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Association between musculoskeletal symptoms and psychosocial factors in tropical crop workers of Spain using standardized Nordic questionnaire and Mini Psychosocial Factors method

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ABSTRACT

Southern Spain (Andalusia) is the only region in Europe capable of producing tropical fruits (avocado, cherimoya, and mango). The sector employs more than 4000 workers. The objective of this research is the integrated assessment of musculoskeletal symptoms and psychosocial factors of tropical crop workers in Andalusia using the 'Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms (NMQ)' and 'Mini Psychosocial Factors (MPF) method'. NMQ is a 28-question multiple-choice questionnaire covering the neck, shoulders, elbows, wrists/hands, back, hips, knees, and ankles. The MPF method comprises 15 questions and analyses a total of 12 psychosocial variables (Autonomy, Compensation, Control, Demands, Emotional, Health, Mental Load, Mobbing, Recognition, Relationships, Rhythm, and Support). In total, 401 interviews were completed with an error/accuracy of 4.66%. The method for selecting the agricultural plots where the workers work was carried out in a random, non-stratified way using UTM (Universal Transverse Mercator) coordinates. Multiple correspondence analysis, the Burt table, and descriptive statistics (with a chi-square test) were used to analyse the results. The results indicate that no high risk exists in any of the psychosocial factor although there is a medium risk. The psychosocial factor "Compensation" stands out. Musculoskeletal symptoms are identified in the back and neck. The symptoms do not prevent the workers from performing their agricultural tasks. Furthermore, the drought conditions over the last three agricultural seasons had the impact of decreasing agricultural wages, and this was slightly detected as an effect on the workers' moral and economic recognition.

1. Introduction

The working environment for agricultural labourers is complex due to exposure and interaction with physical factors (sound, radiation, light, temperature, etc.), adaptive factors (incentive, social, tools, training, etc.) and organismic factors (sex, age, body type, genetics, etc.) (Rohles, 1985). In addition, other aspects such as immigrant labour, sustainable agricultural productions, and even climatic conditions influence the health and safety of workers depending on the area of the world where they perform their tasks (Ghanian et al., 2020). A clear example of this has been described by Marcantonio (2020), who showed that water scarcity, especially in developing countries (Zambia), generates anxiety in agricultural workers.

In both developing nations and advanced economies, agriculture presents as one of the sectors having the greatest risks and dangers for workers (ILO, 2011). These workers sometimes encounter stressful working conditions, tight deadlines, long working hours, and considerable physical and mental workload. This stress and fatigue can diminish concentration and increase the likelihood of making mistakes, which can lead to accidents (EU-OSHA, 2022). Put another way, pain due to musculoskeletal injury can cause additional stress and reduce job satisfaction, creating a vicious cycle between musculoskeletal and

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psychosocial disorders (Du et al., 2022).

Countries such as Spain (bordering Africa) and the United States of America (bordering Central America) have (and require) many immigrant workers to tend their agricultural crops (Briones-Vozmediano et al., 2020; Castillo et al., 2021). This fact produces certain interactions between the workers and the environment which have hardly been studied by the authorities. Research looking at the influence of national health and safety policies in general (Leka et al., 2010), and on the agricultural sector, in particular, is lacking.

In summary, physical health and psychological health at work are influenced by psychosocial factors related to work organization, interpersonal relationships, and the physical environment (Leka, 2022). By promoting safe and sustainable practices in agriculture, a balance can be found between food production, environmental protection, and people's well-being (Meyer et al., 2017).

At least nine organizational and psychosocial risk factors (anxiety, general fatigue, sleep problems, mental load, verbal abuse at work, sexual harassment, feelings of euphoria, working time, and knowing what is expected at work) are significantly related to at least two of the three most common types of musculoskeletal disorders, namely pain in the back, and in the upper and lower extremities (De Kok et al., 2019). For this reason, risk assessment requires a comprehensive approach that addresses both psychosocial and musculoskeletal aspects.

The exposure of workers to their occupational environment affects the human body (mental and musculoskeletal systems), leading to the improvement or deterioration of the structures in the musculoskeletal system (Roman-Liu, 2013).

Several authors (Bao et al., 2016; de Souza et al., 2021; Leite et al., 2021) indicate that musculoskeletal disorders are the result of a complex interaction between physical, biomechanical and psychosocial factors (multifactorial model). Other authors have linked organisational and psychosocial factors with biomechanical factors and these, in turn, with the incidence of musculoskeletal disorders in the shoulder (Bodin et al., 2022) and lower back (Bodin et al., 2020; Nieminen et al., 2021; Igwesi-Chidobe et al., 2024). In addition, tools for the comprehensive identification of biomechanical risks, physical and psychosocial stress have been recently developed (Ruennusan et al., 2023).

Spain is the largest producer of fruit and vegetables in the European Union. It has a great diversity of climates and regions that enables a wide variety of fruits and vegetables to be grown throughout the year. The subtropical climate along the coast of Malaga and Granada provinces (southern Spain – South-western Europe; Fig. 1) makes this region the only tropical fruit production area on the continent, employing more than 4200 people, and with a cultivated area of more than 20,000 ha (avocado, cherimoya, and mango). About 98% of the area where these three crops are grown is located in the provinces of Granada and Malaga. In the former, cherimoyo predominates (97%). In the second, Mango (91%) and Avocado (77%) are the most commonly grown tropical crops. The more than 153,100 tons of production represent over 300 million euros at source, with more than 90% going to international markets (CAPDS, 2015).

Fig. 1. Tropical crop locations in Europe.

Fig. 2 shows the evolution in the total number of agricultural workers (all activities and crops) in the provinces of Granada and Malaga (Spain) over three agricultural seasons (MISSM. Ministry of InclusionSocial Security and Migrations, 2023).

Our research is motivated by the desire to know the working conditions (psychosocial and musculoskeletal) under which agricultural products such as mango, cherimoya, and avocado are obtained in southwest Europe (Spain). The aim is to demonstrate the degree of affection/relationship between musculoskeletal symptoms and psychosocial factors in tropical crop workers in Andalusia (Spain), differentiating by sex and other descriptive environmental parameters. Thus, the study seeks to provide an integrated assessment of musculoskeletal symptoms and psychosocial factors among tropical crop workers in Andalusia using the 'Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms (NMQ)' (Kuorinka et al., 1987) and the 'Mini Psychosocial Factors' (MPF) method (Ruiz and Idoate, 2005).

