Prevalence of Musculoskeletal Disorders and Postural Analysis of Beekeepers

Mohsen Rasoulivalajoozi[a], Mojtaba Rasouli[b], Carmela Cucuzzella[c], Tsz Ho Kwok[d,*]

[a]*Department of Individualized Program, Concordia University, Montreal, Canada*
[b]*National Olympic Committee of the Islamic Republic of Iran, Tehran, Iran*
[c]*Faculty of Environmental Design, University of Montreal, Montreal, Canada*
[d]*Department of Mechanical, Industrial and Aerospace Engineering, Concordia University, Montreal, Canada*

Abstract

Work-related musculoskeletal disorders (WRMSDs) lead to fatigue and decreased productivity in workers, resulting in the need for many affected individuals to seek medical treatment annually. Beekeepers, like other agricultural workers, are susceptible to WRMSDs due to the continuous demands of their work and the repetitive movements involved. Thus, the objective of this study is to determine the prevalence of WRMSDs and assess the level of risk associated with different postures among beekeepers to improve their musculoskeletal health. To achieve this, a cross-sectional study was conducted involving 33 beekeepers, consisting of two stages. Firstly, the Nordic Questionnaire was utilized to assess the prevalence of WRMSDs. Subsequently, the Ovako Working Posture Analysis System (OWAS) was employed to analyze and categorize the riskiest postures into four levels of corrective measures. The findings indicate that the most commonly affected areas were the back (51.5%) and waist (45.4%). The occurrence of WRMSDs in various body regions was significantly associated with the beekeepers' years of experience and weekly working hours. Additionally, the prevalence of neck and back pain was significantly related to their body mass index (BMI). The OWAS postural analysis revealed that the back (36.75%) and arm (21.08%) regions required corrective measures as soon as possible (level III), while the back (26.47%) and legs (14.70%) fell under the category of corrective measures needed in the near future (level II). Combining the postural analysis results, 28.43% were classified as Action Levels (AL) II, 37.73% as level III, and 0.98% as level IV. This study demonstrates that WRMSDs are relatively common among beekeepers, primarily due to their extensive work experience and the adoption of awkward postures during their tasks. As a result, recommendations regarding ergonomics and physiotherapy are provided to alleviate pain and reduce the strain on critical postures.

Keywords: Beekeeper, Agricultural health, Musculoskeletal disorders, Postural analysis, OWAS, workload

1. Introduction

Work-related Musculoskeletal Disorders (WRMSDs) are a significant contributor to occupational morbidity and lost workdays [1], leading to substantial costs in the workplace [2]. These disorders arise from repetitive stress and overuse injuries associated with work activities [3]. Various sectors, including agriculture, have examined WRMSDs and implemented corrective measures to address these injuries. In the agriculture sector, the prevalence of WRMSDs ranges from 0.5 to 16.6 per hundred workers, surpassing the injury rate of 6.8 in the healthcare industry [4, 5]. Despite the use of machinery and technology in modern agriculture, manual work involving repetitive upper limb movements and manual handling of loads remains prevalent. Such activities, along with awkward and static postures, can negatively impact joints in different body regions [6, 7], resulting in injuries and disorders. The specific nature of agricultural activities may lead to varying types of injuries among workers, as seen in the contrasting postures and motions of saffron workers and manual pole harvesters [8].

Beekeeping, a significant sector within agriculture, also presents potential risk factors that can affect the health of beekeepers [9]. The beekeeping process consists of three main stages: 1) setting up new hives and managing overcrowded ones, 2) beekeeping management, including activities like ensuring a healthy egg-laying queen, inspecting hives for queen health and pests, and 3) extracting, bottling, and selling honey. Throughout these stages, beekeepers engage in actions that pose high risks, such as heavy lifting, manual handling, twisting, and assuming awkward positions [4]. Despite advancements in tools and equipment that have reduced labor and risks, previous studies have identified multiple hazards associated with each stage of honey production [10, 11]. However, there is a notable research gap concerning WRMSDs specifically among beekeepers, despite their significant manual involvement in honey production. In the United States alone, the beekeeping workforce is estimated to consist of 115,000 to 125,000 individuals [12]. Neglecting to address WRMSDs within this sector can result in substantial medical costs. Therefore, it is crucial to identify and address musculoskeletal disorders among beekeepers, providing ergonomic corrective measures, recommendations, and ultimately mitigating long-term medical expenses. This paper aims to focus on the honey production process, where beekeeping workers are typically engaged. It seeks to answer two research questions: 1) Which re-

*Corresponding author. Email: tszho.kwok@concordia.ca

gions of the beekeepers' bodies are most commonly affected by the WRMSDs? 2) What body postures put beekeepers at risk of musculoskeletal injuries? Additionally, the paper explores the impact of WRMSDs on beekeepers' health, prioritizing pain in different body regions and determining the appropriate Action Level (AL) for specific combined postures.

This study encompasses two phases to address the research questions. Firstly, a demographic and Nordic questionnaire [13] is utilized to identify potential pain and its correlation with work intensity and duration. Secondly, the Ovako Working Posture Assessment System (OWAS) [14], recognized as a suitable method for evaluating postures and recommending corrective actions, is employed to assess the frequency and duration of different body positions during tasks. By employing these tools to identify existing pains, injuries, and potentially risky body postures in beekeeping, two main hypotheses are tested: H1) Beekeepers, like workers in certain agricultural sectors, experience WRMSDs due to repetitive tasks over time, and H2) Beekeepers encounter awkward and risky postures during their tasks. The study aims to determine the prevalence of WRMSDs and assess the degree of risky postures among beekeepers. Consequently, based on the analysis, ergonomic and therapeutic recommendations can be provided. This study is in line with the UN Sustainable Development Goals (SDGs) concerning sustainable economic growth in the agricultural sector, in which the inter-linkage of empowering small farmers and other factors were highlighted [15]. The contributions of this study are as follows:

- Analysis of WRMSDs prevalence and posture assessment outputs can enable ergonomists and occupational therapists to understand the distribution of hotspots and tensions among different body regions of beekeepers. This understanding can assist occupational and physiotherapists in offering preventive solutions to decrease medical costs and enhance productivity.

