





Article

# Repetitive Movements in Melon Cultivation Workers under Greenhouses

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**Abstract:** Musculoskeletal disorders cause serious problems that affect workers in many sectors. The objective of this study is the ergonomic analysis of melon cultivation farmers in Almeria-type greenhouses. For this, the rapid upper limb assessment (RULA) method has been applied after carrying out a detailed process of observing the farmers’ tasks. The study shows that 65% of the postures have a very-high-risk level, 26% high, 9% average, and no posture is found with a low risk. They also show that in 69.57% of the postures, the upper limbs are less affected than the others such as the neck, trunk, and lower limbs. Measures are proposed to improve the working conditions for workers.

**Keywords:** musculoskeletal disorders; greenhouse; RULA; biomechanics; ergonomics

## 1. Introduction

The sustainability of a manufacturing process consists of three concepts: manufacturing a high-quality product [1], being respectful with the environment [2], and workers’ rights [3,4]. These concepts of triple interaction were drafted in 1987 [5] (Figure 1) and are very important for occupational health and safety (OHS) and/or ergonomics (E).

The International Ergonomics Association (IEA) defines ergonomics as ‘the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance’. Ergonomics is classified into physical, cognitive, and organizational domains (Figure 2). Its objective is to improve and adapt the workplace/environment to people [6].

Musculoskeletal disorders (MSDs) can arise in all types of activities, tasks, or sectors [7]: Agriculture [8,9], health [10,11], industry [12,13], education [14,15], etc.

Some of the most common MSDs are tendonitis, carpal tunnel syndrome, and bursitis. These disorders do not appear suddenly, but develop over time [7].

MSDs result in time away from work leading to high costs for countries (workers and companies). This depends fundamentally on [16,17]:

- Physical and biomechanical factors (load handling, forced postures, and repetitive movements);
- Organizational and psychosocial factors;
- Individual and personal factors.

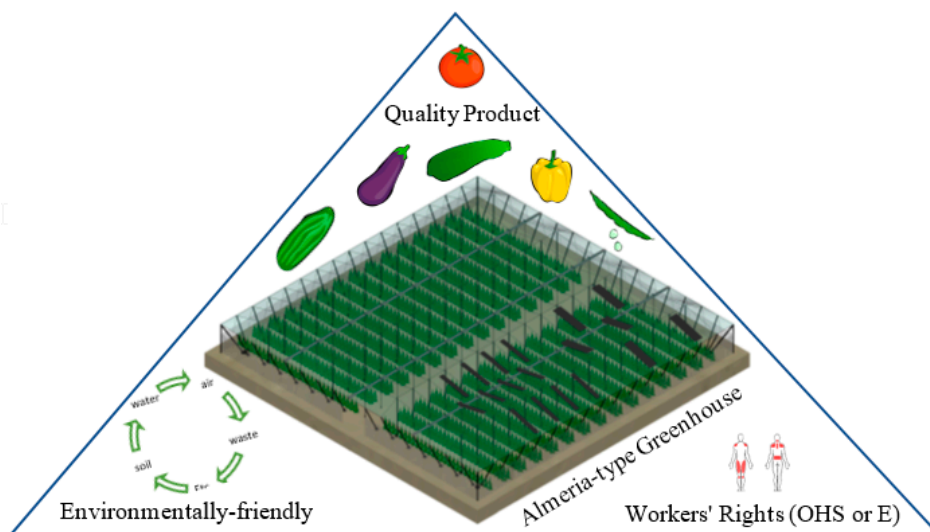


Figure 1. Sustainable agriculture in an Almeria-type greenhouse (southeast of Spain).

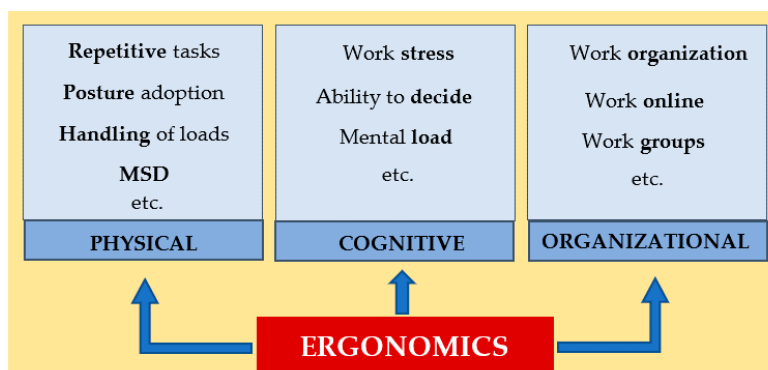


Figure 2. Types of ergonomics (adapted from [6]).

Agriculture is a primary sector in which workers from all over the world suffer work-related diseases or accidents every year [18], so it is necessary to implement actions to achieve safety at work [19,20].

The horticultural sector is one of the industries that presents greater risk (especially for MSDs) for its workers because most of the tasks are manual [8,21–23].

Farmers engaged in greenhouse cultivation are exposed to various risk factors that are a consequence of the materials used in its construction, workplace conditions, chemicals, work at heights, and physical activities [24].