2. Materials and methods

Bearing in mind that the people to be assessed are very heterogeneous, and that they will be working during the assessment, the most suitable approach is to use rapid, easy-to-understand methods that assess parameters representative of musculoskeletal symptoms and psychosocial factors, and which have been validated in Spain. In both cases, we followed the choice of method described by Saaty (1990). Two decision matrices have been constructed containing five criteria (Applicability in agriculture, Number of variables studied by each method, Application time of the method, Statistical reliability, and License costs) with a score of 1–4 points each. Out of a total of 9 musculoskeletal and 6 psychosocial assessment methods, the 'Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms (NMQ)' (Kuorinka et al., 1987) and the 'Mini Psychosocial Factor (MPF)' method (Ruiz and Idoate, 2005) were finally selected as the highest rated. The first is a 28-question multiple-choice questionnaire covering the neck, shoulders, elbows, wrists/hands, back, hips, knees, and ankles (see Appendix A). It was validated in Spain by Martínez-Jarreta et al. (2014). The second is a method that evaluates 12 psychosocial variables (Autonomy, Compensation, Control, Demands, Emotional, Health, Mental Load, Mobbing, Recognition, Relations, Rhythm, and Support) with 15 questions ranging in scores from 1 to 10. Each variable can be high (H), medium (M) or low (L) risk. Karasek's demands-control framework was used to validate this method in Spain (Ruiz and Idoate, 2005; see Appendix B).

If an AWU (Agricultural Work Unit) is considered equivalent to 240 days (8-h days), the number of tropical crop workers is obtained (Table 1).

The sector generates more than one million workdays, which is equivalent to 4232 workers (Table 1). About 75% of these workdays correspond to family work (CAPDS, 2015).

About 1600 interviews were conducted with a response rate of 25.06%, which is equivalent to 401 interviews completed with an error/accuracy of 4.66%. Interviews were conducted from 09/01/2022 to 05/01/2023.

The method for selecting the agricultural plots where the workers worked was carried out in a random, non-stratified way using UTM (Universal Transverse Mercator) coordinates on a map of the Granada and Malaga provinces (Spain). Tropical crop farms are owned by individual farmers (with salaried workers), almost all of which are integrated into farmer groups. Once the owner of the plot were located and permission given, the interviews were carried out. All of the workers had employment contracts. The employer also acts as a worker.

This study complies with the Declaration of Helsinki (1983) recommendations following a favourable report from the Bioethics Committee into Human Research at the University of Almería (Ref: UALBIO2022/

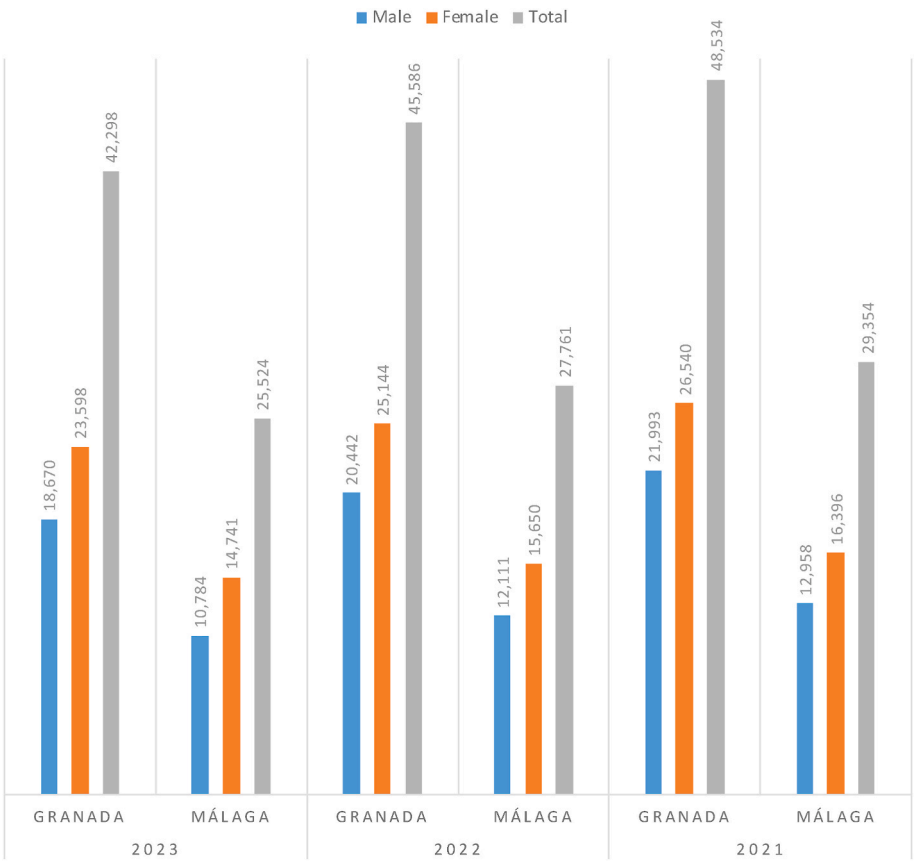

Fig. 2. Number of members in the Special Agricultural System (employees) over three agricultural seasons (average annual data accumulated up to September 2021/22/23; MISSM. Ministry of InclusionSocial Security and Migrations, 2023).

Table 1
Characteristics of the main tropical crops (Coast of Granada and Malaga-2020; CAPDS, 2015).

Crops	Area (ha)	AWU·ha^{-1}	AWUs = Crop Workers	Working days (240 working days ·awu^{-1})
Avocado	12,386	0.21	2601.06	624,254.40
Cherimoya	3035	0.21	637.35	152,964.00
Mango	4731	0.21	993,51	238,442.40
Total	20,152	0.21	4231.92	1,015,660.80

Table 2
Agricultural tasks with associated risks and crops (production trees).

Agricultural tasks	Risks			Crops		
	LM	RA	FP	Avocado	Cherimoya	Mango
Hoeing weeds		a	a	✓	✓	✓
Application of phytosanitary products	a	a	a	✓	✓	✓
Foliar application (non-phytosanitary)	a	a	a	✓	✓	✓
Leaf removal (peeling)		a	a		✓	
Pruning		a	a	✓	✓	✓
Green pruning		a	a	✓	✓	
Flower pruning		a	a			✓
Fruiting pruning		a	a	✓		
Pollination		a	a		✓	
Harvest	a	a	a	✓	✓	✓

[a] LM (load movement): lifting, pushing, dragging, and carrying (a load); RA (repetitive activities); FP (forced postures): static/dynamic.