- The findings from both phases can be compared with existing literature through a systematic review, contributing to the development of a theoretical framework for identifying common postural risks in agriculture.

By combining the outcomes of these phases, this study aims to provide valuable insights into the prevalence of WRMSDs and risky postures among beekeepers. The ergonomic and therapeutic recommendations derived from this research can aid in reducing medical costs and improving the overall well-being and productivity of beekeepers in the agricultural sector.

The remaining sections of the paper are structured as follows: Section 2 provides an overview of beekeeping practices and explores WRMSDs in agricultural and related activities. Section 3 outlines the methodology employed to identify the prevalence of pains and analyze work postures. Section 4 presents the results and findings, while Section 5 offers a comprehensive discussion and recommendations for healthcare providers and designers. Finally, Section 6 concludes the paper, highlights the limitations of the research, and suggests future directions.

2. Literature Review

In general, active workers in the agriculture sector, including beekeepers, face a high risk of health hazards [5, 9]. Naeini et al. [6] identified various injuries associated with agriculture, such as chemical and environmental exposure, eye injuries, lacerations, musculoskeletal sprains, bruises, and chronic conditions like back pain, joint pain, and repetitive strain injuries. These injuries are primarily caused by activities like heavy lifting, twisting, hazardous postures, continuous movement, excessive force, the use of hand tools, and exposure to extreme temperatures [16]. Similarly, beekeepers are also susceptible to such injuries due to their exposure to risky postures and conditions [4]. Given that this paper specifically focuses on work-related WRMSDs among beekeepers within the agriculture sector, the literature review will closely examine relevant studies in both agriculture and beekeeping.

2.1. WRMSDs in agriculture

Numerous studies have investigated the ergonomic risks and injury rates in the agricultural sector. However, most of these studies have predominantly focused on livestock farming or the handling of fruits, vegetables, grain [17, 18], olive harvesting [19] and vine pruning [20]. Nevertheless, when it comes to WRMSDs in agriculture, the combination of force and repetition has been identified as the most common contributing factors [21, 22]. These factors commonly affect body regions such as the neck, back, shoulders, wrists, hips, and knees [23]. For instance, saffron workers experience intense back and shoulder pain due to prolonged periods in a fixed stooped posture [22]. Considering that WRMSDs can manifest in various areas of the body, a systematic review [18] revealed that low back pain (LBP) was the most prevalent issue among farmers, followed by the upper and lower extremities. To prevent WRMSDs, farmers require adequate rest periods to recover from physical exertion or utilize assistive equipment to minimize pressure points and impact forces [23]. Prior studies suggest the utilization of simple machinery tools like prone carts, platforms, and load transfer devices are identified as effective in addressing the common issue of hunched-over works in agriculture [24]. Nevertheless, the application of these farming machines requires careful ergonomic consideration to avoid potential health problems as well, in which most disorders are primarily associated with whole-body vibration (WBV) and the transmission of vibrations to the hands and arms (HATV). The studies suggested that, in spite of the progress made in modern agricultural technologies, manual labor will remain essential in the field of agriculture for the foreseeable future [25]. In addition, educational interventions aimed at enhancing farm workers' knowledge have also proven effective in reducing the risk of musculoskeletal problems [26]. Although certain tasks and postures in the agricultural sector may share similarities, it is crucial to recognize that employing preventive methods for one task or sub-section of farming may not necessarily be applicable or effective for another. Each task and job entails different forces and pressures on the body. Moreover, while some upper limb pain may be common between two different farming activities, the priority actions for mitigating WRMSDs may vary. For instance, the prevalence of WRMSDs in rice cultivation differs from that in potato planting, despite some postural similarities. Rice cultivation exerts pressure on the lower back, hip, wrist, shoulder, and knee [27], whereas potato cultivators experience pressure on the lower back, knee, ankle, and feet regions [28]. Similarly, the beekeeping industry involves its own unique tasks, combined postures, and potential risks that distinguish it from other farming and cultivation activities.

2.2. Beekeeping, Injuries, and Risks

Honeybee products, including wax, pollen, propolis, royal jelly, and venom, are utilized in various ways, such as in apitherapy, which involves using honeybee products for medicinal purposes [29]. However, the beekeeping industry is often primarily associated with honey production [17]. This industry can be classified into three types of production: hobbyists (with 25 colonies or fewer), part-time beekeepers (with 25 to 300 colonies), and commercial beekeepers (with over 300 colonies). While hobbyists and part-timers produce approximately 40 percent of the honey, the remaining 60 percent is produced by around 1,600 commercial beekeepers [30]. According to a report from Iran's Ministry of Agriculture [31], there are approximately 98,000 beekeepers in Iran, overseeing around 8.5 million honeybee colonies [32]. Food and Agriculture Organization (FAO) data indicate that honey production in Iran has surged, rising from around 10,000 tons in 1990 to surpassing 77,000 tons in 2021, marking an almost eightfold increase over the past three decades [33]. Iran accounts for roughly 8-9% of global bee colony numbers and contributes 4-5% to the world's honey production [32], which ranked third globally in honey production, producing 77,152 tons, following China and Turkey [33]. Also, in 2014, the US Occupational Injury Surveillance of Production Agriculture (OISPA) reported that about 1.74 million households were involved in livestock farming, including beekeeping activities [34]. According to the Occupational Safety and Health Administration (OSHA), honey production is considered a high-risk industry in terms of human health [9]. Apiculture involves working with specific tools, in different environmental conditions, and performing various tasks. Therefore, to identify risk factors and symptoms among honey farmers, it is necessary to conduct a detailed analysis of these factors separately. In a relevant ergonomics case study that employed a micro-ergonomics approach, several risky tasks of beekeepers were identified, including awkward positions of the arms, hands, and bodies, excessive lifting beyond recommended weight limits, and exposure to chemicals and bee stings [4]. However, this study did not provide a specific analysis of beekeepers' postures to understand which postures may contribute to musculoskeletal issues in the long run. Another ergonomic investigation conducted by Aiyeloja et al. [35] aimed to assess whether the height of beehive stands and the types of hives affected the ergonomics of honey harvesting. They found that height was a crucial factor influencing bending of body parts and recommended an ergonomic guideline of 80-84cm stand height for beekeepers using Kenya Top Bar hives with falling buffers. However, their focus was primarily on the design of static hives, rather than analyzing farmers' postures and dynamic work, which could potentially contribute to the development of pain over time. In this regard, a study that examined biomechanical overload exposure using a novel multitasking model revealed that women have a borderline risk of back injuries, which may increase with more working time, while men range from an acceptable to borderline risk [36]. However, this research did not provide insights into the most painful regions of beekeepers' bodies or specific levels of risk associated with combined postures. To the best of our knowledge, there is currently a gap in research regarding the prevalence of WRMSDs among beekeepers and the identification of actionable measures based on posture analysis. By addressing our research question, we aim to contribute new knowledge on the prevalence of WRMSDs, posture analysis, and preventive actions to mitigate further risks among beekeepers at the individual worker level (IWL). The analysis of IWL considers ergonomic interventions specific to agriculture, including individual changes, tools, and small equipment [16]. This study represents the first attempt to investigate beekeepers' body postures in relation to the tasks involved in honey production.