Studies in different countries show that the number of workers suffering from musculoskeletal disorders in greenhouse agriculture is high [25,26]. In addition, these also sometimes indicate the specific risk factors that contribute to their development (e.g., physical load, working time, awkward postures, traction, and pushing of heavy loads) and the body areas that are usually most affected (e.g., lower back, knees, shoulders, and neck) [26,27]. Several systems that are very useful are also developed, for example, to evaluate various parameters of workers in a work environment [28].

The analysis of MSDs together with other characteristics of the work are linked with the cultivation being carried out efficiently and with high productivity [29]. Some studies have already focused on finding ways to reduce the labor required in some cultivation tasks [30].

In the province of Almeria (southeast of Spain), there is a large area of greenhouses, representing 31,034 hectares and 52,705 workers for the year 2017–2018 [31]. Some ergonomic studies have been carried out in Almeria, demonstrating that farmers of various cultivations developed MSDs, sometimes resulting in even job abandonments [8,32]. It is important to establish recommendations that allow

certain cultivations or tasks to be carried out safely, after a detailed evaluation of the MSDs developed by workers. Studies of this type, although scarce, have been carried out in the cultivation of crops such as melons and courgettes and in tutored tasks in greenhouses in the province [21–23].

Several evaluation methods allow the ergonomic analysis of workers through observation and subsequent image analyses. These are called semi-direct methods [33]. Each of these methods are usually oriented to different MSD risk factors (Figure 3) [34–50].

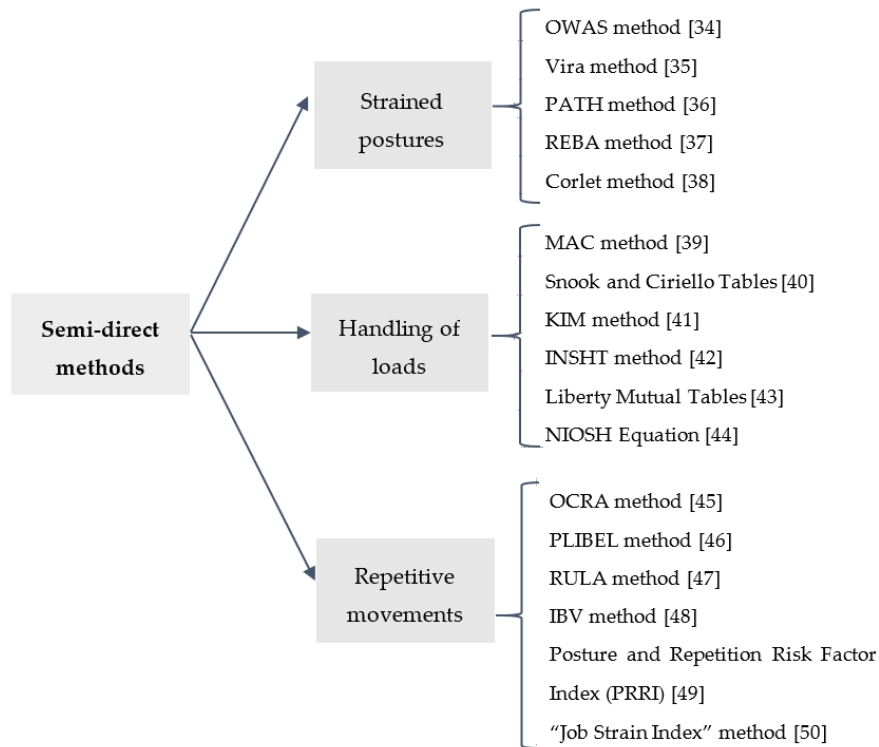


Figure 3. Semi-direct methods (adapted from [33]).

The objective of this study was to conduct an ergonomic analysis with the ‘rapid upper limb assessment’ (RULA) [47] method for melon cultivation workers in Almeria-type greenhouses.

## 2. Materials and Methods

### 2.1. Greenhouse, Cultivation, and Material

An Almeria-type greenhouse (southeast of Spain) of 2800 m<sup>2</sup> was selected and cultivated with a variety of ‘Valverde’ melon and with 0.428 plants·m<sup>-2</sup>. The cultivation period was approximately 3 months.

A Nikon COOLPIX S210 (Mexico City, Mexico) digital camera was used, with 3× optical zoom and digital zoom up to 4×. The effective pixels of the camera are 8.0 million.

### 2.2. Participant Sample

Three workers participated, a 38-year-old woman (height: 1.52 m; weight: 65 kg), a 40-year-old man (height: 1.75 m; weight: 78 kg) and a 79-year-old man (height: 1.65 m; weight: 77 kg).

### 2.3. Evaluation

A decision matrix (Table 1) with a scale from 1 to 5 was used to select the evaluation method.

**Table 1.** Decision matrix for selecting the method.

	OCRA [45]	RULA [47]	Job Strain Index [50]
Consider a large number of risks	5	3	4
Consider more body parts in addition to upper limbs	0	4	0
Long observation period	5	4	4
Low complexity in its application	1	3	3
Total	11	14	11

The method selected was RULA. It was observed that the greatest variation between the scores of the three methods was found in the body parts considered. RULA not only considers the upper limbs, but also evaluates legs, trunk, and neck [47].

Ergomet 3.0. software (MAPFRE ergonomics institute, Madrid, Spain) was used for image analyses [51].