022).

Regarding the tasks performed by the workers, note that, being woody crops (shrubs), the workers interviewed have only performed the tasks included in Table 2. This is because they are working with fruit trees in the production phase.

The coding of the qualitative variables for the workers and their environment is laid out in Table 3. The responses to both questionnaires have also been coded (Appendices A and B).

To analyse the results, SPSS v.29 and XLSTAT2019 software were used. The mathematical techniques employed were descriptive statistics, the Burt's table (Appendix C), Chi square, and Multiple Correspondence Analysis (MCA). The binary and multinomial logistic regression was discarded because non-significant equation components appear. MCA is a statistical technique used to analyse categorical data across multiple variables. The variables represent discrete categories rather than numerical data. MCA seeks to reduce the dimensionality of the categorical data by representing them in a smaller space. This allows one to visualize the relationships between the categories (of the variables) on a three-dimensional plan or graph. Relationships can be analysed analytically and graphically (with clusters). Graphical analysis is much easier considering the frequencies of each, the discrimination, and their spatial proximity. In summary, MCA is a powerful tool for analysing complex categorical data and for understanding associations between different variables in multidimensional studies (Greenacre and Pardo, 2006).

The Burt Table (Appendix C) allows one to identify how each worker responded to each question and to directly associate the NMQ and MPF responses. It is a matrix that shows the category appearance frequency of the variables under study. In this table, the rows represent one categorical variable, the columns represent the other categorical variable, and the values in the table indicate how many times each category

Table 3
Qualitative variables for the workers and their environment.

Variable	Categories	Coding
Age	<25 years	T1
	Between 25 and 40 years	T2
	>40 years	T3
Body Mass Index (BMI=Weight/Height²)	From 17.00 to 18.49 (kg/m²) – Low Weight	W0
	From 18.50 to 24.99 (kg/m²) – Normal Weight	W1
	From 25.00 to 29.99 (kg/m²) – Overweight	W2
	From 30.00 to 34.99 (kg/m²) – Chronic Overweight	W3
	From 35.00 to 39.99 (kg/m²) – Premorbid Obesity	W4
Crop Area	<1 ha	S1
	Between 1 and 3 ha	S2
	>3 ha	S3
Studies	No studies	Ns
	Primary	Pri
	High School	Hs
	Baccalaureate/Vocational Training	Hsp
	University studies	Uni
Height	<1.60 m	A1
	Between 1.60 and 1.70 m	A2
	>1.70 m	A3
Origin	African	Afr
	Asian	Asi
	Spanish	Spa
	Eastern European	EurE
	Hispanic American	His
Sex	Male	ML
	Female	F
Years of experience	<5 years	Z1
	Between 5 and 15 years	Z2
	>15 years	Z3
Crop	Avocado	Avo
	Cherimoya	Che
	Mango	Man
Province	Granada	Gr
	Malaga	Ma
Weight	<70 kg	P1
	Between 70 and 80 kg	P2
	>80 kg	P3

combination occurs. This table allowed us to calculate the chi-square and to determine if there is a significant association between the categorical variables.

3. Results

3.1. Descriptive statistics

The relationship and absolute values of all categories for each variable are shown in the Burt Table (see Appendix C). In turn, Table 4 shows the mode and frequencies of all the categories (by means of a Chi-square test).

According to the frequencies of the different categories (Table 4), the "archetypal" individual would be a man ("ML") of Spanish origin ("Spa"), with no studies ("NS"), over 40 years old ("T3") with more than 15 years of experience ("Z3"), taller than 1.70 m ("A3"), heavier than 80 kg ("P3") and with a BMI between 25 and 29.99 kg m^{-2} ("W2") who works on a farm of between 1 ha and 3 ha ("S2") in which avocado is grown ("AVO") in the province of Granada ("GR"). Regarding the psychosocial factors, the value that is most repeated among workers is that of medium risk, except in Mobbing, Relationships, Health, Support and Mental Load, which would be low risk. Regarding the most significant NMQ questions, the values that are most repeated are related to symptoms in the lower back (q1fs, q4s and q8as) and neck (q12s), which do not prevent the performance of tasks (q9a). Likewise, all variables were significant (Chi-square test; Table 4).

3.2. Descriptive figures

Fig. 3 shows the data on the symptoms (NMQ questions Q1, Q4, Q12 and Q20, related to the environmental variables - Table 3) in the different parts of the body using colours indicating the frequency at which each occurs. The relationship with psychosocial variables (Appendix B) is also shown. Please note that, in both figures, the row "affected population" takes into account the total frequency for that category and the number of individuals who say they have experienced any type of symptom at some time.

92.52% of workers manifested some type of symptom. Of these, 36.3% were unable to carry out their usual work (this does not imply stopping work, they may have changed tasks or reduced their pace) over the preceding 12 months.

The body areas that have interfered most with work in the last twelve months (Table 5), taking into account the total population of respondents, are the lumbar region (12.22%) and the knees (7.98%). Although elbows are a low frequency body area, almost three out of four (73.68%) individuals who suffered pain in this area in the last 12 months were unable to carry out their work (3.49% of the total respondents).

Elbows are the body part least commonly affected in tropical cultivation, with over 10% of the population affected exclusively in the Uni category (university studies). In contrast, the lumbar region is the body area where discomfort is most commonly experienced, far exceeding 50% in most variables, both "once" (Q4, Q12, Q20 of NMQ) and "in the last year" (Q1). The neck, upper back, and knees are the next most common areas.

The cultivation of cherimoya (Che) is the most likely of the three crops to cause symptoms in its workers. In total, 90% of workers have suffered problems in the lumbar region in the last year, 69% in the upper back and 68% in the neck.

Workers working on cultivation areas greater than 3 ha (S3) have a lower incidence of discomfort in all body areas.

Symptoms are more common in men (ML) than in women (F).

Age is a key factor in the increase in symptoms. The knees and lumbar region are the most affected by this variable.

According to the body mass index, it is up to 9% more likely to find symptoms in overweight workers (W2 and W3) than in those who are not (W1).

The more years of experience the worker has, the greater the chances of finding symptoms in several body areas. Even though there is a higher percentage of the population affected in Z2 (between 5 and 15 years of experience), the percentages for each area are higher in Z3 (more than 15 years of experience).

Workers with a low level of education (only primary education or none at all) have more of their population affected by symptoms; furthermore, the percentages for each body area are also higher. From there on, the higher the education level, the lower the number of symptoms mentioned.

