Safety Science 187 (2025) 106838

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

# Physical load assessment of greenhouse cucumber farmers using OWAS and RULA methods

Salvador De-Benavides-Jiménez [a], Marta Gómez-Galán [a,b,*], Juan-Carlos Rubio-Romero [c], Manuel Díaz-Pérez [b,d], Ángel-Jesús Callejón-Ferre [a,b]

[a] Department of Engineering, University of Almería, CIMEDES Research Center (CeiA3), Ctra. Sacramento, s/n, La Cañada, 04120 Almería, Spain
[b] Laboratory-Observatory of Andalusian Working Conditions in the Agricultural Sector (LASA), Avda. Albert Einstein, 4. Isla de la Cartuja, 41092 Seville, Spain
[c] School of Industrial Engineering, University of Málaga, C/Dr. Ortiz Ramos, s/n, Teatinos 29071 Málaga, Spain
[d] Department of Engineering, University of Almería, CIAMBITAL Research Center (CeiA3), Ctra. Sacramento, s/n, La Cañada, 04120 Almería, Spain

ARTICLE INFO

*Keywords:*
Physical strain
Biomechanics
Farmers
Task evaluation

ABSTRACT

Work-related musculoskeletal disorders (MSDs) are very common in the agricultural sector because most tasks are manual. This study attempts to analyse the forced postures and repetitive movements in greenhouse cucumber workers. Two semi-quantitative assessment methods (Ovako Working Analysis System and Rapid Upper Limb Assessment) were used following an exhaustive field analysis of the work. The results indicate the need to avoid continuous back flexion, leg flexion and arm elevation. The tasks with the highest risk of MSDs are T1 (transplant furrow) and T4 (planting seedlings), which carry a 46% and 72% level-3 risk, respectively. Postural training for workers, mechanising tasks, and improving their physical state could reduce the risk of MSD.

## 1. Introduction

Around 1.71 billion people worldwide suffer from musculoskeletal disorders (MSDs; Cieza et al., 2020). Work-related MSDs are very common, affecting workers' health and impacting national economies (EU-OSHA, 2020a). In Norway, the mean economic cost of MSDs was €22,600, according to a study that considered 509 participants over a six-month period (Killingmo et al., 2024). In Kansas, they accounted for $20,097 in indemnity and medical costs from 2014 to 2022 (Manning and Jorgensen, 2024). In Belgium, more than €3 billion correspond to healthcare costs, and €2 billion to absenteeism (Gorasso et al., 2022) while in Denmark shoulder musculoskeletal disorders represent an annual cost of approximately €1.21 billion (Sorensen et al., 2022).

In the agricultural sector, most tasks are carried out manually (Riemer and Bechar, 2016), meaning that workers often suffer from MSDs (Tatar et al., 2023). The most common ones are shoulder injuries, synovitis and tenosynovitis, hernias, epicondylitis, different nervous system disorders (e.g., carpal tunnel syndrome) and arthropathies (EU-OSHA, 2020b). The lower back and upper limbs are the most affected body parts (EU-OSHA, 2020c). Physical risk factors that stand out include repetitive movements, awkward positions, and heavy loads (Benos et al., 2020). These disorders can also be associated with psychosocial risks (Du et al., 2022), which will depend on the age of the agricultural worker, his/her physical condition, etc. (Rohles, 1985).

The use of agricultural vehicles (Shukla et al., 2023) or certain cases involving mechanization can also cause MSDs (Milani and Monteiro, 2012). However, they tend to decrease with their use compared to manual task performance (Fethke et al., 2020; Ojha and Kwatra, 2016). A study concluded that the trunk flexion of farmers was less harmful when they worked with machinery (Khan et al., 2020). The type of MSD depends on the equipment and the worker, so to prevent them it is necessary to consider ergonomic principles in their design and use anthropometric data from farmers in each country. (Abouee-Mehrizi et al., 2022).

To prevent MSDs, it is necessary to study the tasks involved in cultivating each crop independently and to identify the most affected areas of the body. Studies of this type have been conducted on different continents (Varguese and Panicker, 2022; Table 1).

There are several methods for assessing MSDs (Yazdanirad et al., 2018), which can be classified as direct reading, semi-quantitative, and self-reported. To select a method, one should consider the type of research and the purpose for which the data will be used (David, 2005).

* Corresponding author at: Department of Engineering, University of Almería, CIMEDES Research Center (CeiA3), Ctra. Sacramento, s/n, La Cañada, 04120 Almería, Spain.
*E-mail address:* mgg492@ual.es (M. Gómez-Galán).

https://doi.org/10.1016/j.ssci.2025.106838
Received 12 November 2024; Received in revised form 21 January 2025; Accepted 25 February 2025
Available online 6 March 2025

**Table 1**
Main areas of the body affected according to the crop.

| Plant/Crop | Continent | Body areas affected |
|---|---|---|
| Tomato (Ceccihi et al., 2010) | Europe | Upper limbs |
| Grapes (Brumitt et al., 2011) | North America | Back |
| Flowers (Barrero et al., 2012) | South America | Upper limbs |
| Hazelnuts (Colantoni et al., 2013) | Europe | Upper limbs |
| Oil palm (Henry et al., 2015) | Asia | Neck/ Back/ Shoulders |
| Sweet Potato (Kearney et al., 2016) | North America | Back/Shoulders |
| Rice (Neubert et al., 2017) | Asia | Knees/Feet |
| Fruits (Thetkathuek et al., 2018) | Asia | Neck / Lower Back |
| Blueberries (Kim et al., 2018) | North America | Shoulders/Upper Limbs |
| Apple (Houshyar and Kim, 2018) | Asia | Lower back/ Knees/ Neck/ Shoulders |
| Vegetables and strawberries ( Pinzke and Lavesson, 2018) | Europe | Lower back |
| Pineapple (Salleh et al., 2019) | Asia | Back/Lower Limbs |
| Dates (Mokdad et al., 2019) | Africa | Shoulders/ Hands/ Wrists/ Lower back/ Hips/ Knees/ Feet |
| Banana (Simas et al., 2020) | South America | Lower Back/ Shoulder / Knees |
| Mango (Boriboonsuksri et al., 2022) | Asia | Lower back/ Right shoulder/ Upper right arm |

- Direct reading methods: Obtaining data with sensors and other devices placed on the body. Drawbacks include the need to train personnel to use them, their high cost, and some equipment that can only be used in a laboratory setting (David, 2005). Nevertheless, these methods are precise and objective (Amasay et al., 2009).
- Semi-quantitative methods: based on prior observation of the work and the assessment of postures (Takala et al., 2010). These methods are low cost and applicable to a wide range of sectors. However, they are less accurate and more time-consuming than direct reading methods (David, 2005; Takala et al., 2010).
- Self-reported methods: carrying out questionnaires or interviews (Kilbom, 1994). These methods are easy to use and cheaper than other methods, but have poorly proven data reliability (David, 2005).