3. Methodology

In order to investigate the prevalence of WRMSDs and identify the riskiest postures, as well as determine the AL for preventive measures, a two-phase model was implemented (Fig. 1). The first phase involved the use of the Nordic Questionnaire to assess whether the tasks performed by beekeepers led to excessive exertion, overloading forces, and pressures. This questionnaire allowed us to gather information on the prevalence of symptoms related to work activities. In the second phase, a posture analysis method was employed to determine if beekeepers were adopting risky and awkward postures while carrying out their tasks. This analysis helped prioritize the AL and provided more precise ergonomic and preventive recommendations. This cross-sectional study was conducted in two stages between August 2022 and October 2022, involving 33 active beekeepers engaged in honey production. All participants were willing to take part in all phases of the study and provided their consent. Subjects were randomly recruited through word of mouth and phone calls, and they consisted of both male (54.4%) and female (45.5%) beekeepers aged between 30 and

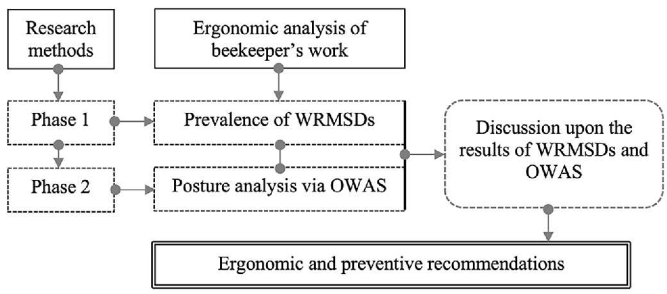


Figure 1: Overview of the methodology.

56. Demographic variables for the participants are presented in Table 3.

Table 1: Demographic data for 33 participants (18 males and 15 females).

Variables	Min-Max	Mean	Std
Age	30–58	45.09	7.60
Weight (kg)	57–104	77	10.95
Height (cm)	158–188	166.24	17.76
Work experience (year)	1–15	3.79	3.79
Weekly work hours	3–30	17.16	7.07
BMI	19.20-32.30	26.56	3.157

All subjects included in the study were required to have experience in beekeeping as part-time or full-time jobs and possess knowledge of basic beekeeping procedures. Individuals who used special tools like exoskeletons and those involved in managerial roles or the bottling and selling sectors of the beekeeping industry were excluded from the study. Participants were healthy and did not have any ongoing or long-term diseases that could impact the results of the study. The included participants were instructed to wear appropriate clothing, such as bee suits, to ensure their safety and allow for the exposure of specific body regions (trunk, legs, etc.) during video and photography sessions [37]. The research was conducted in Kordkuy, Iran, which is a city located in the Golestan province in the northern part of the country, with a significant number of beekeepers operating in the region. The study obtained ethical approval from the Concordia University Human Research Ethics Committee, with the certification number of ethical approval being 30016767. All participants in the study completed and signed informed consent forms, indicating their voluntary participation and understanding of the study's purpose and procedures.

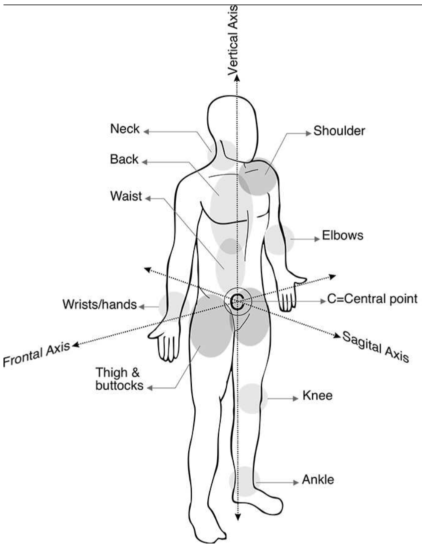
It's important to highlight that our study did not encompass "migratory beekeeping" [38], a practice commonly employed to enhance beekeepers' production and income [39]. In migratory beekeeping, beehives are relocated from nectar-exhausted areas to nectar-rich ones, often at varying altitudes [40]. We opted not to include migratory beekeeping in our research for two primary reasons. Firstly, migratory beekeeping mainly involves tasks like loading and unloading hive boxes on trucks, which occur only a few times a year and are not part of the routine beekeeping-specific tasks. Secondly, participation in migratory beekeeping does not guarantee active engagement in beekeeping as a primary occupation.