By nationality, Hispanic American workers suffer from slightly fewer symptoms than the rest.

Regarding the relationship between psychosocial factors and musculoskeletal symptoms, an individual presenting a low risk is less likely to have had symptoms than those above this risk level, except for the "control" and "relationships" factors.

In tropical crop cultivation, there are few cases of individuals being at high risk in most of the psychosocial factors. However, more than 25% of the population surveyed is at high risk in the "Autonomy" factor and more than 40% in the "Emotional" factor.

3.3. Multiple-correspondence analysis

The three most relevant dimensions were analysed. The first explains 34.887% of the variance with a Cronbach's α coefficient of 0.976 and an eigenvalue of 27.212; the second dimension explains 14.021% with a Cronbach's α coefficient of 0.920 and an eigenvalue of 10.937; and the

Table 4
Frequency and mode for the different qualitative variable categories.

Variable	Category	Frequency	%	Variable	Category	Frequency	%	Variable	Category	Frequency	%	Variable	Category	Frequency	%
Sex[a]	F	66	16.46	Q1d[a]	q1dn[a]	323	80.55		q3bn[a]	303	75.56	Q9[a]	q9N4	89	22.19
	ML[a]	335	83.54		q1dsa	17	4.24		q3bs	31	7.73		q9N7	59	14.71
Age[a]	T1	40	9.98		q1dsd	54	13.47	Q3c[a]	q3cN1	67	16.71		q9a[a]	189	47.13
	T2	146	36.41		q1dsi	7	1.75		q3cn[a]	330	82.29		q9b	34	8.48
	T3[a]	215	53.62	Q1e[Attention: All the "a" in the "category column" should be "*" referring to the mode]	q1en[a]	260	64.84		q3cs	4	1.00		q9c	17	4.24
Height[a]	A1	17	4.24		q1es	141	35.16	Q3d[a]	q3dN1	67	16.71		q9d	13	3.24
	A2	109	27.18	Q1f[a]	q1fn	148	36.91		q3dn[a]	319	79.55	Q10[a]	q10N4	89	22.19
	A3[a]	275	68.58		q1fs[a]	253	63.09		q3ds	15	3.74		q10N7	59	14.71
Weight[a]	P1	83	20.70	Q1g[a]	q1gn[a]	353	88.03	Q3e[a]	q3eN1	67	16.71		q10n[a]	141	35.16
	P2	115	28.68		q1gs	48	11.97		q3en[a]	264	65.84		q10s	112	27.93
	P3[a]	203	50.62	Q1h[a]	q1hn[a]	265	66.08		q3es	70	17.46	Q11[a]	q11N4[a]	89	22.19
Body Mass Index[a]	W1	99	24.69		q1hs	136	33.92	Q3f[a]	q3fN1	67	16.71		q11N7	59	14.71
	W2[a]	258	64.34	Q1i[a]	q1in[a]	329	82.04		q3fn[a]	211	52.62		q11n[a]	134	33.42
	W3	43	10.72		q1is	72	17.96		q3fs	123	30.67		q11s	119	29.68
	W4	1	0.25	Q2a[a]	q2aN1	67	16.71	Q3g[a]	q3gN1	67	16.71	Q12[a]	q12n	181	45.14
Crop Area[a]	S1	96	23.94		q2an[a]	325	81.05		q3gn[a]	320	79.80		q12s[a]	220	54.86
	S2[a]	204	50.87		q2as	9	2.24		q3gs	14	3.49	Q13[a]	q13N12	181	45.14
	S3	101	25.19	Q2b[a]	q2bN1	67	16.71	Q3h[a]	q3hN1	67	16.71		q13n[a]	198	49.38
Crop[a]	Avo[a]	200	49.88		q2bn[a]	306	76.31		q3hn[a]	276	68.83		q13s	22	5.49
	Che	100	24.94		q2bs	28	6.98		q3hs	58	14.46	Q14[a]	q14N12[a]	181	45.14
	Man	101	25.19	Q2c[a]	q2cN1	67	16.71	Q3i[a]	q3iN1	67	16.71		q14n	142	35.41
Origin[a]	Afr	29	7.23		q2cn[a]	320	79.80		q3in[a]	311	77.56		q14s	78	19.45
	EurE	17	4.24		q2cs	14	3.49		q3is	23	5.74	Q15[a]	q15N12[a]	181	45.14
	His	24	5.99	Q2d[a]	q2dN1	67	16.71	Q4[a]	q4n	89	22.19		q15a	72	17.96
	Spa[a]	331	82.54		q2dn*[a]	314	78.30		q4s[a]	312	77.81		q15b	93	23.19
Years of experience[a]	Z1	92	22.94		q2ds	20	4.99	Q5[a]	q5N4	89	22.19		q15c	40	9.98
	Z2	118	29.43	Q2e[a]	q2eN1	67	16.71		q5n[a]	255	63.59		q15d	10	2.49
	Z3[a]	191	47.63		q2en[a]	322	80.30		q5s	57	14.21		q15e	5	1.25
Studies[a]	Hs[a]	145	36.16		q2es	12	2.99	Q6[a]	q6N4	89	22.19	Q16a[a]	q16aN12[a]	181	45.14
	Hsp	75	18.70	Q2f[a]	q2fN1	67	16.71		q6n[a]	181	45.14		q16aN15	72	17.96
	Ns	50	12.47		q2fn[a]	285	71.07		q6s	131	32.67		q16an	81	20.20
	Pri	113	28.18		q2fs	49	12.22	Q7[a]	q7N4	89	22.19		q16as	67	16.71
	Uni	18	4.49	Q2g[a]	q2gN1	67	16.71		q7a	59	14.71	Q16b[a]	q16bN12[a]	181	45.14
Province[a]	Gra[a]	250	62.34		q2gn*[a]	320	79.80		q7b	79	19.70		q16bN15	72	17.96
	Ma	151	37.66		q2gs	14	3.49		q7c[a]	88	21.95		q16bn	107	26.68
Q1a[a]	q1an[a]	250	62.34	Q2h[a]	q2hN1	67	16.71		q7d	59	14.71		q16bs	41	10.22
	q1as	151	37.66		q2hn[a]	302	75.31		q7e	27	6.73	Q17[a]	q17N12[a]	181	45.14
Q1b[a]	q1bn[a]	304	75.81		q2hs	32	7.98	Q8a[a]	q8aN4	89	22.19		q17N15	72	17.96
	q1bsa	32	7.98	Q2i[a]	q2iN1	67	16.71		q8aN7	59	14.71		q17a	131	32.67
	q1bsd	44	10.97		q2in[a]	317	79.05		q8an	103	25.69		q17b	12	2.99
	q1bsi	21	5.24		q2is	17	4.24		q8as[a]	150	37.41		q17c	4	1.00
Q1c[a]	q1cn[a]	382	95.26	Q3a[a]	q3aN1	67	16.71	Q8b[a]	q8bN4	89	22.19		q17d	1	0.25
	q1csa	2	0.50		q3an[a]	298	74.31		q8bN7	59	14.71				
	q1csd	12	2.99		q3as	36	8.98		q8bn[a]	136	33.92				
	q1csi	5	1.25	Q3b[a]	q3bN1	67	16.71		q8bs	117	29.18				
Q18[a]	q18N12[a]	181	45.14	Q24[a]	q24N20[a]	229	57.11		q27s	88	21.95		Emo-L	47	11.72
	q18N15	72	17.96		q24N23	81	20.20	Q28[a]	q28N20[a]	229	57.11		Emo-M[a]	184	45.89
	q18n	106	26.43		q24a	36	8.98		q28N23	81	20.20	Support[a]	Sup-L[a]	342	85.29
	q18s	42	10.47		q24b	38	9.48		q28n	53	13.22		Sup-M	59	14.71
Q19[a]	q19N12[a]	181	45.14		q24c	11	2.74		q28sa	11	2.74	Compensation[a]	Com-H	29	7.23
	q19N15	72	17.96		q24d	6	1.50		q28sd	17	4.24		Com-L	154	38.40
	q19n	114	28.43	Q25a[a]	q25aN20[a]	229	57.11		q28si	10	2.49		Com-M[a]	218	54.36