In Spain in 2021, 63.2 % of agricultural workers suffered from back pain, 60.5 % from upper limb discomfort, and 65.8 % from lower limb discomfort (INSST, 2023).

In Andalusia (Spain), greenhouse cultivation is the most dynamic type of agriculture (Junta de Andalucía, 2023). In Almeria province, ag provides the second highest level of employment after the service sector. In the third quarter of 2023, 52,000 ag workers were employed (INE, 2023). The surface area of greenhouse cultivation in this province is close to 35,000 ha. Cucumber cultivation covers 5,614 ha, being the largest area after pepper (12,583 ha), watermelon (11,400 ha), tomato (8,201 ha), and courgette (8,013 ha). Cucumber production in Almeria is 574,678 tons and 527,447 tons of this vegetable are exported from this province (2021/2022 season). In 2021/2022 the price of this product increased by 35.9 % (Cajamar, 2022). Despite the importance of this crop (Fig. 1), there is only one study found on the health and safety of greenhouse cucumber workers in the "Web of Science" database (Callejón-Ferre et al., 2011).

This research is justified given the scarcity of studies assessing the musculoskeletal risks faced by agricultural workers growing cucumbers in Spanish greenhouses. The aim is to determine whether the musculoskeletal system of agricultural workers who grow this vegetable in Andalusia is affected. The study attempts to identify the forced postures and repetitive movements in greenhouse cucumber workers in Almeria, the Andalusian province with the highest level of cucumber production. The MSDs for each task will be analysed and the most affected body areas will be identified.

## 2. Materials and methods

### 2.1. Description of the study area and the workers

The study was carried out in two greenhouses (agricultural season 2021–2022), both located in El Ejido (Almeria, Spain), specifically in the Campo de Dalías agricultural region (latitude: 36.810392, longitude: −2.861728; decimal degrees). The two greenhouses are asymmetrical, drip irrigated, with clayey soil covered in sand and surface areas of

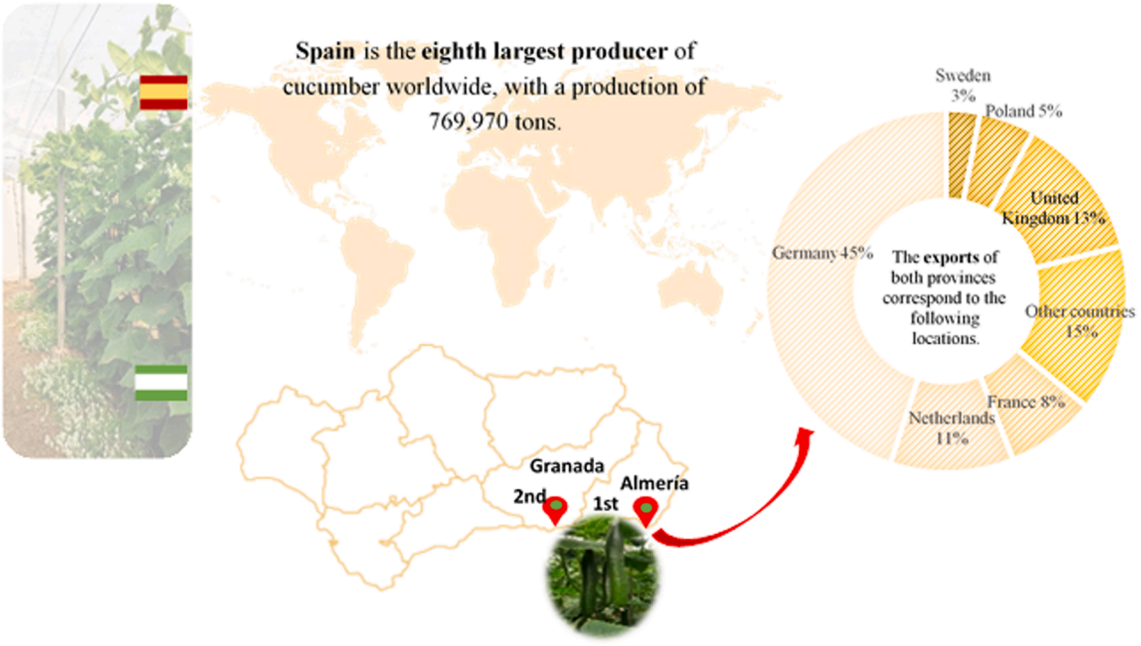



**Fig. 1.** Importance of cucumber cultivation in Spain (FAOSTAT, 2022; CAGPDS, 2023).

9,000 $m^2$ and 10,000 $m^2$. The crop is the "Almeria cucumber", also known as the "Dutch cucumber". The workforce consists of six male agricultural workers. The number of workers varies between one and six for each task, depending on its difficulty and estimated duration.

This research is based on assessing the postures and repetitive movements undertaken while executing the tasks, regardless of the personal characteristics of the agricultural workers or the type of greenhouse. This is because cucumber cultivation tasks are carried out in a very similar way in all Almerian cucumber greenhouses (5,614 ha), with the postures adopted by farmers being practically the same (Fig. 2). For this reason, the study does not focus on individual workers, but on a large number of postures for each agricultural task.

### 2.2. Method selection

Choosing the MSD assessment method depends on the application's purpose, the task characteristics, the assessor, and the tools available for data collection and analysis (Takala et al., 2010). The selected method should be simple and quick to use (David, 2005). Each of these criteria is analysed below and related to the methods (Table 2):

After analysing the above criteria (Table 2), direct reading and self-reported methods were ruled out for use in this study.

Among the semi-quantitative methods, it is difficult to choose one that adapts to all the study needs and work to be assessed, since each possesses its own characteristics. The application of more than one method for more complete results is considered a good option (Takala et al., 2010).

In this research, we selected two semi-quantitative methods, one to assess forced postures and the other to assess repetitive movements.

The following conditions were set to select the method for assessing forced postures:

- It is not possible to apply just any method to specific sectors (David, 2005). Therefore, a method is sought that can be applied to the agricultural sector.
- In each task, the worker adopts more than one posture. All the positions should be assessed over the entire crop cycle.
- One wants to analyse the body in general, considering several different body areas.

One method that meets all these requirements is OWAS (The Ovako Working Analysis System; Karhu et al., 1977). It is widely applied in the agriculture sector (Gómez-Galán et al., 2017). For example, OWAS has been used to assess farmers of eucalyptus (Cunha et al., 2012), vineyards (Nwe et al., 2012), apples (Callea et al., 2014), oil palm fruits (Ng et al., 2015), asparagus (Sakmoto et al., 2017), etc. It allows numerous postures to be assessed for each task and considers back, arms, legs, and load (Karhu et al., 1977; Takala et al., 2010).

**Fig. 2.** Task "Planting seedlings" carried out by different workers.

To select the assessment method for repetitive movements, the following conditions were set:

- A method that can be applied to agricultural work.
- Most of the tasks (transplanting, picking, etc.) in cucumber cultivation involve repetitive and forced movements of the upper limbs. These body members need to be analysed.