### 2.3.1. Rapid Upper Limb Assessment Method

The RULA method originated in 1993 and was proposed by McAtamney and Corlett [47]. It is a method used for the evaluation of repetitive movements in work environments [47]. It can be classified within the group of semi-direct evaluation methods [33]. The evaluated factors are [47]:

- Posture adopted by different parts of the body (wrists, forearms, arms, neck, trunk, and legs);
- Static muscle action or repetition;
- Load.

The evaluation results indicate whether it is necessary to take corrective measures and in what period of time [47].

### 2.3.2. Data Collection Techniques and Data Analyses

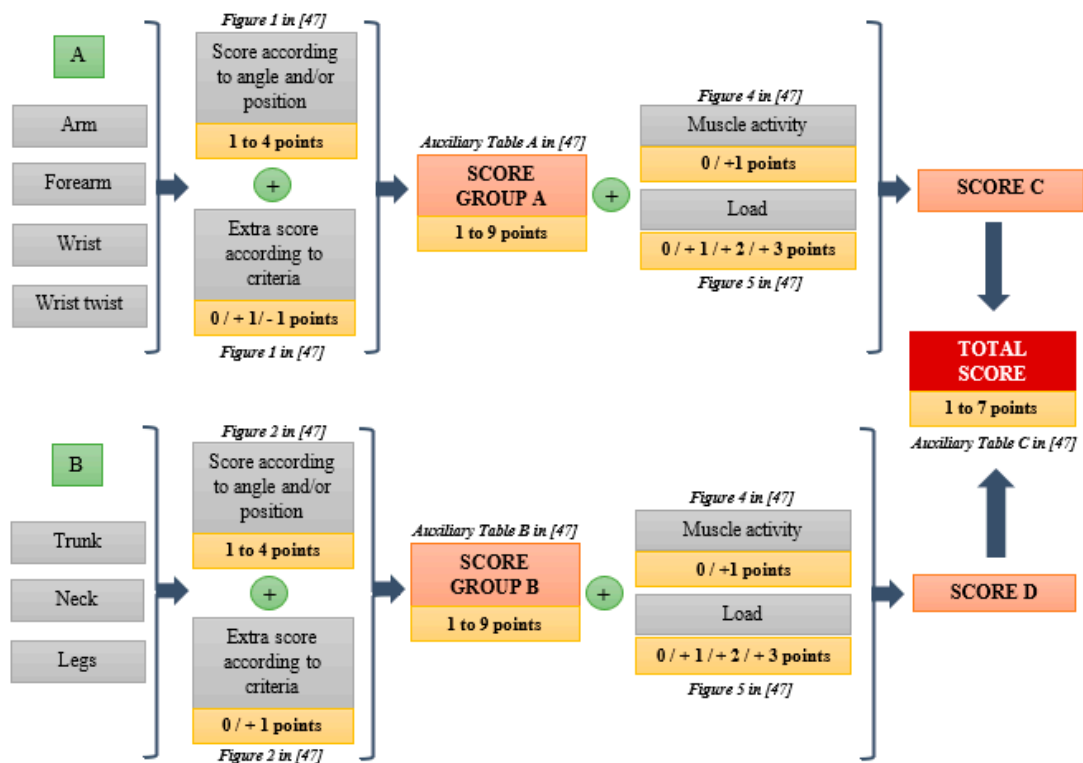
The different phases of the RULA method application in the case study were [47]:

- Observation of postures through video recordings of each of the cultivation tasks;
- Selection of postures by task (agricultural work) that the worker performs more frequently or those which are more harmful;
- The right and left parts of the body are individually evaluated. The one exposed to the greatest postural load (or both in case of doubt) is selected. In this evaluation, the most exposed body part was selected;
- Measurements of angles in each posture (Appendix A). This was done on the images obtained from the observation;
- The last steps of the method application were done using the Ergomet software [51]:
  - (a) Scores: The method establishes scores by body area (according to measured angles or posture) in addition to muscular action and load (Figure 4).
  - (b) Action level: There are four action levels according to the final score (Table 2).

**Table 2.** RULA action levels (adapted from [47,51]).

Action Level	Score	Corrections
1	1–2	It is not necessary to take actions. Acceptable risk.
2	3–4	It may be necessary to adopt some modifications, but not in a short period.
3	5–6	Corrections must be implemented in the task performance in a short period.
4	7	Corrections must be implemented in the task performance immediately.

Green: action level 1; yellow: action level 2; orange: action level 3; red: action level 4.



**Figure 4.** Calculation process in RULA (Rapid Upper Limb Assessment) method (adapted from [47,51]).

#### 2.4. Melon Cultivation Tasks

The cultivation tasks are similar for all greenhouse melon workers in the province of Almeria (southeast of Spain). These coincide with those described by Gómez-Galán et al. (2018) [21]: Transplanting (making holes and planting), phytosanitary treatments (manual and with tractors), bee pollination, leaf removal, harvesting (cutting, harvesting, and transporting containers), and greenhouse cleaning (plant removal, greenhouse plant removal, and greenhouse sweeping).

### 3. Results

After the observation phase, the angles for each of the postures for each task are presented in Table 3 (Appendix A).