3.1. Phase 1: Prevalence of WRMSDs

The data collection process involved a comprehensive questionnaire that covered demographic characteristics, the assessment of WRMSDs, and physical parameters such as height, weight, and Body Mass Index (BMI). For the assessment of WRMSDs, the Nordic Questionnaire, developed by Kuorinka [13] in 1987 and subsequently adapted for evaluating the prevalence of musculoskeletal disorders among workers, was used. The Nordic Questionnaire is commonly used in cross-sectional studies for assessing musculoskeletal disorders, and its validity and reliability have been confirmed by experts [41, 42]. This questionnaire analyzes nine body parts (three in each upper limb, lower limb, and trunk) to determine the occurrence of pain [43] (Fig. 2). Participants were asked to indicate if they experienced musculoskeletal disorder symptoms and pain in these body regions during the twelve months and the past seven days [44]. The questionnaire provides a human figure as a reference to assist participants in identifying and reporting their symptoms accurately. In order to test the first hypothesis, which examines the relationship between WRMSDs and various factors such as age, weight, height, BMI, work experience, and gender, the study employed the presence of WRMSDs as the dependent variable, while the independent variables encompassed the aforementioned factors. While BMI is a convenient rule-of-thumb, it lacks statistical precision when applied to groups, and using its precise value may not yield meaningful results. Therefore, the analysis categorized BMI into six levels: underweight (up to 18), normal weight (18.5-25), overweight (25-30), class 1 obesity (30-35), class 2 obesity (35-40), and class 3 obesity (>40) [45]. The collected data were then processed and analyzed using the SPSS software (Statistical Package for the Social Sciences - Version 28). Descriptive statistics were calculated to summarize the data, and chi-square tests were conducted to investigate any significant associations between variables such as age, height, BMI, and reported WRMSDs. The chi-square test is a statistical method used to determine if there is a meaningful relationship between two variables. The p-value associated with the chi-square test represents the probability that the observed correlation between the variables in the data occurred due to random chance. A small p-value indicates that the observed results are unlikely to be the result of chance alone. Typically, a p-value threshold of 0.05 (5%) is often used to determine statistical significance. This means that if the calculated p-value is less than 0.05, the results are considered statistically significant [46].

3.2. Phase 2. Posture Analysis

In studies focusing on posture analysis, various methods are employed, including the Ovako Working Posture Analysis System (OWAS), Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA) techniques [47] and occupational repetitive actions (OCRA) [48]. Recent research has indicated that RULA and OCRA provide accurate estimates of postural loads and their association with WRMSDs [49]. However, considering that beekeepers engage their entire bodies in their tasks, RULA and OCRA, which primarily focus on the upper limbs, are not suitable for our study [19, 50]. In the case of REBA, it does not take into account the duration of tasks or the specific sequence of postures, instead focusing solely on measuring effort intensity [51, 52]. OWAS, on the other hand, does not require extensive training [53]. This feature reduces the likelihood of influencing subjects' postures and allows for a realistic representation of their routine work postures. Consequently, we opted to utilize the OWAS method in the second step of our analysis, as it allows for posture analysis and the identification of corrective exercises initially developed by



Demographic information			Body parts	Problems (aches, pains, discomforts) during the last 12 months, 7 days (Yes/NO)	
				12 months	7 days
Age (year)			Neck		
Weight (kg)			Shoulder		
Height (cm)			Elbow		
Work experience (year)			Hand and wrist		
Weekly work hours			Back		
BMI Metric			Waist		
Gender	F		Thigh & buttocks		
	M		Knee		
			Ankle		

Figure 2: The NORDIC questionnaire used in this study, customized by the authors.

Table 2: The procedure of OWAS method in 5 steps.

Steps	Duties	Outputs
1	Recording the observation via photos and video	Analysis of photos
2	Categorizing and scoring the postures of the back, arms, feet, and pressure of the load	Identifying of each code
3	Determining each work posture's code based on the OWAS table	A four-digit code
4	Classification of the OWAS score based on the OWAS table	Four action levels
5	Description of results	Action level for each region and combined posture

Ovako Oy in Finland [14]. The OWAS method involves five steps for postural analysis (refer to Table 2).

In OWAS, specific numerical codes are assigned to three body parts: back, arms, and legs. Each code represents the posture of the corresponding body part, with four codes for the back, three for the arms, and seven for the legs. The load being handled by the worker is assigned a load code ranging from 1 to 3 (Load codes: $1 = Wt < 10$ kg, $2 = 10 < Wt < 20$ kg, and $3 = Wt > 20$ kg). Action levels are then determined based on the duration of work (refer to Fig. 3). By combining these four codes to form a 4-digit number known as the "posture code" and referring to Fig. 4, AL for the overall body posture are generated, ranging from I to IV [54]. A higher AL indicates a more harmful posture, where AL I indicates no action required, AL II suggests action required in the near future, AL III denotes the need for corrective action as soon as possible, and AL IV indicates that immediate action is necessary to prevent further deterioration of physical health. These postures get higher order of corrective action measurements [55]. During the data collection process, a video was recorded for approximately 45 minutes while the beekeepers were engaged in their work. Then, with every change of posture, screenshots were taken from the video, resulting in a total of 90 images. These images were then evaluated using the OWAS method to assess the postures exhibited by the beekeepers. By following all the steps of the OWAS method and analyzing the outcomes, the degree of corrective measures needed for each AL was determined and compared with the results obtained from the questionnaire. The OWAS method categorizes postures into the four AL [22, 14]. This method relies on a straightforward and systematic classification of working conditions, accompanied by careful observation of work tasks [14]. OWAS has been widely used in various fields and professions for several decades due to its simplicity, practicality, and proven validity [56].