The method selected was RULA (The Rapid Upper Limb Assessment; McAtamney and Corlett, 1993). It has been successfully used in agriculture (Gómez-Galán et al., 2020). It is notable for its detailed assessment of the arm, forearm, and wrist (McAtamney and Corlett, 1993).

The OWAS and RULA methods contain significant differences, allowing a more detailed semi-quantitative MSD analysis to be performed.

### 2.3. Assessment methods

The OWAS method classifies postures into 252 possible combinations, depending on the position of the back, arms, legs and the load held. From the analysis, risk levels are obtained. The method assesses a set of postures over a period of time. The right and left sides of the body are analysed together (Karhu et al., 1977).

The RULA method focuses on MSDs of the upper limbs. It considers the posture adopted, the frequency of the activity, and the load involved. It classifies body members into two groups: group A (arm, forearm, and wrist) and group B (neck, trunk, and legs). From the analysis, the action level is obtained. The method assesses individual postures, those involving the greatest postural load. The right and left sides of the body are assessed separately (McAtamney and Corlett, 1993).

The application of these methods to greenhouse cucumber cultivation is detailed below:

*PHASE 1: Observation (Common for both methods).*

- Visit to the greenhouse. On-site observation of all the tasks via video recording.

Field work: The greenhouse is visited on the days that the farmer is working during the cucumber cultivation season. Safe areas are selected for recording, without obstructing the worker's path. An evaluator records with the camera, moving along the greenhouse lines as the worker progresses.

To obtain the images necessary for the application of the OWAS method, a considerable recording time is required. A minimum observation time is set for each task (10 min) but it is advisable to record 20 min or more to have sufficient material, since in the analysis phase some images will be discarded. It is recorded from several perspectives, ensuring that the three parts of the body evaluated by the method and the load held are visualized. Recording of the same task should be continuous as far as possible, in order not to lose any of the postures adopted by the farmer.

For the RULA method, the recording is carried out considering that the images obtained must be parallel to the camera plane so that the angles can be measured in true magnitude. Videos are made of the right and left sides of the body.

- Identification of the tasks and postures involved in cucumber cultivation, carried out by two evaluators trained in occupational risk prevention.

*PHASE 2: Image Selection and Assessment (Independent for Each Method).*

**Table 2**
Selection of the method type (YES: This method category can be used; NO: It is not possible to use this method category).

| Method selection criteria (Takala et al., 2010) | Definition for this research | Requirements for this research | Direct reading methods | Semi-quantitative methods | Self-reported methods |
|---|---|---|---|---|---|
| *Purpose* | The purpose is to assess the postures adopted by the workers and the repetitive movements made during the different cucumber crop tasks in order to analyse MSDs – not to assess a group of workers, but rather their postures. | – Assessment of postures.<br>– Assessment of repetitive movements.<br>– Assessment exclusively of MSD and not of psychosocial disorders.<br>– Participation of only a few workers. The sample of the study is postures. | YES | YES | **NO**<br>They are discarded since these methods must be applied to a large number of workers to obtain accurate results (Abdesalam et al., 2023). |
| *Task characteristics* | Agriculture is characterized by highly repetitive work and physical demands (Das, 2023). The workplace (greenhouse) does not guarantee the workers' comfort (Callejón-Ferre et al., 2009). It involves exposure to very high temperatures during certain months (von Elsner et al., 2000). | –Non-invasive methods to avoid discomfort.<br>– Application of the method in the workplace. | **NO**<br>They are discarded due to the complexity of applying them in situ, being better suited for use in the laboratory (Alberto et al., 2018). Placing sensors on the body of agricultural workers while they carry out their greenhouse work is uncomfortable for them. | YES | YES |
| *Assessors* | Assessors with training in occupational risk prevention, MSD assessment methods, and engineering (the use of specific technological equipment and software). | –The assessors in this study have degrees in the field of engineering and occupational risk prevention. | YES | YES | YES |
| *Data collection and analysis tools* | Low-cost or free-license tools. | –Limited financial resources. | **NO**They are discarded on cost grounds as considerable financing is needed to acquire the necessary equipment (David, 2005). | YES | YES |

o Selection of images containing the postures to be analysed:

*OWAS:* Images showing the worker's posture are selected every 5 s, using Kinovea software (Kinovea, 2025), a video analysis tool that allows images to be downloaded automatically by entering a sampling time. Invalid images are manually deleted. The selected time (5 s) is low, since farmers change posture frequently due to the repetitive nature of the tasks. With a longer time, consecutive postures would not be considered. 50 postures are selected for each task.

*RULA:* According to the authors of the method, the postures held for the longest time or with the greatest postural load are selected by sight (McAtamney and Corlett, 1993). Therefore, the most repeated ones and those that the farmer reported were most uncomfortable were selected. The side of the body that is considered most affected by observation is evaluated, and in case of doubt, both.

o Posture Assessment:

OWAS: Each posture is assigned a 4-digit code (Appendix A). The codes, which are classified by tasks, are then introduced into the Ergomet software *(*INERMAP, 2011*)*. The risk level of each posture and each part of the body is obtained independently, in addition to the repetition percentages.

RULA: The angles formed by the different parts of the body are measured with AutoCAD and the postures are analysed. The data are entered into the Ergomet software *(*INERMAP, 2011*)* and one score is obtained for group A and another for group B. These scores are modified according to the frequency of the activity (static, repetitive, occasional) and the load handled, obtaining C and D scores. With theses, one obtains a final score that provides the risk level (Appendix B).

The selection and analysis of postures are carried out by two evaluators trained in occupational risk prevention.

*PHASE 3: Proposals for improvement (Common for both methods).*

o If necessary, improvement measures to prevent MSD are proposed.

### 2.4. Study material

The following material was used for the research:

o *Xiaomi POCO X3 NFC mobile camera.* For video recording during the observation period. It has a quad rear camera and its lens features are:
- Main 64 megapixel camera.
- 13 megapixel ultra wide angle camera.
- 2 megapixel macro camera.
- 2 megapixel depth camera. 1.75 μm pixel.

o *Kinovea Software.* To support image selection at certain time intervals (5 s with the OWAS method).
o *AutoCAD software.* For measuring the angles between different body zones.
o *Ergomet 3 software (*INERMAP, 2011*).* For data analysis and obtaining results using the OWAS and RULA methods.
o *DAZ Studio 4.16 Pro and Adobe Photoshop CS6 software.* 3D modelling to represent some of the positions taken by the workers (Appendix C).

### 2.5. Cultivation work and tasks

Cucumber cultivation is divided into tasks (T), 18 in total (Appendix C), that were carried out during the cultivation cycle (from October 24th to June 2nd):

o Transplant furrow (T1): Holes are made to place the cucumber seedling.
o Hole making (T2): Holes are punctured to place the cucumber seedling.