The results of the measurements made are shown for the 23 evaluated postures (Appendix A), which consist of the angles formed by the different parts of the body (Table 3). These measured angles are those established by the RULA method for the evaluation. For the arm, the greater angles are presented in the ‘melon harvesting (way 2)’ task, specifically in posture 18, with a value of 119° and in posture 13 with 91°. In the ‘melon cutting’ task, the angle measured in posture 9 also takes the value of 91°. For the forearm, the greater angles are presented in ‘making holes’ and ‘melon harvesting (way 1)’ tasks, with 94° (posture 1) and 82° (posture 11), respectively. For the angles measured on the wrist, two high values are differentiated, which are also quite different from the rest, being 70° (posture 22) for the ‘greenhouse plant removal’ task and 43° (posture 3) for the ‘planting’ task. On the neck, ‘melon harvesting (way 2)’ and ‘melon cutting’ tasks stand out. In the first task, the position of the neck acquires an angle of 61° (posture 13) and in the second, an angle of 43° (posture 9). Finally, regarding the trunk, there are three different tasks where the angles are greater compared to the others. The first is the ‘melon cutting’ task with a value of 112° (posture 9), the next is the ‘melon harvesting (way 2)’ task with a value of 105° (posture 13), and the third is the ‘planting’ task with an angle of 102° (posture 3).

**Table 3.** Angles about the postures of each task.

Tasks	Subtasks (See Appendix A)	Posture	Angles (°)				
			Arm	Forearm	Wrist	Neck	Trunk
Transplanting	Making holes (ST1)	1	24	94	26	33	20
	Planting (ST2)	2	63	18	20	12	63
		3	85	29	43	15	102
Phytosanitary treatments	Manual treatment (ST3)	4	33	62	12	13	3
		5	19	80	0	26	4
	Tractor treatment (ST4)	6	39	49	24	21	22
		7	23	71	0	9	10
Leaf removal	Leaf removal (ST5)	8	60	62	0	34	15
	Melon cutting (ST6)	9	91	38	22	43	112
		10	76	45	28	33	95
Harvesting	Melon harvesting (way 1) (ST7)	11	34	82	0	16	84
		12	14	65	10	14	0
		13	91	59	0	61	105
		14	88	24	13	37	58
	Melon harvesting (way 2) (ST8)	15	14	54	16	13	26
		16	57	70	0	20	20
		17	31	75	17	17	26
		18	119	38	0	0	17
	Transporting containers (ST9)	19	55	13	24	24	17
		20	37	51	8	20	22
Cleaning	Plant removal (ST10)	21	44	80	30	0	79
	Greenhouse plant removal (ST11)	22	27	24	70	0	17
	Greenhouse sweeping (ST12)	23	30	73	0	13	36

Table 4 shows the partial scores ‘C’ and ‘D’ and the total (Figure 4) of each task assessed (Appendix A).

The highest score is ‘9’ (Table 4) and it is related to posture 12 of the subtask ‘melon harvesting (way 1)’. The lowest partial score is ‘3’ of posture 4 corresponding to the subtask ‘manual treatment’. Both are related to the trunk, neck, and legs (Figure 4).

Postures (Table 4) 1 (‘making holes’), 3 (‘planting’), 16 (‘melon harvesting (way 2)’), and 22 (‘plants removal’) have a similar result (17.39% of the total postures) in both the columns of ‘Score C’ and ‘Score D’ (Figure 4).

Postures (Table 4) 4 (‘manual treatment’), 18 (‘melon harvesting (way 2)’), and 19 (‘transporting containers’) are the only ones where a higher value is observed in Score C than in D (13.04% of the total analyzed).

In the other postures (69.57% of the total), a higher score is observed for the ‘Score D’ column compared to the ‘Score C’ column (Table 4).

Regarding the total score (Table 4), most postures have relatively high values. The lowest ‘4’ score corresponds to the ‘making holes’ and ‘manual treatment’ subtasks. The highest value ‘7’ is associated with the subtasks ‘planting’, ‘leaf removal’, ‘melon cutting’, ‘melon harvesting (ways 1 and 2)’, ‘plants removal’, and ‘greenhouse sweeping’.

‘Phytosanitary treatments’ is the only cultivation task that does not involve a posture of risk level 4 (Tables 2 and 4). For this task, risk level 3 predominates (high risk). In addition, the subtask of ‘manual treatment’ shows the least harmful posture, with a risk level 2 (medium risk).

For the rest of the tasks, risk level 4 is mostly observed, except for risk level 3 in the subtasks of ‘transporting container’ and ‘plants removal’, and risk level 2 in ‘making holes’ (Tables 2 and 4).

Table 4. Ergomet 3.0 results.

Tasks	Subtasks (See Appendix A)	Posture	Score C	Score D	Total Score (See Table 2)
Transplanting	Making holes (ST1)	1	4	4	4
	Planting (ST2)	2	5	6	7
		3	6	6	7
Phytosanitary treatments	Manual treatment (ST3)	4	5	3	4
	Tractor treatment (ST4)	5	4	5	5
		6	4	6	6
Leaf removal	Leaf removal (ST5)	7	4	5	5
	Melon cutting (ST6)	8	6	7	7
		9	5	6	7
Harvesting	Melon harvesting (way 1) (ST7)	10	5	7	7
		11	5	8	7
	Melon harvesting (way2) (ST8)	12	6	9	7
		13	5	6	7
		14	5	6	7
		15	6	7	7
		16	6	6	7
		17	6	6	7
		18	7	8	7
		19	7	6	7
Cleaning	Transporting containers (ST9)	20	5	4	5
	Plant removal (ST10)	21	4	6	6
		22	6	8	7
Greenhouse plant removal (ST11)	23	5	5	6	
	Greenhouse sweeping (ST12)	24	5	7	7

Yellow: action level 2; orange: action level 3; red: action level 4.