4. Results

Analyzing the responses from the Nordic questionnaire allows us to address the first research question regarding the prevalence of WRMSDs in different body regions among beekeepers. In this study, the findings indicate that all participants experienced WRMSDs at least once in the last 12 months. As shown in Fig. 5, the back had the highest prevalence of disorders (51.5%), followed by the waist (45.4%), while the hand and wrist had the lowest prevalence (9.09%). Examining Table 3, no significant correlations were found between the prevalence of WRMSDs and factors such as age, height, weight, and gender of the beekeepers ($p > 0.05$). However, significant correlations were observed between work experience and the occurrence of WRMSDs in the neck, shoulder, elbow, back, waist, and knee, except for the hand and wrist ($p = 0.169$), thigh and buttocks ($p = 0.329$), and ankle ($p = 0.144$). Similar patterns were observed for weekly work hours, except for the elbow and knee ($p > 0.05$). Furthermore, a significant relationship was

Regions of body											
Back	1=Straight	I	I	I	I	I	I	I	I	I	I
	2=Bent forward/backward	I	I	I	II	II	II	II	II	III	III
	3=Twisted or side bent	I	I	II	II	II	III	III	III	III	III
	4=Bent and twisted	I	II	II	III	III	III	III	IV	IV	IV
Arms	1=Both below shoulder	I	I	I	I	I	I	I	I	I	I
	2=One at/above shoulder	I	I	I	II	II	II	II	II	III	III
	3=Both at/above shoulder	I	I	II	II	II	II	II	III	III	III
Legs	1=Sitting	I	I	I	I	I	I	I	I	I	II
	2=Standing with both legs straight	I	I	I	I	I	I	I	I	II	II
	3=Standing with weight on one straight leg	I	I	I	II	II	II	II	II	III	III
	4=Standing with both knees bent	I	II	II	III	III	III	III	IV	IV	IV
	5=Standing with weight on one bent knee	I	II	II	III	III	III	III	IV	IV	IV
	6=Kneeing	I	I	II	II	II	III	III	III	III	III
	7=Walking	I	I	I	I	I	I	I	I	II	II

Percentage of working time: 0 20 40 60 80 100

Figure 3: Code of each region and its corresponding AL (I, II, III, and IV) accordingly to the percentage of working time. Action level (AL) I: no action required; II: action required in the near future; III: action required as soon as possible; and IV: action required immediately.

Back	Arms	Legs 1			Legs 2			Legs 3			Legs 4			Legs 5			Legs 6			Legs 7		
	Loads	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	1	I	I	I	I	I	I	I	I	I	II	II	II	II	II	II	I	I	I	I	I	I
	2	I	I	I	I	I	I	I	I	I	II	II	II	II	II	II	I	I	I	I	I	I
	3	I	I	I	I	I	I	I	I	I	II	II	III	II	II	III	I	I	I	I	I	II
2	1	II	II	III	II	II	III	II	II	III	III	III	III	III	III	III	II	II	II	II	III	III
	2	II	II	III	II	II	III	II	III	III	III	IV	IV	III	IV	IV	III	III	IV	II	III	IV
	3	III	III	IV	II	II	III	III	III	III	III	IV	IV	IV	IV	IV	IV	IV	IV	II	III	IV
3	1	I	I	I	I	I	I	I	I	II	III	III	III	IV	IV	IV	I	I	I	I	I	I
	2	II	II	III	I	I	I	I	I	II	IV	IV	IV	IV	IV	IV	III	III	III	I	I	I
	3	II	II	III	I	I	I	II	III	III	IV	IV	IV	IV	IV	IV	IV	IV	IV	I	I	I
4	1	II	III	III	II	II	III	II	II	III	IV	IV	IV	IV	IV	IV	IV	IV	IV	II	III	IV
	2	III	III	IV	II	III	IV	III	III	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	II	III	IV
	3	IV	IV	IV	II	III	IV	III	III	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	II	III	IV

Figure 4: The OWAS Action Level (AL) for various postures. For example, code 4322 stands for Back=4, Arm=3, Leg=2, and Load=2, and its AL is III.

Table 3: The p-values between the demographics and the prevalence of WRMSDs. *p-value less than 0.05 is significant.

	Body regions with WRMSDs								
Demographics	Neck	Shoulder	Elbow	Hand & wrist	Back	Waist	Thigh & buttocks	Knee	Ankle
Work experience	*0.007	*0.033	*0.011	0.169	*0.004	*0.009	0.329	*0.020	0.144
Weekly work hours	*0.027	*0.033	0.516	0.106	*0.025	*0.031	0.404	0.202	0.479
BMI	*0.009	0.130	0.093	0.102	*0.002	0.189	0.315	0.165	0.616
Age	0.404	0.535	0.198	0.080	0.430	0.306	0.082	0.499	0.698
Weight	0.156	0.846	0.497	0.213	0.344	0.815	0.790	0.472	0.313
Height	0.490	0.123	0.315	0.106	0.483	0.563	0.771	0.589	0.927
Gender	0.585	0.351	0.629	0.151	0.192	0.351	0.372	0.379	0.818

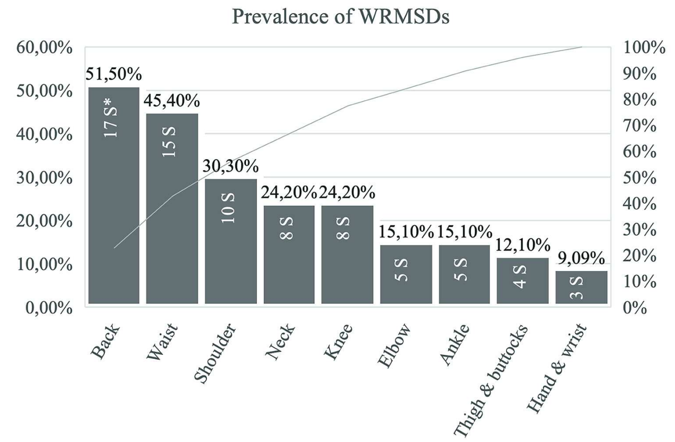


Figure 5: The frequency and prevalence of WRMSDs in nine regions of the body during the last year, based on the Nordic Questionnaire.