- o Seedling placement (T3): The seedlings are placed.
- o Planting seedling (T4): The seedling is buried manually.
- o Anchoring (T5): When the plant begins to grow, it is tied to an upper thread so that it grows vertically.
- o Plant trellis at medium–low height (T6): As the plant grows, it is guided by the vertical thread so that it grows straight. The task is recorded when the plant is of medium–low height.
- o Plant trellis at elevated height (T7): The task is recorded when the plant is at its maximum height. It is fixed to the top of the thread with a plant clip.
- o Phytosanitary treatments (T8): Chemicals are applied to prevent and eliminate pests or diseases in the plant.
- o Introducing auxiliary fauna (T9): To prevent pests. Sachets with auxiliary fauna are placed at a medium height from the plant.
- o Thinning the plant (T10): Using pliers, leaves are removed from the plant to encourage its growth.
- o Tipping the plant (T11): The plant is supported by a horizontal thread so that it can continue growing in the downward direction of the thread.
- o Picking 1 (T12): The cucumbers are collected and placed in boxes. After collecting several lines from the greenhouse, the boxes are manually placed on a pallet. Cucumbers are not harvested from a specific part, but from the lower, middle or upper part. This task refers to the harvesting prior to tipping the plant.
- o Picking 2 (T13): This task refers to the harvesting of the cucumber after tipping the plant.
- o Driving forklift (T14): A forklift is used to introduce the pallets with the boxes into the greenhouse. When they are full of cucumbers, they are removed outside and placed in a truck for distribution.
- o Sweeping (T15): The greenhouse is swept to remove leaves, roots, etc.
- o Root pulling (T16): The root of the plant is pulled out with a sickle and then removed from the greenhouse.
- o Cutting down the plant (T17): The plant is placed in the ground once the entire cucumber has been collected and its root has been removed.
- o Leaf blowing (T18): A blower is used to remove any remaining leaves.

The postures adopted by workers during these tasks have been evaluated and selected according to the OWAS and RULA methods.

## 3. Results

### 3.1. OWAS method results

A total of 50 positions adopted by workers for each task (T1-T18) were assessed. The study sample comprised 900 postures adopted by the workers over the entire cucumber cultivation period.

Table 3 shows the level of risk by task according to OWAS. The most common level is 1, present in 16 of the 18 tasks. T2 (Hole making), T8 (Phytosanitary treatments) and T18 (Leaf blowing) stand out, since 100 % of these postures fall within this risk level.

Risk level 2 is the next most common, featuring 15 tasks. It is worth mentioning T14 (Driving forklift) and T16 (Root pulling), which have more than 95 % of the postures belonging to this level.

Higher risk levels (levels 3 and 4) are less frequent. Level 3 is present in 7 tasks, the highest risk being in T4 (Planting seedlings) at 72 %. Level 4 only appears in T1 (Transplant furrow) with a 4 % risk.

Table 3 also presents the level of risk by posture and task. T18 (Leaf blowing) is characterized by a single posture with straight back, arms below the shoulders, walking, and a load less than 10 kg (code 1171),

**Table 3**
Risk levels by posture and task.

| | Posture Codes and Repetition Percentages | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **T1 - Transplant Furrow** | 2131 | 2241 | 2141 | 2151 | 2231 | 2251 | 1141 | 2221 | 2121 | 4231 | 4241 | 4151 |
| | 26% | 10% | 4% | 16% | 12% | 6% | 2% | 4% | 6% | 10% | 2% | 2% |
| **T10 - Thinning the Plant** | 1121 | 1131 | 1141 | 1171 | 1221 | 1231 | 1321 | 1331 | 2121 | 2131 | 2221 | |
| | 26% | 6% | 4% | 8% | 2% | 2% | 8% | 2% | 38% | 2% | 2% | |
| **T13 - Picking 2** | 1121 | 1131 | 1141 | 1171 | 1221 | 2121 | 2131 | 2141 | 2171 | 3121 | 4121 | |
| | 10% | 2% | 6% | 6% | 8% | 32% | 12% | 4% | 4% | 6% | 10% | |
| **T17 - Cutting down the plant** | 1321 | 2221 | 1171 | 2121 | 1231 | 1221 | 2231 | 1131 | 1121 | 2131 | | |
| | 20% | 2% | 20% | 26% | 2% | 12% | 2% | 4% | 10% | 2% | | |
| **T5 - Anchoring** | 4231 | 2121 | 2141 | 2131 | 2231 | 4221 | 1121 | 4131 | 2241 | | | |
| | 8% | 44% | 20% | 8% | 4% | 4% | 2% | 8% | 2% | | | |
| **T4 - Planting Seedling** | 2141 | 2121 | 2131 | 2151 | 2221 | 2241 | 2231 | 2321 | | | | |
| | 48% | 12% | 6% | 2% | 2% | 22% | 6% | 2% | | | | |
| **T7 - Plant trellis at elevated height** | 1321 | 1121 | 1221 | 1131 | 3121 | 2221 | 3321 | | | | | |
| | 48% | 18% | 14% | 4% | 4% | 8% | 4% | | | | | |
| **T9 - Introducing auxiliary fauna** | 1121 | 1131 | 1171 | 2121 | 2131 | 2141 | 2151 | | | | | |
| | 42% | 2% | 8% | 30% | 10% | 2% | 6% | | | | | |
| **T15 - Sweeping** | 1121 | 1171 | 2121 | 2131 | 2141 | 2151 | 2171 | | | | | |
| | 10% | 8% | 40% | 28% | 4% | 4% | 6% | | | | | |
| **T16 - Root pulling** | 2321 | 2121 | 2221 | 2131 | 2171 | 1121 | 1171 | | | | | |
| | 4% | 72% | 12% | 6% | 2% | 2% | 2% | | | | | |
| **T3 - Seedling Placement** | 2131 | 2121 | 1171 | 1121 | 2141 | 1131 | | | | | | |
| | 80% | 4% | 8% | 2% | 2% | 4% | | | | | | |
| **T11 - Tipping the plant** | 1131 | 1221 | 1321 | 1121 | 2221 | 2321 | | | | | | |
| | 14% | 26% | 46% | 10% | 2% | 2% | | | | | | |
| **T12 - Picking 1** | 1121 | 2121 | 1171 | 1221 | 1321 | | | | | | | |
| | 58% | 24% | 2% | 12% | 4% | | | | | | | |
| **T2 - Hole Making** | 1121 | 1131 | 1231 | 1221 | | | | | | | | |
| | 76% | 6% | 2% | 16% | | | | | | | | |
| **T8 - Phytosanitary treatments** | 1171 | 1121 | 1271 | 1221 | | | | | | | | |
| | 72% | 24% | 2% | 2% | | | | | | | | |
| **T6 - Plant trellis at medium-low height** | 1121 | 1131 | 1141 | | | | | | | | | |
| | 88% | 10% | 2% | | | | | | | | | |
| **T14 - Driving forklift** | 2111 | 4111 | 1121 | | | | | | | | | |
| | 84% | 14% | 2% | | | | | | | | | |
| **T18 - Leaf Blowing** | 1171 | | | | | | | | | | | |
| | 100% | | | | | | | | | | | |