There is not any posture represented in green (Table 4, Figure 5), that is, without risk. Risk level 4 (very high; Table 2) represents 65% of the evaluated postures (Figure 5); risk level 3 (high; Table 2) represents 26% and risk level 2 (medium; Table 2) 9% (Figure 5).

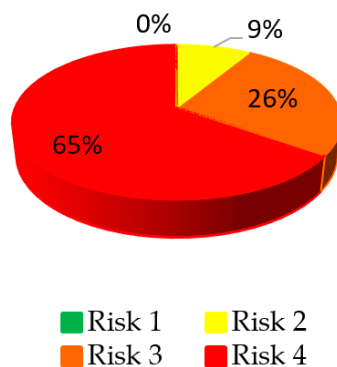


Figure 5. Risk levels.

#### 4. Discussion

According to the obtained results, it is observed that for the postures evaluated with this method, there are three levels of risk (levels 2, 3, and 4) for the entire melon cultivation, which could lead to problems in the musculoskeletal system and therefore, may require corrective actions to be implemented in a medium or short period of time, or immediately. However, none of the postures evaluated is category 1, which encompasses postures of acceptable risk. For the workers' body parts, the upper extremities are less damaged than the rest of those evaluated by RULA. These results are discussed in detail below.



#### 4.1. Risk Levels in Cultivation Tasks

Most assessed postures (65%) (Table 4 and Figure 5) have the highest level of risk (Table 2), so immediate actions are required for the improvement of workers' tasks; however, these results do not seem to match with reality since not all melon cultivation workers under Almeria-type greenhouses (8000 workers; [31]) are with MSD. Although, the RULA method is more oriented to the assessment of repetitive movements, another study using the OWAS (Ovako Working Posture Assessment System) method (for forced postures) indicates a medium risk [21], far from the results of this study; however, the results are similar to those found in melon cultivation in South Korea using the RULA, OWAS, and REBA (Rapid Entire Body Assessment) methods [52].

We can observe in Table 4, that the biggest problems appear during harvesting, planting, leaf removal, and cleaning. This may be due to two fundamental facts. The first is that the melon is a creeping cultivation (at ground level and not in height) [32,53] which means that the manual labor of the workers with the trunk is excessively inclined (bent over). The second, especially in the harvesting task, is the manipulated weight with a bent back for a certain period. Both the causes coincide in the analysis of another creeping greenhouse cultivation crop like courgettes [22]. In addition, although without being a creeping cultivation, something similar occurs with the oil palm [54]. In addition, another study in India showed that in agriculture, in general, the task of harvesting is one of the most injuring, since it obtained a score of 5 or higher with the RULA method, in most of the assessed cases [55].

Of the two types of harvesting (ST7 and ST8, Table 4) both present the same score with a very-high-risk level, but the subtask ST7 adopts less forced postures [21]. For this reason, ST7 will be more favorable than ST8.

Regarding the phase of 'phytosanitary treatments', it shows (Table 4) that manual treatments are less harmful than tractor treatments. This fact is a bit controversial because it is assumed that the mechanization of work reduces the risk of MSDs [56]. In our study, the "under greenhouse" fact makes that small tractors with limited maneuverability are required (Appendix A) [57]. Manual treatments require taking a hose with a treatment gun connected to a pump tank and walking with it in an upright position (Appendix A).

In most postures, the body parts of group B (trunk, neck, and legs) are more affected than the upper limbs associated with group A (arm, forearm, wrist, and wrist turn; Figure 4). This is again related to what has been described above, that melon under a greenhouse is a creeping cultivation (at ground level). All this is also described globally by Almodovar-Molina et al. (2011) [58] where workers in agriculture, livestock, forestry, and fishing suffer from musculoskeletal disorders mainly in the lower back, neck, and upper back. They also occur in the legs, but in a smaller rate than in the rest of the affected body parts.

The results obtained by the RULA method are negative and could be overrated for two reasons. One of the reasons is that, in order to apply the method, it is necessary to previously select the postures that at first sight are more harmful or frequent and therefore may involve a higher risk. Then, it is already assumed that the results of less harmful postures will not be reflected. The second reason is that RULA does not contemplate working times when applying the method. Some very harmful postures may not be adopted for a long period or they may alternate with less harmful ones, which would reduce their impact on the workers. On the contrary, other methods consider the time of adoption of the posture as a risk factor for musculoskeletal disorders [59].

Finally, it should also be mentioned that melon cultivation can be considered sustainable because it meets the three conditions of high quality, respect for the environment, and workers' rights. The latter is because law guarantees workers' rights in the European Union. Studies, such as the present work, encourage the improvement of the sustainability of melon cultivation by analyzing agricultural tasks. In other words, workers are evaluated in order to improve their working conditions.



#### 4.2. Limitation and Advantages of the Study

For the present study, the harmful postures adopted and their repetition were identified during the performance of the different tasks, since in all melon greenhouses in the southeast of Spain they are performed in a very similar way, as they are repetitive tasks. Therefore, a large sample of workers is not the subject of the study, but a detailed observation of the performance of the tasks.