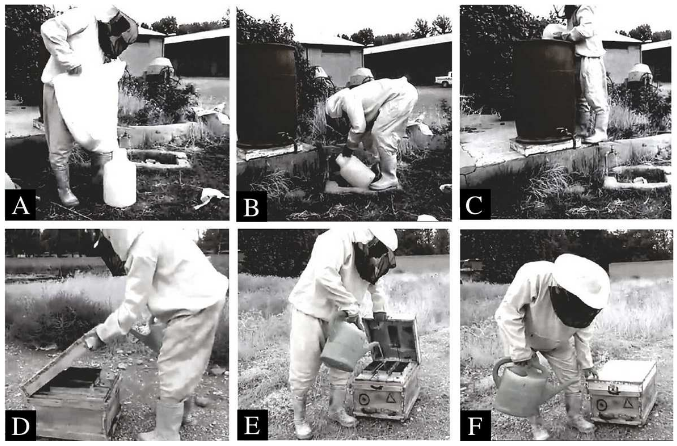


Figure 6: Phases of preparing pouring solution in honeybee hives (A, B and C) and pouring into hives (D, E and F). Corresponding posture codes: A=4133, B=4141, C=1122, D=2142, E=4132, and F=4152.

identified between BMI and the presence of pain in the neck and back ($p < 0.05$), but no significant relationship was found in other regions. These findings confirm the significantly prevalent occurrence of WRMSDs in various body regions among beekeepers and support the first hypothesis that their musculoskeletal systems are at risk due to the repetitive tasks involved.

During the OWAS analysis, we screened the initial 90 images extracted from a video, identifying 14 unique postures that represent a complete cycle of a beekeeper's work when providing the hives with the solution. The entire process can be divided into two primary stages: preparing the solution (A-C) and pouring it into the hives (D-F), as shown in Fig. 6. The first stage mainly involves tasks performed while standing, while the second stage requires more complex postures, including bending, twisting, standing, and sitting. Using these images along with Fig. 3 and Fig. 4, we determined the AL for both the body sections (back, arms, and legs) and the entire body.

The determination of the AL for each body section considered both the body posture and the duration spent in that specific posture. The results, presented in Table 4, revealed that the most critical postures for the back are twisting and side bending (26.47%) as well as bending and twisting (36.75%), categorized as AL II and AL III, respectively. These findings suggest that maintaining such back postures during beekeeping can have detrimental effects on the musculoskeletal system. For the arms, the second posture (one at/above shoulder) at 21.8% required corrective action as soon as possible (AL III). This posture occurred when beekeepers needed to remove the beehive lid, resulting in one hand being raised above the shoulders, often in a bent position and at a significant distance from the hive. However, while pouring the solution, beekeepers maintained a posture where only one hand was positioned above the shoulder, eliminating the need for both hands to be raised simultaneously, and therefore, the posture of both hands at/above the shoulder was not observed. Regarding the arms, the second posture (one at/above shoulder) was the only one requiring corrective action as soon as possible, accounting for 21.8% (AL III). This posture occurred when beekeepers needed to remove the beehive lid, resulting in one hand being raised above the shoulders, often in a bent position and at a considerable distance from the hive. However, during the process of pouring the solution, beekeepers maintained a different posture, where only one hand was positioned above the shoulder, eliminating the need for both hands to be raised simultaneously. Consequently, the posture of both hands at/above the shoulder was not observed. Additionally, during the preparation of the solution, beekeepers sometimes poured sugar from a lower height than the platform on which the solution container was placed. In such instances, they either stood on the platform or utilized objects like a ladder or a short stool to pour the sugar, thus avoiding the need to raise their arms above the shoulder. Regarding the legs, most postures are in AL I, with no actions required. Only the fourth

Table 4: Identifying the level of corrective measures by the triple body regions based on the OWAS method.

	Posture	%time	AL
Back	1=Straight	7.85	I
	2=Bent forward/backward	28.92	I
	3=Twisted or side bent	26.47	II
	4=Bent and twisted	36.75	III
Arms	1=Both below shoulder	78.92	I
	2=One at/above shoulder	21.08	III
	3=Both at/above shoulder	-	-
Legs	1=Sitting	26.96	I
	2=Standing with both legs straight	2.45	I
	3=Standing with weight on one straight leg	25.98	I
	4=Standing with both knees bent	14.70	II
	5=Standing with weight on one bent knee	0.98	I
	6=Kneeling	-	-
	7=Walking	28.92	I

Table 5: The level of cumulative frequency and the percentage of combined postures and corrective measurements related to any of them

Posture codes*	#	%time	AL
1122, 3111, 1211, 3173	4	32.85	I
4141, 3211, 2112, 4132	4	28.43	II
4133, 4232, 2142, 2172, 2141	5	37.73	III
4152	1	0.98	IV

*Each of these four-digit codes represents a unique posture. According to the OWAS procedure, the digits—from left to right—indicate the posture of the Back, Arms, Legs, and Force, respectively.

posture (standing with both knees bent) was categorized as AL II and accounted for 14.70% of the time. It would be ideal to eliminate this posture in the near future. Surprisingly, no observations were made of beekeepers kneeling while performing activities, which could possibly be attributed to their desire for efficiency.

To determine the AL for the combined postures, we used Fig. 4 to find a four-digit code representing each posture. For instance, the posture in Fig. 6A is 4133, where the first digit represents the critical back posture (4 = Bent and twisted), the second digit indicates the arm position (1 = Both below shoulder), the third digit represents the leg posture (3 = standing with weight on one straight leg), and the final digit denotes the load (3 = >20 kg). Accordingly, we identified the corrective AL for all the body postures, resulting in 32.85% falling into AL I, 28.43% in AL II, 37.73% in AL III, and 0.98% in AL IV (see Table 5). The most frequently occurring postures (4133, 4232, 2142, 2172, 2141) are classified as AL III, indicating that beekeeping is a high-risk activity that requires prompt corrective actions to reduce musculoskeletal injuries. Among all the combined postures, posture 4152 has the highest AL (IV), where the back is bent and twisted, and the beekeeper is standing with weight on one bent knee. In this particular posture, beekeepers pour the solution and inspect the hives while carrying a load in one hand (Fig. 3F). Fortunately, this posture only lasts for a short duration, but it should still be avoided.