Risk level 1
Risk level 2
Risk level 3
Risk level 4

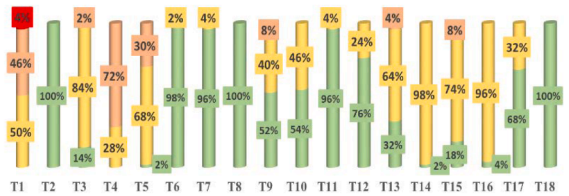



*Table 3. Risk levels by posture and task.*

**Table 4**
Risk levels by body area.

| | Back | | | | Arms | | | Legs | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| **T1** | 2% | 84% | 0% | 14% | 56% | 44% | 0% | 0% | 10% | 48% | 18% | 24% | 0% | 0% |
| **T2** | 100% | 0% | 0% | 0% | 82% | 18% | 0% | 0% | 92% | 8% | 0% | 0% | 0% | 0% |
| **T3** | 14% | 86% | 0% | 0% | 100% | 0% | 0% | 0% | 6% | 84% | 2% | 0% | 0% | 8% |
| **T4** | 0% | 100% | 0% | 0% | 68% | 30% | 2% | 0% | 16% | 12% | 70% | 2% | 0% | 0% |
| **T5** | 2% | 78% | 0% | 20% | 82% | 18% | 0% | 0% | 50% | 28% | 22% | 0% | 0% | 0% |
| **T6** | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 88% | 10% | 2% | 0% | 0% | 0% |
| **T7** | 88% | 4% | 8% | 0% | 30% | 18% | 52% | 0% | 92% | 8% | 0% | 0% | 0% | 0% |
| **T8** | 100% | 0% | 0% | 0% | 96% | 4% | 0% | 0% | 26% | 0% | 0% | 0% | 0% | 74% |
| **T9** | 52% | 48% | 0% | 0% | 100% | 0% | 0% | 0% | 72% | 12% | 2% | 6% | 0% | 8% |
| **T10** | 58% | 42% | 0% | 0% | 84% | 6% | 10% | 0% | 76% | 12% | 4% | 0% | 0% | 8% |
| **T11** | 96% | 4% | 0% | 0% | 24% | 28% | 48% | 0% | 86% | 14% | 0% | 0% | 0% | 0% |
| **T12** | 76% | 24% | 0% | 0% | 84% | 12% | 4% | 0% | 98% | 0% | 0% | 0% | 0% | 2% |
| **T13** | 32% | 52% | 6% | 10% | 92% | 8% | 0% | 0% | 66% | 14% | 10% | 0% | 0% | 10% |
| **T14** | 2% | 84% | 0% | 14% | 100% | 0% | 0% | 98% | 2% | 0% | 0% | 0% | 0% | 0% |
| **T15** | 18% | 82% | 0% | 0% | 100% | 0% | 0% | 0% | 50% | 28% | 4% | 4% | 0% | 14% |
| **T16** | 4% | 96% | 0% | 0% | 84% | 12% | 4% | 0% | 90% | 6% | 0% | 0% | 0% | 4% |
| **T17** | 68% | 32% | 0% | 0% | 62% | 18% | 20% | 0% | 70% | 10% | 0% | 0% | 0% | 20% |
| **T18** | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |

Risk level 1 Risk level 2 Risk level 3 Risk level 4

T1: Transplant Furrow; T2: Hole Making; T3: Seedling Placement; T4: Planting Seedling; T5: Anchoring; T6: Plant trellis at medium-low height; T7: Plant trellis at elevated height; T8: Phytosanitary treatments; T9: Introducing auxiliary fauna; T10: Thinning the Plant; T11: Tipping the plant; T12: Picking 1; T13: Picking 2; T14: Driving forklift; T15: Sweeping; T16: Root pulling; T17: Cutting down the plant; T18: Leaf Blowing

which is associated with the lowest risk level. T1 (Transplant furrow) includes the widest variety of postures, a total of 12, of which the rotated and flexed back, one arm raised, legs flexed, with balanced weight and a load less than 10 kg (code 4241) and the rotated and flexed back, arms below the shoulders, legs flexed with unbalanced weight and a load less than 10 kg (code 4151) stand out. Both are associated with the highest risk level although they only account for 4 % of the task postures. The load handled during all the tasks is less than 10 kg.

Finally, the risk levels are presented according to the positions of each part of the body assessed (Table 4). The farmer performs most tasks with the back completely straight or with the back bent. T4 (Planting seedling) and T16 (Root pulling) are always carried out with the back bent over, so they are associated with risk level 3. In contrast, T8 (Phytosanitary treatments) and T18 (Leaf blowing) are always performed with a straight back, so their risk level is 1. The most unfavourable back position (rotated and inclined) is present in various tasks with a repetition percentage equal to or less than 20 %, for which the associated risk level is 2.

The arms are usually below the shoulders (minimal risk level). The highest risk level in which one or both arms are raised is level 2, which is the case for only three tasks.

Throughout the cultivation, the legs are usually straight, or one is flexed and one straight. Of the latter, T3 (Seedling placement) stands out, for which the risk level is 3 since it is a much-repeated position. This level of risk is also present in T4 (Planting seedlings) for weight-balanced, flexed legs.

### 3.2. RULA method results

A total of 49 images corresponding to the 18 tasks were analysed. For each one, the right side of the body, the left side, or both were analysed according to the repetitiveness or greater postural load.

Table 5 shows the angles measured for each posture (P) according to the RULA method, the scores, and their associated risk level. The highest C score is 7 points, which is highlighted in T1 (Transplant furrow) for the right side of the body (P1) and T12 (Picking 1) for the left side (P17). The highest D score (8 points) is present in T1 (Transplant Furrow), T4 (Planting seedling), T5 (Anchoring), T7 (Plant trellis at elevated height) and T16 (Root pulling), in all cases, for both sides of the body (P1, P5, P6, P8 and P24).

Regarding the total score, a value of 7 corresponds to the highest risk (level 4). This is present in 8 of the tasks analysed. Of these, T1 (Transplant furrow) and T10 (Plant Thinning) are the only ones where the risk changes to the left side of the body (level 3). The lowest risk level is 2, present in 8 tasks. This level is identical for both sides of the body, except in T2 (Hole Making) for P2.

## 4. Discussion

The combined flexion of the back and legs in these workers (T1: Transplant furrow, T4: Planting seedling and T5: Anchoring; Appendix C; Tables 3 and 5) may be due to the crawling nature of some tasks. These facts are consistent with the studies by Riemer and Bechar (2016) and Kee (2022).

Back flexion combined with a straight leg position (example: posture 2121; Table 3), can cause lumbar compression (Pinzke & Lavesson, 2018). This is one the most affected back area in various crops (McMillan et al., 2015), with an MSD prevalence of 74 % (Varguese and Panicker, 2022). In tasks such as “Introducing auxiliary fauna” (T9, Appendix C), back flexion (Tables 4 and 5) could be reduced using collaborative robots (Yerebakan and Hu, 2024).