Decision making and knowledge about the assessing method take a fundamental role when making measurements. There is great subjectivity in the placement of the axes on each part of the body or in the drawing of the joints. For this reason, measurements of the same posture by different assessors can provide different results, although it is also true that by following the same criteria there should not be too much variation.

There is also a certain subjectivity in the selection of postures, since in this case it is also the assessor who must decide during the observations process which postures may be the most harmful for the workers.

An advantage of this study is that the method evaluates which postures of each task can be harmful and require modification, without altering the work pace of the farmers and without the need to ask questions after the development of the tasks, since it is only based on observations.

#### 4.3. Recommendations

Recommendations regarding the tools or equipment to be used [21,60]:

- (a) In 'melon harvesting (way 2)', when the containers are stacked and have a high height, small stools could be used.
- (b) In the 'making of holes', 'leaf removal', 'melon cutting', or 'sweeping' task, it would be advisable to use tools with handles that can be adjusted according to the height of the worker.
- (c) For 'melon harvesting (both ways)', it would be recommended to use carts so as not to transport the boxes manually.
- (d) Use of carts to sit and be able to circulate in the workplace for subtasks such as 'planting', 'cutting' or 'melon harvesting'.
- (e) Use of tractors more adapted to the Almeria-type greenhouses.

Recommendations for the execution of tasks [21,61]:

- (a) In subtasks such as 'melon harvesting (both ways)', lift loads by placing the legs with the balanced weight, using both hands and placing the load near the body.
- (b) In 'melon harvesting (way 1)', when heavier loads are lifted such as boxes full of melons, this subtask should be performed by two workers.
- (c) For subtasks that are practically carried out on the ground such as 'planting', 'melon cutting' and part of 'melon harvesting', knee bending is recommended.
- (d) For all cultivation tasks, change the posture after two minutes. Performing work shifts and tasks together are also recommended.
- (e) For tasks that may be possible, change arm and hand frequently, provided that the task does not involve much precision or force.

Finally, recommendations on how to organize or plan the work [21,62]:

- (a) Taking ergonomic training courses for workers.
- (b) In subtasks such as 'melon harvesting (both ways)', putting less load in the boxes, so that their weight is lower, or use smaller boxes, with less capacity for melons. Also, recommend using the way 1 of melon harvesting (ST7) instead of way 2 (ST8).
- (c) Taking breaks of 10 min after performing 50 min of repetitive tasks, so that the upper limbs do not suffer too much.

- (d) Rotate between different subtasks, for example, in harvesting, to alternate the collection with the transport of containers and within the collection, to alternate between the actions of taking up from the ground, passing the melons to another worker, and throwing them into the containers.
- (e) Reorganization of work [8].
- (f) Physical training of workers [8].
- (g) Perform, whenever possible, the harvesting task with more workers and less time. The cost of the work will be the same since the employer pays for hours worked.

## 5. Conclusions

The tasks of melon workers under greenhouses in Almeria (southeast of Spain) have been evaluated using the RULA method, concluding that 65% of the adopted postures present a very-high-risk level.

Most of the tasks are of great physical demand with little mechanization, so recommendations are proposed on tools or equipment to be used, execution of the tasks, and how to organize/plan the tasks.

Finally, RULA is a good method for evaluating worker' tasks, but it could overestimate their results.

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**Conflicts of Interest:** The authors declare no conflicts of interest.

Appendix A

This appendix shows the 115 measurements made on the images of the selected postures in the observation process.