(*continued on next page*)

Table 4 (*continued*)

Variable	Category	Frequency	%	Variable	Category	Frequency	%	Variable	Category	Frequency	%	Variable	Category	Frequency	%
	q19s	34	8.48		q25aN23	81	20.20	Mobbing[a]	Mob-H	1	0.25	Control[a]	Con-H	24	5.99
Q20[a]	q20n[a]	229	57.11		q25an	40	9.98		Mob-L[a]	357	89.03		Con-L	142	35.41
	q20s	172	42.89		q25as	51	12.72		Mob-M	43	10.72		Con-M[a]	235	58.60
Q21[a]	q21N20[a]	229	57.11	Q25b[a]	q25bN20[a]	229	57.11	Relationships[a]	Rel-H	13	3.24	Demands[a]	Dem-H	38	9.48
	q21n	131	32.67		q25bN23	81	20.20		Rel-L[a]	206	51.37		Dem-L	5	1.25
	q21sa	4	1.00		q25bn	64	15.96		Rel-M	182	45.39		Dem-M[a]	358	89.28
	q21sd	23	5.74		q25bs	27	6.73	Health[a]	Hea-H	4	1.00	Mental Load[a]	MeL-H	3	0.75
	q21si	14	3.49	Q26[a]	q26N20[a]	229	57.11		Hea-L[a]	262	65.34		MeL-L[a]	271	67.58
Q22[a]	q22N20[a]	229	57.11		q26N23	81	20.20		Hea-M	135	33.67		MeL-M	127	31.67
	q22n	113	28.18		q26a	64	15.96	Recognition[a]	Rec-H	64	15.96				
	q22s	59	14.71		q26b	9	2.24		Rec-L	128	31.92				
Q23[a]	q23N20[a]	229	57.11		q26c	14	3.49		Rec-M[a]	209	52.12				
	q23n	81	20.20		q26d	4	1.00	Autonomy[a]	Aut-H	114	28.43				
	q23sa	29	7.23	Q27[a]	q27N20[a]	229	57.11		Aut-L	114	28.43				
	q23sd	43	10.72		q27N23	81	20.20		Aut-M[a]	173	43.14				
	q23si	19	4.74		q27n	3	0.75	Emotional[a]	Emo-H	170	42.39				

*Mode.
[a] Chi-square test ($p < 0.05$).

third dimension explains 12.066% of the variance with a Cronbach's α of 0.905 and an eigenvalue of 9.411. For the model as a whole, the cumulative variance was 60.974% with a mean Cronbach's coefficient α of 0.949 and a cumulative eigenvalue of 47.560. Therefore, the model is very reliable.

Table 6 shows the discrimination values (and their means) of each variable with respect to each of the three dimensions.

The first dimension mainly discriminates musculoskeletal aspects (NMQ) with great consistency, except those related to question Q1, referring to elbows (Q1c), wrists/hands (Q1d), hips and thighs (Q1g) and ankles/feet (Q1i). Likewise, the second and third dimensions discriminate NMQ questions. The variables for the physical environment (crop, years of experience, crop area, and province) are also discriminated by the first dimension but with less force than in the NMQ. The same occurs with the variables for the psychosocial environment (Recognition). Perhaps the second dimension discriminates the psychosocial variable "Compensation" to some degree. The rest of the variables have low rates of discrimination in each dimension (Table 6).

Fig. 4 shows the relationship between all the 259 categories studied in two dimensions. NMQ-related categories are displayed with "•-red" (Fig. 4). Those referring to the individual characteristics of the workers (age, BMI, studies, height, origin, sex, years of experience, and weight) appear with "▲-green" (Fig. 4). Those related to the farm (province, crop, and crop area) are indicated with "+" (Fig. 4) and those related to psychosocial factors are shown with "▲-purple" (Fig. 4). Clusters with the categories that most discriminate by each dimension (light blue arrows) are also observed, in addition to almost all those related to NMQ.

A video has been made (Fig. 5) that shows the relationship between the categories in three dimensions; however, it shows that the proximity relationship between categories with the inclusion of a third axis does not vary too much with respect to the two-dimensional graph, except in the greater proximity of Z3 to Cluster 3 just in front of the category "EueE". This is the only relevant aspect that might vary with respect to the two-dimensional factorial plan.

In Cluster 1, one can see relationships between large farms (S3 – 25.19%) of Mango (Man – 25.14%) in the province of Malaga (Ma – 37.66%) with workers that have little experience (Z1 – 22.94%) where there are no problems with recognition (Rec-L – 31.92%); perhaps there might be problems with "Control-H″ and "Rhythm-H″ but they do not discriminate well in the model (Table 5). Musculoskeletal problems are not related. It should be noted that the "T1" category appears to be related to younger workers (9.98%) who, in turn, would be the ones with the least experience, but the "T1" model does not discriminate well either, and this relationship is not very significant.