Flexion and rotation of the back in a seated position (T14: Driving

**Table 5**
Angles obtained for each part of the body.

| Task | Posture | Side | Angles | | | | | Scores | | | Risk |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Arm | Forearm | Wrist | Neck | Trunk | C | D | Total | |
| T1 | P1 | Rgt | 95° | 26° | 12° | 24° | 96° | 7 | 8 | 7 | |
| T1 | P1 | Left. | 50° | 38° | 7° | 22° | 78° | 4 | 8 | 6 | |
| T2 | P2 | Rgt | 7° | 31° | 0° | 33° | 1° | 3 | 4 | 4 | |
| T2 | P2 | Left. | 103° | 39° | 14° | 28° | 5° | 5 | 4 | 5 | |
| T3 | P3 | Rgt | 17° | 41° | 21° | 13° | 33° | 4 | 6 | 6 | |
| T3 | P3 | Left. | 57° | 33° | 0° | 15° | 78° | 3 | 6 | 5 | |
| T3 | P4 | Rgt | 61° | 46° | 6° | 26° | 104° | 4 | 7 | 6 | |
| T4 | P5 | Rgt | 99° | 23° | 13° | 22° | 106° | 5 | 8 | 7 | |
| T4 | P5 | Left. | 102° | 13° | 13° | 32° | 102° | 5 | 8 | 7 | |
| T5 | P6 | Rgt | 95° | 10° | 5° | 14° | 99° | 5 | 8 | 7 | |
| T5 | P6 | Left. | 65° | 65° | 5° | 15° | 106° | 5 | 8 | 7 | |
| T6 | P7 | Rgt | 44° | 60° | 27° | 18° | 2° | 4 | 3 | 3 | |
| T6 | P7 | Left. | 41° | 49° | 7° | 18° | 3° | 3 | 3 | 3 | |
| T7 | P8 | Rgt | 109° | 25° | 0° | 29° | 6° | 5 | 8 | 7 | |
| T7 | P8 | Left. | 110° | 34° | 8° | 26° | 8° | 5 | 8 | 7 | |
| T7 | P9 | Rgt | 112° | 43° | 16° | 23° | 21° | 4 | 7 | 6 | |
| T8 | P10 | Rgt | 15° | 100° | 9° | 18° | 3° | 3 | 3 | 3 | |
| T8 | P10 | Left. | 8° | 98° | 18° | 20° | 11° | 3 | 3 | 3 | |
| T8 | P11 | Rgt | 119° | 15° | 18° | 25° | 4° | 4 | 3 | 3 | |
| T9 | P12 | Rgt | 41° | 38° | 19° | 12° | 24° | 4 | 5 | 5 | |
| T9 | P12 | Left. | 40° | 39° | 45° | 20° | 20° | 4 | 5 | 5 | |
| T10 | P13 | Rgt | 75° | 56° | 25° | 13° | 41° | 6 | 7 | 7 | |
| T10 | P13 | Left. | 49° | 41° | 8° | 7° | 50° | 4 | 7 | 6 | |
| T11 | P14 | Rgt | 121° | 15° | 56° | 26° | 14° | 6 | 6 | 7 | |
| T11 | P14 | Left. | 96° | 73° | 8° | 32° | 12° | 5 | 6 | 7 | |
| T12 | P15 | Rgt | 104° | 20° | 26° | 11° | 0° | 6 | 2 | 4 | |
| T12 | P15 | Left. | 81° | 46° | 19° | 14° | 12° | 4 | 2 | 3 | |
| T12 | P16 | Rgt | 33° | 38° | 10° | 21° | 51° | 4 | 6 | 6 | |
| T12 | P17 | Rgt | 54° | 64° | 46° | 8° | 4° | 6 | 3 | 5 | |
| T12 | P17 | Left. | 70° | 42° | 0° | 5° | 0° | 7 | 3 | 6 | |
| T13 | P18 | Rgt | 58° | 62° | 19° | 13° | 3° | 5 | 3 | 4 | |
| T13 | P18 | Left. | 38° | 54° | 8° | 10° | 1° | 4 | 3 | 3 | |
| T13 | P19 | Rgt | 118° | 17° | 12° | 27° | 15° | 4 | 6 | 6 | |
| T13 | P20 | Rgt | 56° | 25° | 10° | 17° | 37° | 5 | 5 | 6 | |
| T14 | P21 | Rgt | 52° | 38° | 24° | 12° | 12° | 5 | 3 | 4 | |
| T14 | P21 | Left. | 58° | 78° | 14° | 15° | 15° | 5 | 3 | 4 | |
| T15 | P22 | Rgt | 11° | 88° | 72° | 45° | 20° | 3 | 5 | 4 | |
| T15 | P22 | Left. | 21° | 46° | 14° | 23° | 25° | 3 | 5 | 4 | |
| T15 | P23 | Rgt | 99° | 49° | 10° | 29° | 108° | 4 | 5 | 5 | |
| T16 | P24 | Rgt | 68° | 42° | 11° | 18° | 91° | 5 | 8 | 7 | |
| T16 | P24 | Left. | 70° | 58° | 10° | 5° | 83° | 5 | 8 | 7 | |
| T16 | P25 | Rgt | 100° | 23° | 27° | 17° | 92° | 4 | 7 | 6 | |
| T16 | P25 | Left. | 92° | 22° | 6° | 8° | 83° | 4 | 7 | 6 | |
| T17 | P26 | Rgt | 69° | 54° | 15° | 29° | 95° | 5 | 6 | 7 | |
| T17 | P26 | Left. | 96° | 6° | 9° | 38° | 93° | 5 | 6 | 7 | |
| T17 | P27 | Rgt | 114° | 33° | 37° | 13° | 8° | 4 | 7 | 6 | |
| T17 | P27 | Rgt | 110° | 13° | 9° | 41° | 2° | 4 | 7 | 6 | |
| T18 | P28 | Rgt | 12° | 47° | 14° | 16° | 0° | 3 | 3 | 3 | |
| T18 | P28 | Left. | 8° | 20° | 11° | 19° | 0° | 2 | 3 | 3 | |

Action level 1 Action level 2 Action level 3 Action level 4

T1: Transplant Furrow; T2: Hole Making; T3: Seedling Placement; T4: Planting Seedling; T5: Anchoring; T6: Plant trellis at medium-low height; T7: Plant trellis at elevated height; T8: Phytosanitary treatments; T9: Introducing auxiliary fauna; T10: Thinning the Plant; T11: Tipping the plant; T12: Picking 1; T13: Picking 2; T14: Driving forklift; T15: Sweeping; T16: Root pulling; T17: Cutting down the plant; T18: Leaf Blowing

forklift; Appendix C; Tables 3, 4 and 5) is due to the driver's seat not offering good lumbar support and that the forklift does not have mirrors for controlled manoeuvring. Seats designed using anthropometric data and technical characteristics (Mehta et al., 2008) along with indirect camera and monitor visualization would improve the postures of these agricultural workers (Rakhra and Mann, 2013).