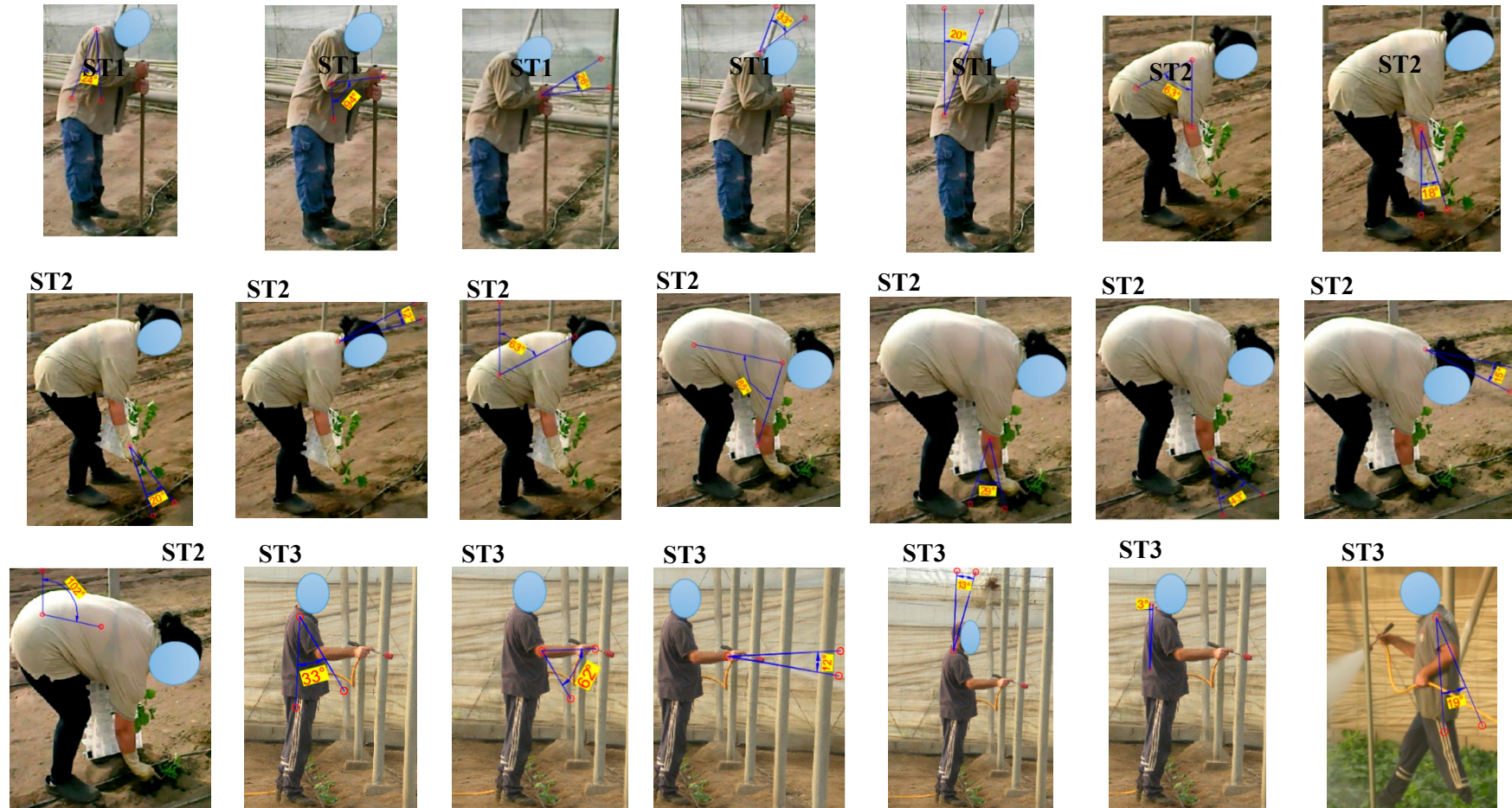


Figure A1. Cont.