In Cluster 2, relationships are observed between small and medium farms (S1 -23.94% and S2-50.87%) of Avocado (Avo – 49.88%) in the province of Granada (Gra-62.34%) with workers of high and medium years of experience (Z2-29.43% and Z3-47.63%) where problems in the lower back (Q6s) and shoulders (Q2bs) might have prevented them from carrying out their work. Also, on the border with cluster 3, we find Q4s (77.81%-lower back). Regarding the psychosocial categories, Com-L (38.40%), Rec-M (52.12%), and Com-M (54.36%) have their relationship slightly highlighted in this cluster due to their discrimination in the model.

In Cluster 3, very strong relationships were observed in almost all the NMQ categories, together with Rec-H (15.96%) and Com-H (7.23%), being associated with Cherimoya cultivation (Che-24.94%). For their frequencies in the different NMQ categories, Q7b (19.70%), Q1fs (63.09%), Q1es (35.16%), Q8bs (29.18%), Q1as (37.66%), Q3fs (30.67%), Q11s (29.68%), Q8as (37.41%), Q7c (21.95%), Q12s (54.86%) and Q14s (19.45%) stand out. These categories are related to problems in the back (upper and lower) and neck. Finally, although it would be at the limit of Cluster 2, Z3 (47.63%), it could also have been considered at the limit of Cluster 3; however, this proximity would indicate that cherimoya cultivation requires more experienced workers.

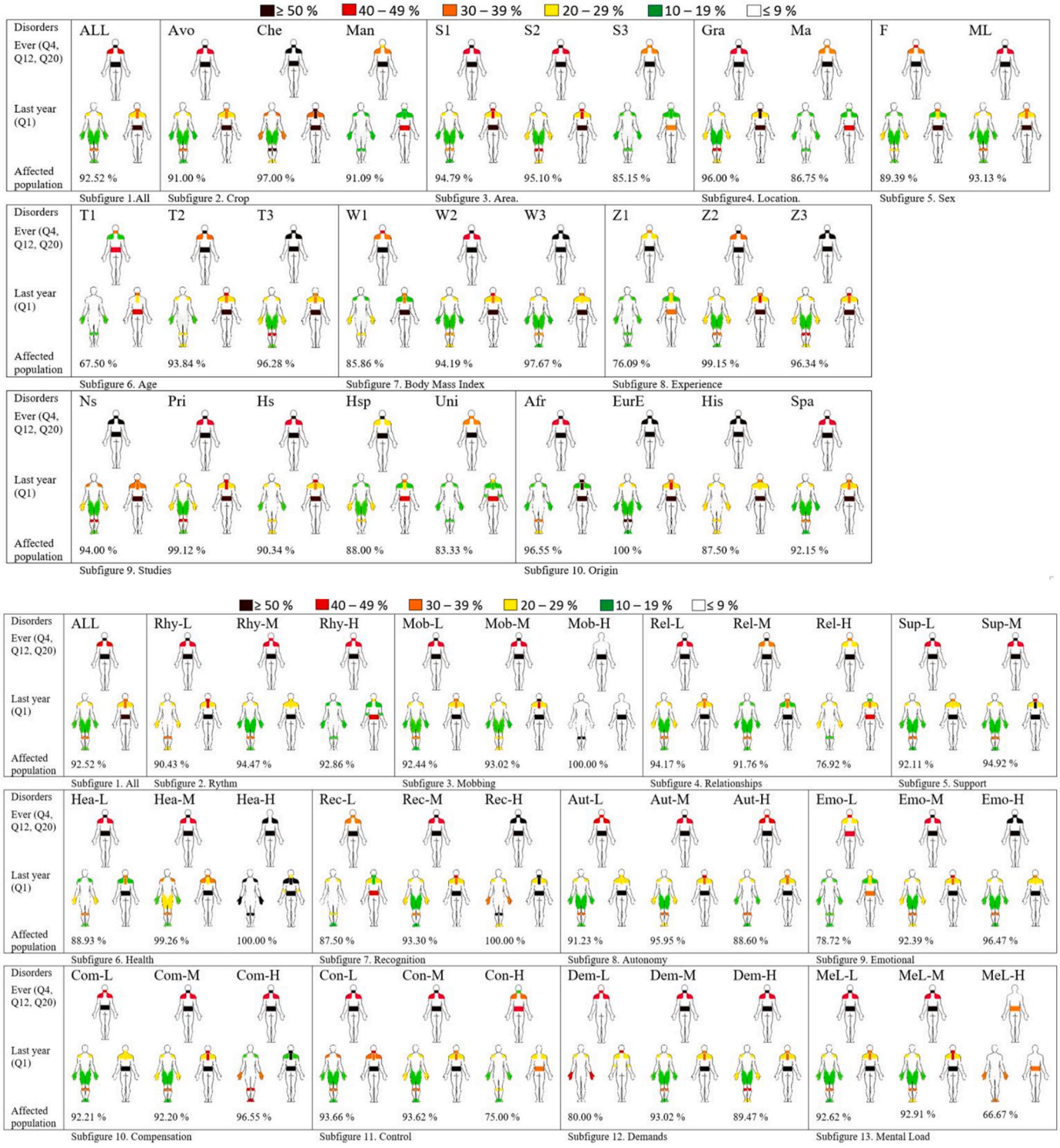

Fig. 3. Percentages of the most common disorders according to the environmental (crop, area, location, sex, age, body mass index, experience, studies, and origin) and psychosocial (mobbing, relationships, support, health, recognition, autonomy, emotional, compensation, control, demands, and mental load) variables.

Table 5
Percentages of the population that have been unable to carry out their work activity in the last 12 months according to the body area in which they suffered discomfort.

	Neck	Shoulders	Elbows	Wrists/Hands	Back, upper	Lumbar region	Hips/thighs	Knees	Ankles/feet
Of the total	2.24 %	6.98 %	3.49 %	4.99 %	2.99 %	12.22%	3.49 %	7.98 %	4.24 %
Of those affected	5.96 %	28.87 %	73.68 %	25.64 %	8.51 %	19.37 %	29.17 %	23.53 %	23.61 %

Table 6
Discrimination values of the variables with respect to the three dimensions.