Taking all of the above into account, it seems apparent that these workers can develop MSDs in the back and legs (Tables 4 and 5), body areas that are usually affected in agriculture (Ulrey and Fathallah, 2013; Min et al., 2016). The ergonomic load occurring due to recurrent back flexion is high (T1: Transplant furrow, T3: Seedling placement, T4: Planting seedling, T14: Driving forklift, T15: Sweeping, T16: Root pulling and T17: Cutting down the plant; Table 4), as described by Baek et al. (2023). Something similar happens with the flexion of one or both legs (T3: Seedling placement, T4: Planting seedling and T5: Anchoring; Table 4), which is also affected by the uneven ground surface (sanded greenhouse). Straining the legs is common in tasks that are carried out on earthy terrain (Juntaracena et al., 2018).

Arm elevation (Tables 3, 4 and 5) is mainly due to trellising work being frequently carried out in the upper tiers of the plant (T7: Plant trellis at elevated height and T11: Tipping the plant; Appendix C). Determining the optimal working height when doing this work in a greenhouse (Vazquez-Cabrera, 2016) or using tools to prevent injuries (Gobor et al., 2013) would be measures allowing work to be done with the arms below shoulder level.

The most serious musculoskeletal disorders can prevent farmers from

carrying out their usual work (McMillan et al., 2015; Min et al., 2016). The risks obtained for cucumber cultivation do not result in the incapacity of workers. Nonetheless, it is essential to implement measures as soon as possible to reduce such disorders; for example, ergonomic training for workers, rotation between tasks, rest periods, mechanization of tasks (Barneo-Alcantara et al., 2021), improvement in physical condition (Sharan and Ajeesh, 2012), incorporating participatory ergonomics (INSST, 2020), equipment-use training (Mehta et al., 2018) or redesigning tools used in the greenhouse (Jain et al., 2018).

The risks found using RULA are generally higher than those found using OWAS. This is because the former analyses the most detrimental posture of each task and the latter evaluates a set of postures (McAtamney and Corlett, 1993; Karhu et al., 1977).

Part of this study could be extrapolated to other cucumber farms around the world if crop management is similar. Example: using a trellis, in a greenhouse with a plastic cover, in similar latitudes, similar varieties, etc. In other studies of musculoskeletal evaluations with other crops (Bae et al., 2011; Kim et al., 2006) this fact has been contrasted, identifying that the risk of MSD was the same for melon harvesting tasks in different parts of the world.

Regarding this study's limitations, they concern the following:

- The assessor's subjectivity while carrying out the image analysis. Two evaluators were involved in this study. Including a third evaluator could help with a more accurate analysis.
- The recording of work not being continuous because the agricultural worker takes breaks or moves to other areas of the greenhouse. This causes the 5-second interval used for the selection of postures to not always be constant. Breaks and movements are not considered material for analysis, only the postures during the performance of the task.
- There are tasks where recording may be compromised. This is the case of "phytosanitary treatments", since during the recording there is a mist of the fluid that does not allow the image to be seen perfectly. In addition, evaluators sometimes keep a distance for safety reasons, which means using zoom.

## 5. Conclusions

Cucumber agricultural workers in Andalusian greenhouses are at risk of suffering musculoskeletal disorders as a result of certain tasks. The tasks that present the greatest danger to workers are T1 (Transplant Furrow), T4 (Planting Seedlings) and T5 (Anchoring).

The body area most affected during this cultivation is the back, and it is important to avoid continuous flexion as much as possible. Arm elevations and leg flexions also lead to high levels of risk.

To prevent musculoskeletal disorders, it is recommended that cucumber farmers warm up 15 min before starting their workday. The upper and lower limbs and back could be mobilized, performing slow and unforced movements. At the end of the workday, workers should also stretch, holding each exercise for approximately 15 s.

Using mechanization as much as possible is also recommended to reduce MSDs, although it is not very developed for greenhouse agriculture.

The use of tools with extendable handles to adjust them to the height of the worker in tasks such as "hole making", the use of carts to perform tasks while sitting in tasks such as "transplant furrow", "seedling placement", "planting seedling" or "anchoring" and the use of pneumatic or electric scissors for "thinning the plant" are good alternatives to reduce MSDs.

Other measures relating to work management include taking breaks, alternating between different tasks, training workers on postural stress, improving their physical condition and efficient organisation.

Part of this study could be extrapolated to other crop farmers working under similar conditions.

## CRediT authorship contribution statement

**Salvador De-Benavides-Jiménez:** Writing – review & editing, Writing – original draft, Visualization, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Marta Gómez-Galán:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Juan-Carlos Rubio-Romero:** Writing – review & editing, Supervision, Resources, Methodology, Investigation, Conceptualization. **Manuel Díaz-Pérez:** Writing – review & editing, Supervision, Resources, Methodology, Investigation, Conceptualization. **Ángel-Jesús Callejón-Ferre:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

## Funding

This work was supported by the Laboratory-Observatory in Andalusian Working Conditions in the Agricultural Sector (LASA) [grant number 301315]; and Research Group TEP987 of the University of Almería [grant number 500189].

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgement

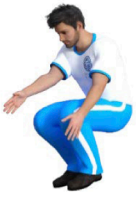
The authors would like to acknowledge the assistance received from the *Instituto Andaluz de Prevención de Riesgos Laborales (IAPRL)* and the Laboratory-Observatory in Andalusian Working Conditions in the Agricultural Sector. Also, to Full Professor Juan-Carlos Rubio-Romero, as this idea arose during the research stay carried out by Marta Gómez-Galán under his supervision in the 2021–22 academic year in the Department of Economics and Business Administration at the University of Malaga (Spain).

## Appendix A:. OWAS method

.

**Table A1**
OWAS coding and risk levels (Karhu et al., 1977).

| 1ST DIGIT: BACK POSITION | | | | 2ND DIGIT: ARM POSITION | | |
|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |
| 1 Straight | 2 Bent (incline>20°) | 3 Twisted | 4 Bent and twisted | 1 Low | 2 One low and one high | 3 Both elevated |

| 3RD DIGIT: LEG POSITION | | | | | | |
|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |
| 1 Seated | 2 Standing, straight Legs | 3 Standing, leg straight (thigh-calf angle>150°) and bent | 4 Standing or squatting, legs bent, and weight balanced | 5 Standing or squatting, legs bent, and weight unbalanced | 6 On your knees (one or two supported) | 7 Walking |

| 4TH DIGIT: LOAD LIFTED | | | RISK LEVELS ACCORDING TO OWAS | | | |
|---|---|---|---|---|---|---|
|  |  |  | Non-detrimental posture. No actions to take. | Posture that can be harmful. Corrective actions in a short period of time. | Harmful posture. Corrective actions in the shortest possible time. | Very harmful posture. Immediate corrective actions. |
| < 10 kg | 10-20 kg | >20 kg | | | | |
| 1 | 2 | 3 | 1 | 2 | 3 | 4 |

## Appendix B:. RULA method

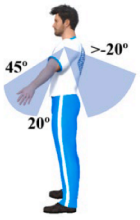
.