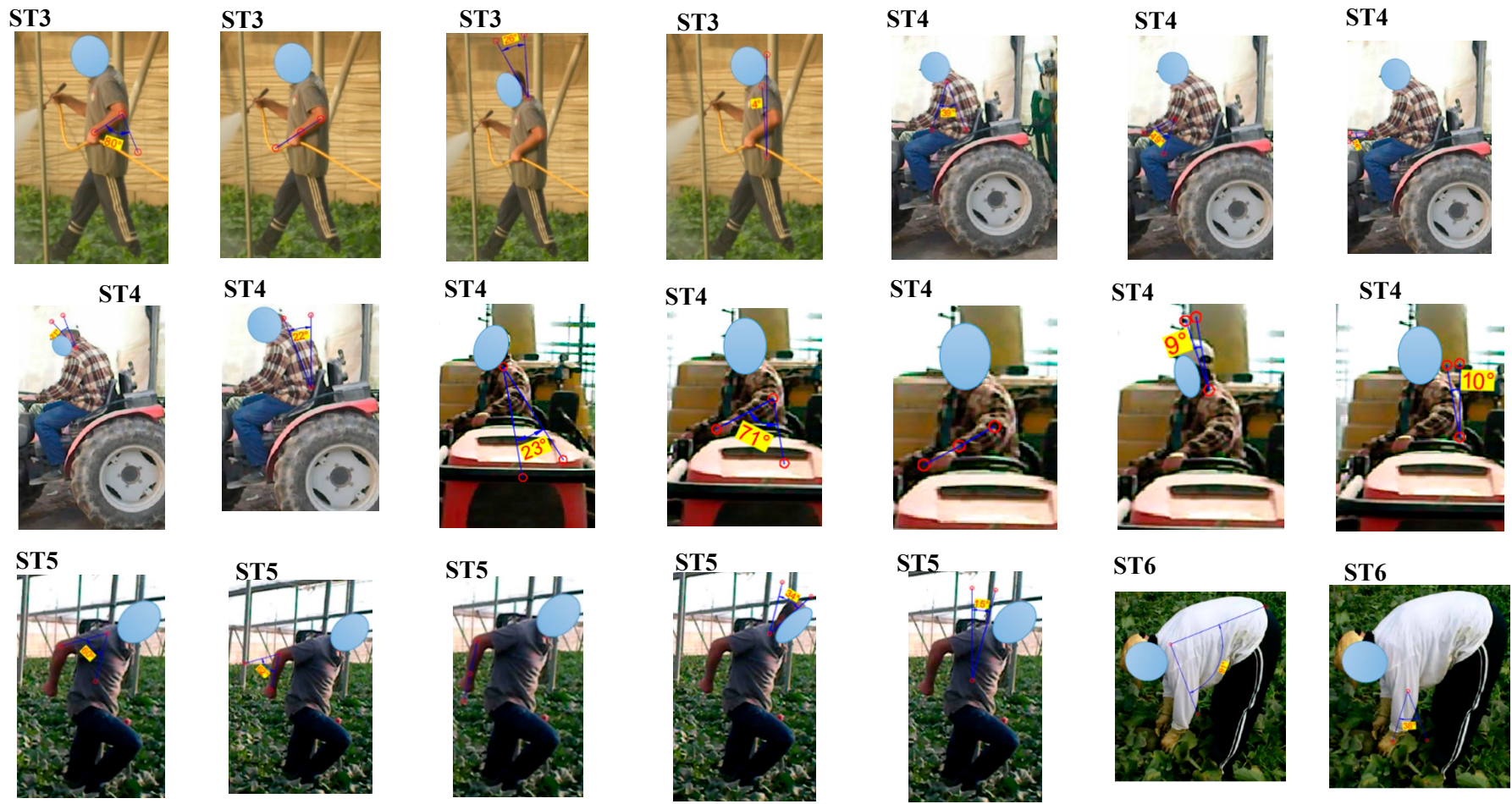


Figure A1. Cont.



Figure A1. Cont.



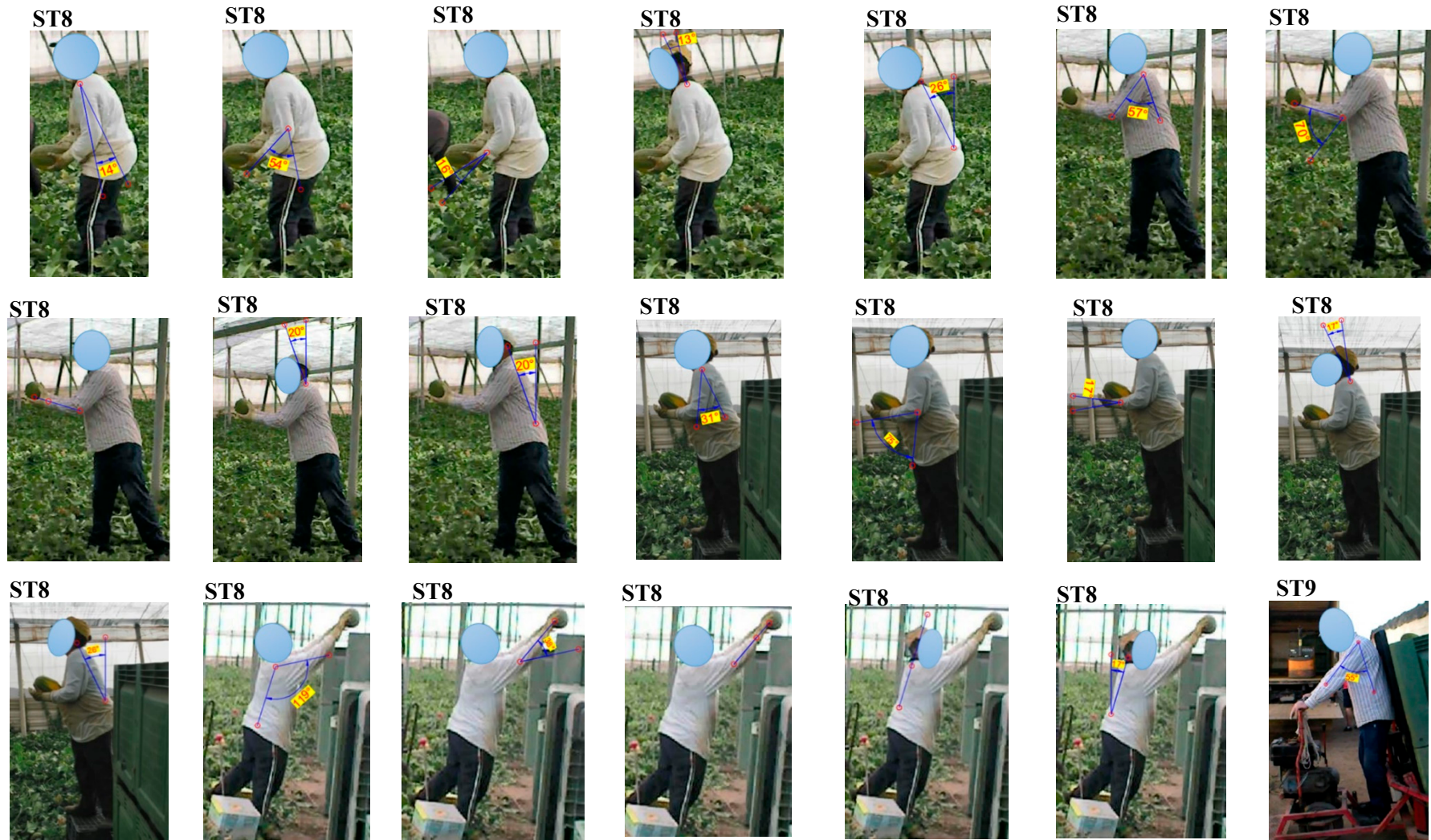


Figure A1. Cont.



Figure A1. Cont.





**Figure A1.** Measurements. Tasks corresponding to the codes indicated in Figure A1; ST1: (Making holes); ST2: (Planting); ST3: (Manual treatment); ST4: (Tractor treatment); ST5: (Leaf removal); ST6: (Melon cutting); ST7: (Melon harvesting (way 1)); ST8: (Melon harvesting (way 2)); ST9: (Transporting containers); ST10: (Plant removal); ST11: (Greenhouse plant removal); ST12: (Greenhouse sweeping).

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