These findings confirm the second hypothesis that beekeepers often encounter awkward and risky postures during their tasks, answering the second research question regarding the specific body postures that put beekeepers at risk of musculoskeletal injuries. By preventing discomfort postures and mitigating risks at the individual worker level (IWL), beekeepers' health and well-being are improved, inclusive and sustainable economic growth, employment, and decent work for all are developed within the realm of small-scale agriculture, which are parts of the United Nations SDGs [57].

5. Discussion

The findings of our study revealed that the back, waist, and shoulder had the highest prevalence of pain among beekeepers. Additionally, we observed that work experience and weekly work hours significantly influenced the occurrence of WRMSDs in most body regions of beekeepers. Through our analysis, we identified common body postures that exposed beekeepers to risky and unhealthy working conditions. We established four degrees of action measurements for each posture, providing valuable insights into the potential risks faced by honey workers, similar to other agricultural sectors [22]. These findings emphasize the need for corrective measures to address WRMSDs in beekeepers and underscore the importance of physiotherapists, ergonomists, and medical designers in improving and optimizing the working conditions of beekeepers. By taking action to prevent and alleviate pain, we can enhance the quality of life for beekeepers. To the best of our knowledge, this is the first attempt to analyze the working conditions of beekeepers in relation to WRMSDs and decipher the critical postures associated with these disorders.

During the pouring of solutions into the hives, beekeepers are often required to maintain bending and standing postures for extended periods. This repetitive twisting and bending of the trunk increases the risk of WRMSDs, particularly in the lower back region. Similar working postures and associated WRMSDs have been reported among farmers in various studies [18, 58]. In our analysis of postures, we found that specific postures involving twisting or side bending of the back and bending with twisting were associated with higher AL (II and III), indicating increased risk. The absence of support for transferring the load and the additional weight of the solution bucket can have adverse effects on the middle and lower back, subjecting these areas to higher forces. To minimize the risk of WRMSDs, it is recommended that beekeepers take regular rest breaks and wear waist protection gear. Physiotherapists and brace designers should prioritize measures aimed at reducing load and tension on the back and waist. Regular rest breaks can help alleviate the negative effects of prolonged standing and inappropriate workstation postures, such as static muscle contraction, increased pressure on intervertebral discs, muscle tension on ligaments and muscles, reduced tissue flexibility, and alterations in the curvature of the spine. Previous studies [6] have also emphasized the need for adequate rest among farmers engaged in prolonged activities, as these factors contribute to increased risk of WRMSDs in the spinal regions [59]. Although optimizing stand height has been suggested to reduce pressure [60], it is important to note that dynamic work involves a dynamic distribution of load and pressure. For example, in a working posture in interaction with a manual wood-chipper, the RULA method shows that due to flexion of the chest and postural asymmetries, the biomechanical pressure can engage the upper limbs involving the forearm and wrist [61]. Therefore, pressure may shift to other body regions such as the neck, shoulders, elbows, and knees, which are already at risk of significant WRMSDs, leading to exacerbated pain. This may ultimately increase the AL considerations for the arms and legs. Our analysis using the OWAS method revealed that a significant percentage of arm postures (21.08%) were at/above shoulder level with AL III, and a considerable percentage of leg postures (14.70%) involved standing with both knees bent with AL II, indicating significant tension in these areas. Considering the additional pressure from other regions on the arms and legs, it becomes crucial to address the need for appropriate support and design interventions such as straps or exoskeletons to distribute and manage the pressure on the entire body of beekeepers. Regarding body weight, our findings indicated a potential association between overweight (BMI: 25-30) and obesity (BMI: 30-35) with WRMSDs in the neck and back. It is plausible that excess weight can exert additional strain on the already burdened bones and joints, leading to increased discomfort. Furthermore, in the long term, overweight factors may contribute to significant problems in other soft tissues of the lower extremities, including the knees, ankles, and hips [62]. However, no significant correlations were observed between BMI and WRMSDs in other regions of the body. Further investigations with larger participant samples are required to establish stronger evidence and confirm these associations. Given the global rise in obesity rates, interventions aimed at reducing BMI are recommended to alleviate WRMSDs among workers [63].

In addition to analyzing WRMSDs, we utilized the OWAS method for postural analysis to assess the ergonomic load and corrective levels among beekeepers. We identified 14 different postures during beekeeping tasks, with 12 of them falling within the riskiest range, categorized as AL II, III, and IV. This stark contrast with other agricultural activities, such as saffron harvesting [22], which had only four different combined posture codes, highlights the dynamic and multifaceted nature of beekeepers' work. Beekeepers constantly switch between various tasks within a single work cycle, subjecting them to more demanding and fatiguing working conditions, which in turn intensify the risks of WRMSDs [64]. Moreover, the significant percentage of postures categorized as AL III and IV (38.71% in total) indicates that beekeepers frequently adopt high-risk working postures that require attention soon as possible. Similar combined posture codes may be observed in other work environments where workers perform comparable tasks, providing valuable insights for managers and workers to swiftly implement corrective measures. For instance, pruning, irrigation, or harvesting greenhouse crops that involve working with shrubs positioned below the farmers' height may entail risky work positions akin to those encountered by beekeepers.

5.1. Recommendations

Providing ergonomics training and therapeutic recommendations can greatly assist beekeepers in optimizing their workplace layout, maintaining optimal postures while performing tasks, and using farming equipment correctly [43]. To that end, a comprehensive set of ergonomic recommendations (see Table 6) was developed through unanimous consensus among three experienced physiotherapists. These recommendations were based on discussions revolving around musculoskeletal disorders and posture analysis.