**Table B1**
RULA scores and risk levels (McAtamney and Corlett, 1993).

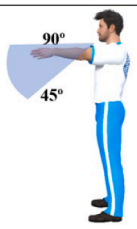
**GROUP A SCORE**

**ARM SCORE**


1
20° to extension to 20 ° to flexion




2
Extension > 20°
20° < Flexion < 45°




3
45° < Flexion < 90°


4
Flexion > 90°

**MODIFICATION OF ARM SCORE**

+1
Raised shoulder or rotated arm

+1
Abducted Arms

-1
There's a point of support

**FOREARM SCORE**


1
60° < Flexion < 100°

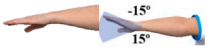

2
Flexion < 60°
Flexion > 100°

**FOREARM SCORE MODIFICATION**

+1
On one side of the body

+1
Crossing the midline

**WRIST SCORE**




1
Neutral position

2
Flexion or extension > 0° and < 15°


3
Flexion > 15°

**WRIST SCORE MODIFICATION**

+1
Radial deflection

+1
Cubital deflection

**TWISTED WRIST SCORE**

1
With/without pronation or median supination

2
Extreme pronation or supination

**GROUP B SCORE**

**NECK SCORE**


1
0° < Flexion ≤ 10°


2
10° < Flexion ≤ 20°


3
Flexion > 20°


4
Extension of any degree

**MODIFICATION OF NECK SCORE**

+1
Head Rotation

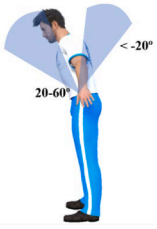
+1
Lateral head inclination

**TRUNK SCORE**

**TRUNK SCORE**

(continued on next page)

**Table B1** (*continued*)

| | | | | MODIFICATION | |
|---|---|---|---|---|---|
|  |  |  |  |  |  |
| 1<br>Sitting or well supported Trunk-hip angle 90º | 2<br>Flexion between 0º and 20º | 3<br>20º < Flexion ≤ 60º | 4<br>Flexion > 60º | +1<br>Trunk Rotation | +1<br>Lateral inclination of the trunk |

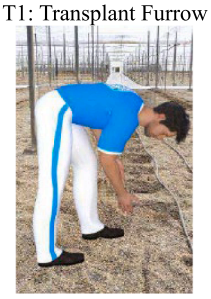
| LEG SCORE | | | C & D SCORE | ACTIVITY FREQUENCY | LOAD |
|---|---|---|---|---|---|
|  |  |  | The A and B scores can be increased according to the frequency of the activity and the load handled, becoming C and D scores, respectively. | a) Static (more than 1 min)<br>b) Repetitive (more than 4 times in 1 min) | a) 2 to 10 kg (intermittent)<br>b) 2 to 10 kg (static or repetitive)<br>c) >10 kg (intermittent)<br>(d) >10 kg (static or repetitive)<br>(e) Sudden loads |
| 1<br>Sitting with legs and feet well supported | 1<br>Standing with balanced weight | 2<br>Both feet are not supported, or the weight is not balanced | A → C<br>B → D | *a) y b) +1* | a) *+1*; b) y c) *+2*; d) y e) *+3* |

| RISK LEVELS ACCORDING TO OWAS | | | | |
|---|---|---|---|---|
| Score | 1-2 | 3-4 | 5-6 | 7 |
| Action | Acceptable Risk | Work action may be necessary. | Redesign the work. | Urgent modifications. |
| Risk Level | 1 | 2 | 3 | 4 |

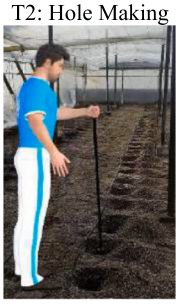
**Appendix C:. Cucumber cultivation phases and tasks**

**Transplantation**

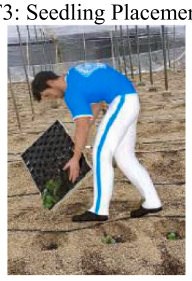
T1: Transplant Furrow



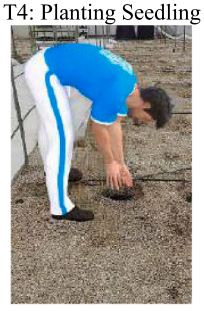
T2: Hole Making



T3: Seedling Placement



T4: Planting Seedling



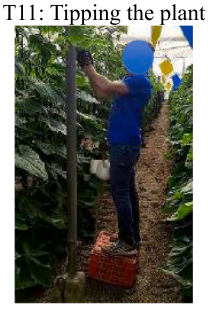
**Plant training**

T5: Anchoring

T6: Plant trellis at medium-low height

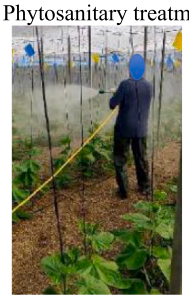
T7: Plant trellis at elevated height

T11: Tipping the plant



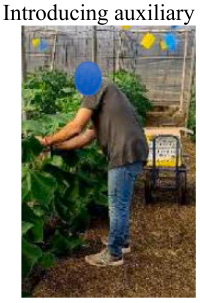
**Phytosanitary treatments**

T8: Phytosanitary treatments



**Use of auxiliary fauna**

T9: Introducing auxiliary fauna

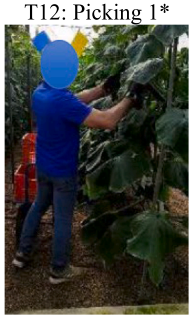


**Pruning**

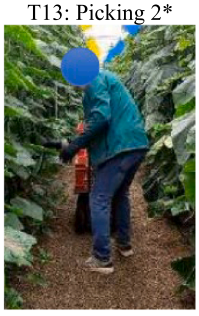
T10: Thinning the Plant

**Picking**

T12: Picking 1*



T13: Picking 2*

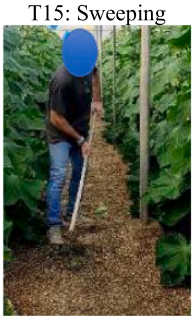


T14: Driving forklift

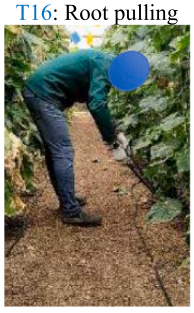
**Picking 1 is prior to the overturning of the plant and picking 2 is subsequent to overturning the plant.*

**Cleaning**

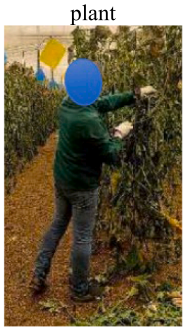
T15: Sweeping



T16: Root pulling



T17: Cutting down the plant



T18: Leaf Blowing

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