Variables	Dimension				Variables	Dimension				Variables	Dimension			
	1	2	3	Mean		1	2	3	Mean		1	2	3	Mean
Sex	0.004	0.006	0.001	0.004	Q2g	0.806	0.127	0.009	0.314	Q16b	0.362	0.213	0.188	0.255
Age	0.061	0.019	0.009	0.030	Q2h	0.805	0.128	0.009	0.314	Q17	0.360	0.209	0.201	0.257
Height	0.006	0.003	0.002	0.004	Q2i	0.822	0.153	0.040	0.338	Q18	0.360	0.206	0.187	0.251
Weight	0.015	0.007	0.001	0.008	Q3a	0.808	0.148	0.013	0.323	Q19	0.364	0.207	0.188	0.253
BMI	0.012	0.019	0.018	0.017	Q3b	0.807	0.146	0.310	0.421	Q20	0.139	0.530	0.243	0.304
Crop Area	0.100	0.023	0.021	0.048	Q3c	0.806	0.127	0.011	0.314	Q21	0.149	0.548	0.286	0.328
Crop	0.176	0.042	0.045	0.088	Q3d	0.807	0.148	0.009	0.322	Q22	0.183	0.551	0.321	0.352
Origin	0.028	0.002	0.023	0.017	Q3e	0.826	0.175	0.047	0.350	Q23	0.177	0.612	0.592	0.461
Years Experience	0.128	0.035	0.006	0.056	Q3f	0.823	0.151	0.028	0.334	Q24	0.170	0.608	0.597	0.458
Studies	0.078	0.030	0.028	0.046	Q3g	0.806	0.127	0.009	0.314	Q25a	0.170	0.606	0.591	0.456
Province	0.183	0.011	0.029	0.074	Q3h	0.807	0.140	0.015	0.321	Q25b	0.170	0.605	0.580	0.452
Q1a	0.314	0.099	0.061	0.158	Q3i	0.812	0.165	0.015	0.331	Q26	0.176	0.617	0.628	0.474
Q1b	0.138	0.058	0.503	0.233	Q4	0.461	0.000	0.048	0.170	Q27	0.170	0.606	0.578	0.451
Q1c	0.003	0.017	0.008	0.010	Q5	0.466	0.014	0.052	0.177	Q28	0.173	0.609	0.604	0.462
Q1d	0.082	0.011	0.015	0.036	Q6	0.468	0.000	0.050	0.172	Rhythm	0.012	0.032	0.017	0.020
Q1e	0.260	0.033	0.046	0.113	Q7	0.626	0.017	0.063	0.235	Mobbing	0.006	0.008	0.006	0.007
Q1f	0.560	0.000	0.039	0.200	Q8a	0.625	0.007	0.057	0.230	Relationships	0.020	0.011	0.025	0.019
Q1g	0.030	0.001	0.004	0.012	Q8b	0.631	0.037	0.057	0.242	Health	0.054	0.026	0.076	0.052
Q1h	0.168	0.025	0.005	0.066	Q9	0.626	0.007	0.077	0.236	Recognition	0.104	0.022	0.075	0.067
Q1i	0.055	0.001	0.000	0.019	Q10	0.624	0.000	0.061	0.228	Autonomy	0.040	0.002	0.041	0.027
Q2a	0.807	0.131	0.014	0.317	Q11	0.624	0.002	0.050	0.226	Emotional	0.050	0.006	0.022	0.026
Q2b	0.806	0.128	0.309	0.414	Q12	0.286	0.204	0.179	0.223	Support	0.005	0.000	0.004	0.003
Q2c	0.810	0.134	0.009	0.318	Q13	0.288	0.204	0.179	0.224	Compensation	0.017	0.004	0.082	0.034
Q2d	0.807	0.129	0.012	0.316	Q14	0.286	0.204	0.196	0.229	Control	0.037	0.006	0.044	0.029
Q2e	0.806	0.127	0.009	0.314	Q15	0.363	0.223	0.190	0.258	Demands	0.017	0.000	0.011	0.009
Q2f	0.808	0.129	0.011	0.316	Q16a	0.361	0.205	0.206	0.257	Mental Load	0.008	0.009	0.017	0.011

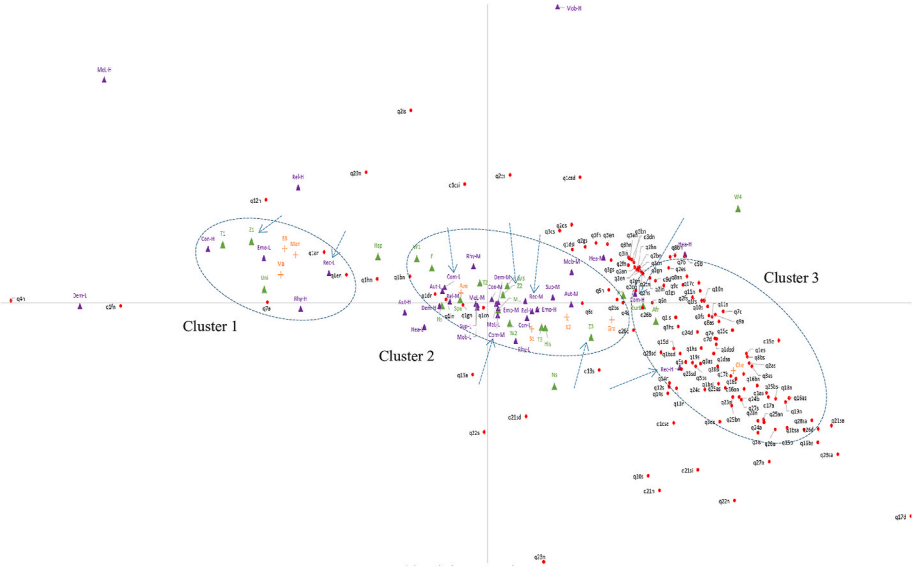

Fig. 4. Relationship of all the variable categories in 2 dimensions.

