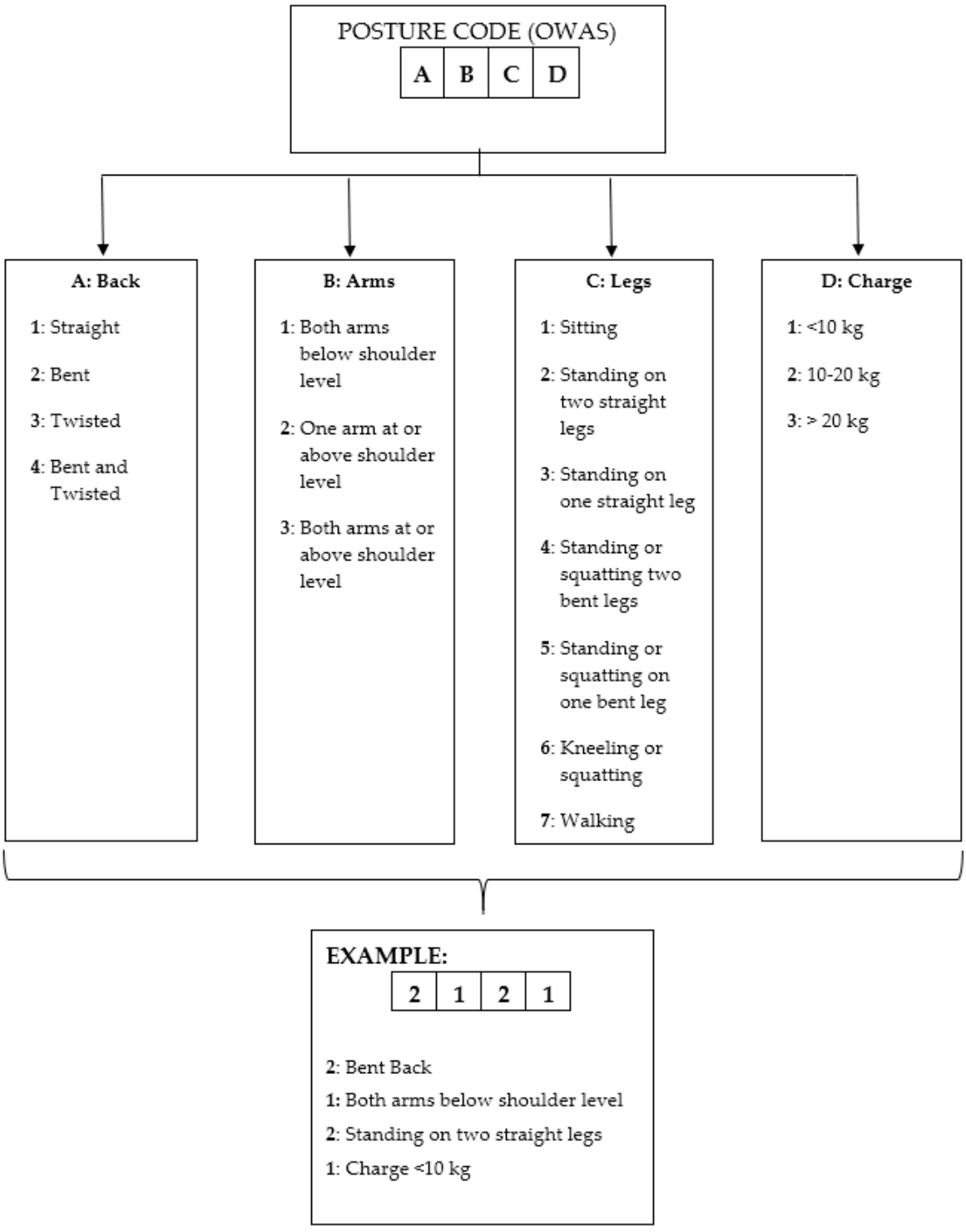


Figure A1. Posture code (OWAS).

Appendix B

Table A1. Variables and variables categories analyzed in the multiple correspondence analysis.

Variables	Categories	Coding
Cultivation task (T)	Removing sand	T1
	Making holes	T2
	Transplanting	T3
	Covering holes	T4
	Aerating soil	T5
	Spraying	T6
	Harvesting	T7
	Stringing	T8
	Plant unstringing	T9
	Greenhouse plant removal	T10
Posture code (PC)	See Appendix A and Table 4	
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)	Risk 1	R1
	Risk 2	R2
	Risk 3	R3
	Risk 4	R4
Risk combination (RC)	1+2	RC1
	1+2+3	RC2
	1+2+3+4	RC3
	2+3	RC4
	1	RC5
	1+3	RC6

Appendix C

Some general recommendations to avoid the risk of developing musculoskeletal disorders would be [9,32,33]:

1. Tasks should be performed at a height adjusted to workers, using, for example, tools with extensible handles, stools, etc.
2. Workers should alternate between standing and sitting postures, in those tasks which could be possible.
3. In repetitive actions, farmers should take breaks during their performance or alternate with other tasks.

4. The use of means, such as carts, wheelbarrows, etc., should be done.
5. Distribute the courgettes among several boxes, so that they do not weigh as much. In addition, boxes must have a good grip, so that the worker does not find very difficult to pick them up.
6. The loads must be brought close to the body before lifting them. Another recommendation is to alternate this task with others of a different type.

Table A2. Recommendations.

Tasks	Bent Back	Forced Legs Postures	Some Repetitive Actions	Manual Handling of Loads
Removing sand	1	2	3	
Making holes	1		3	
Transplanting	1	2	3	4, 6
Covering holes	1	2	3	
Aerating soil	1	2	3	
Spraying		2	3	
Harvesting	1	2	3	4, 5, 6
Stringing	1	2	3	
Plant unstringing		2	3	
Greenhouse plant removal	1	2	3	4, 6

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