4. Discussion

Our research results indicate that 17.46% of the workers are immigrants (Afri, EurE and His), which does not coincide with similar studies previously carried out on other crops (greenhouses in Almería province and olive groves in Jaén province) in southern Spain (Andalusia) located within a 100 km radius (Fig. 1). Montoya-García et al. (2013) reported that 41.61% were foreign workers, Callejón-Ferre et al. (2015) indicated 42.15%, Lopez-Aragon et al. (2018) found 51% and Barneo-Alcántara et al. (2020) reported 53.76%. In these studies, the percentage of women workers ranged between 15 and 30%; in our research it was 16.46%. Evidently, there has been an upward trend of immigrant workers from 2013 to 2020, which coincides with the immigration data published by the authorities (MISSM. Ministry of InclusionSocial Security and Migrations, 2023). The discrepancy found may be because tropical crops are located in provinces in southern Spain that are very touristic, such as Malaga and Granada, and it is possible that foreign workers prefer the tourism sector, which pays better wages. Another cause might be that tropical crops are a relatively recent arrival compared to classic crops. Remember that this area has a microclimate that makes it unique in Europe and, therefore, specialised agricultural work is required that has never before been carried out on the continent (experience is valued in this sector). Regarding women workers, it is curious that, in the agrarian census, there are more women than men registered in both provinces (Fig. 2) whereas, in our study, the majority are male (83.54%). This can be explained by the fact that women work more in the agri-food industry (handling and processing of agricultural products) and less in field crops.

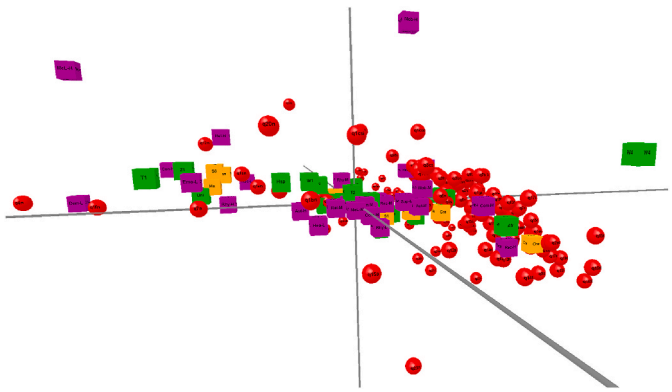

Fig. 5. Relationship of all the categories of variables in 3 dimensions (https://youtu.be/iUJsIIMqgTw; Appendix D).

In Fig. 2, one can see that the registered workforce has been decreasing from 2021 to 2023 in both provinces by around 5% per year; this fully coincides with the report by the International Labour Organization regarding the climatic conditions (drought) in these cultivation areas (ILO, 2019). In Andalusia, this is related to lower agricultural production as a result of a period of drought from 2021 to the present (CAPDR and Ministry of AgricultureFisheries and Rural Development, 2023). The drought is affecting agricultural output in Andalusia (Spain). Lower production means fewer days of work and higher prices for consumers. For this reason, workers are losing income and this might be the reason why the psychosocial factors "high recognition (Rec-H)" and "high compensation (Com-H)" are the ones with the greatest discrimination in the MCA model (see Cluster 3 – Fig. 4), especially in Cherimoya cultivation. The "Recognition" factor is related to the worker's tasks and achievements, while the "Compensation" factor relates to moral and economic recognition as a consequence of the work carried out. There are fewer workdays and lower incomes; this factor has been slightly detected in cherimoya cultivation, as already mentioned.

These psychosocial issues are strongly associated with back (lower and upper; Bodin et al., 2020; Nieminen et al., 2021; Igwesi-Chidobe et al., 2024) and neck symptoms (Cluster 3 – Fig. 4); however, for the most part, these symptoms do not prevent agricultural tasks from being carried out (Table 5). This fact may be associated with the attitude and aptitude of agricultural workers, although physical limitations and psychosocial disorders do not help when it comes to tasks being carried out correctly (Gonzales et al., 2020).

The explanation for why cherimoya cultivation is the most harmful of the three crops under study could be because of the additional specific tasks of pollination and leaf removal (Table 2). The pollination task requires expert personnel, which would explain why the workers with the greatest experience "Z3" (who are usually the oldest; Clay et al., 2014) are associated with cherimoya cultivation.

Mango crop workers are the least experienced (Z1) and, interestingly, they are not related to musculoskeletal or psychosocial problems, according to the MCA model (Figs. 4 and 5). Those who have less experience are usually the youngest and so they are probably in better physical condition (in better health; Battams et al., 2014).

Avocado workers are characterized by workers of medium (Z2) and high years of experience (Z3), for whom there is a strong association with problems in the lower back and shoulders (Bodin et al., 2022). Possibly the specific agricultural tasks undertaken with this crop punish the shoulders a little more than the others. As with cherimoya cultivation, most workers with symptoms continue to perform their tasks.

In general, this research has found that agricultural workers are exposed to significant musculoskeletal symptoms (Osborne et al., 2012); however, psychosocial factors would be at a medium-low level. Therefore, new prevention and improvement programs for working conditions need to be implemented that go far beyond the classic recommendations (good physical condition, training, rotation of shifts, etc.). Effects derived from climate change (drought, energy, floods, pests, lower production, high temperatures, etc.) must start to be taken into account, along with the development of aspects such as globalization (referring to the conditions of immigrant workers), mechanization of agricultural tasks, and digitalization (Siegrist and Bollmann, 2023). The sustainability of systems (agricultural systems included) will form the basis of good production; they need to be respectful of the environment and the working conditions in which this production is carried out (Sinclair et al., 2021).

With regard to any limitations present in this research, it should be noted that the data have been obtained from crops that are already in the production phase. After planting, tropical crops require a few years of growth before they become productive. During this period, work is carried out which varies somewhat from that described in our research. An example of this is that there would be no harvesting task. Furthermore, it would have been interesting to have completed the study with videos showing each agricultural task to allow subsequent assessment with other specific methods (forced postures and/or repetitive movements). The latter limitation could be the rectified in future research by digitizing the agricultural tasks.

5. Conclusions

Tropical crops workers in Andalusia (southern Spain) are exposed to high and medium-low musculoskeletal symptoms and psychosocial risks; however, these symptoms do not prevent them from carrying out their agricultural tasks. The most affected body areas are the back (lower and upper) and the neck, with cherimoya cultivation tasks reporting the most symptoms compared to those of avocado and mango crops.

It also seems that the drought conditions experienced over the last three agricultural seasons have had an impact in reducing the number of agricultural workdays and this fact has been slightly detected as an effect on the moral and economic recognition of workers.

CRediT authorship contribution statement

Marta Gómez-Galán: Writing – original draft, Methodology, Investigation, Conceptualization. **Manuel Díaz-Pérez:** Writing – review & editing, Validation, Supervision, Methodology, Investigation. **Juan-Carlos Rubio-Romero:** Writing – review & editing, Validation, Supervision, Methodology, Investigation. **Ángel-Jesús Callejón-Ferre:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition.

Declaration of competing interest

The authors declare that they have no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ergon.2024.103672.

Data availability

Data will be made available on request.

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