Table 6: Physical and occupational therapists' recommendations. Note that no degree of importance and priorities are considered.

No	Therapists' recommendations
1	Regular visiting by medicine team
2	Avoiding overload, overuse, overwork, and overtraining actions
3	Obeying the related job rules
4	Using auxiliary equipment & assistive products (e.g., shoulder strap, knee strap, lumbar belt, and exoskeleton)
5	Taking regular median rest (sitting, stretching, lying back extension, etc.)
6	Considering the physical fitness programs
7	Training for work-related skill
8	Preventing the pains by lowering the continuous working time
9	Optimization of the workplace by the adjustability of the height of the hive

According to these recommendations, beekeepers should take any symptoms or aches seriously, as WRMSDs can be exacerbated by risky combined postures. Regular visits to physiotherapists can help identify and prevent future risks of injury or disability through timely and appropriate care [65]. Physiotherapists strongly advise beekeepers to avoid tasks that surpass their physical capabilities. Repetitive overloading not only puts strain on the back but can also increase short-term risks when it becomes a routine. Studies have suggested that incorporating regular breaks (involving sitting, stretching, and lying back extensions) [66] and adhering to occupational therapist-developed health protocols and fitness programs can help maintain optimal health and safety levels [67]. Following such routines and seeking guidance from physiotherapists can reduce inflammation, improve mobility and flexibility, restore natural movement patterns, and alleviate pain and discomfort symptoms [68]. While there is currently no specific exoskeleton designed for beekeepers, implementing short-term measures such as using shoulder and knee straps or exploring suitable exoskeletons under the guidance of a physiotherapist can significantly alleviate pressure on the back, shoulders, and legs [62, 63]. Kinesiology tape has limited effectiveness in treating musculoskeletal injuries and is not recommended for pain reduction [69]. Instead, back or shoulder brace straps are highly beneficial, providing comfort, reducing the risk of bruising and injury, promoting health and performance, and, most importantly, correcting posture [70].

In addition, educational programs focusing on work-related skills can raise workers' self-awareness regarding their physical condition, enabling them to identify any suspicious pain in their bodies. Such programs foster a sense of social support at work and outside, enhance job engagement, provide insight into career development, and emphasize the importance of personal growth and skill enhancement [71]. The ergonomic conditions of workstations should be improved through collaborative efforts involving employees, occupational therapists, and experts [72, 14]. Optimizing the agricultural environment for beekeepers can enhance their physical activity, stress management, engagement, and environmental performance (EP) [73]. Lastly, we recommend the design of assistive products, such as exoskeletons, to alleviate pain in different regions of the body.

6. Conclusion

The objective of this study was to examine the impact of beekeeping tasks on beekeepers' musculoskeletal system, particularly in relation to work-related musculoskeletal disorders (WRMSDs). Similar to other farming activities, beekeepers are susceptible to WRMSDs. To investigate this, we conducted a two-phase procedure that identified the most prevalent WRMSDs in nine body regions and identified the riskiest postures associated with these tasks. The results from the Nordic Questionnaire indicated that WRMSDs are relatively common among beekeepers in multiple body regions. These disorders are significantly influenced by the beekeepers' extensive work experience and inadequate working conditions. The OWAS postural analysis revealed the correction levels required for each body region and the combined postures that pose the greatest risk. Most beekeepers exhibited postures categorized in AL II, III, and IV, emphasizing the need for prompt corrective measures. This confirms our hypothesis that beekeepers experience significant WRMSDs and adopt risky and awkward postures during their tasks. By identifying similar combined codes in other agricultural activities, managers and workers can swiftly implement corrective measures to prevent MSD-related consequences. Based on these findings, it is crucial to implement ergonomic intervention programs and correct postures during activities. A set of ergonomic and physiotherapeutic recommendations, developed in collaboration with three physiotherapists and two members of the research team, should be promptly adopted to prevent pain exacerbation in various body regions. Furthermore, the design of adjustable assistive products, such as exoskeletons, is highly recommended to alleviate beekeepers' work overload.

This study has several limitations, including a small number of participants and the inability to collect motion laboratory data in an authentic clinical environment. The use of beekeeping clothes hindered the collection of postural analysis data on angles and codes in certain cases. During the filming, participants positioned themselves in an ideal posture to minimize movement while remaining comfortable, which may not accurately reflect their routine work postures during beekeeping (which involve shifting, weight redistribution, and motions). However, the research team made every effort to capture the most representative postures for analysis. Additionally, this investigation was a cross-sectional study that did not gather information on the long-term effects of implementing ergonomic recommendations. Future studies should conduct longitudinal research to examine the impact of ergonomic recommendations over time. For further analysis, it is recommended to employ a Man-Machine System (MMS) approach to comprehensively review the job, which potentially can reduce risks and improve both system productivity and the well-being of workers [61]. MMS is an analytical framework in ergonomics that analyzes working processes by considering four key elements: Person, Equipment, Environment, and Task, which can be subject to in-depth analysis [74]. Considering the MMS framework and other provided information, it is apparent that two accessible factors, humans and tools, can be easily integrated into the investigation of the beekeeping process. The worker's postures as a human aspect have already been examined in this study, while the equipment used in beekeeping (such as buckets and beekeeping clothes) can also be considered. Designing an exoskeleton as an assistive product for beekeepers could help reduce loads and fatigue during their work. Furthermore, an anthropometric examination can explore whether the equipment used during work affects the worker's productivity and the quality of their performance.

References

[1] S. Bao, Chapter 20 - mechanical stress, in: M. Lotti, M. L. Bleecker (Eds.), Handbook of Clinical Neurology, Vol. 131 of Occupational Neurology, Elsevier, 2015, pp. 367–396. doi:10.1016/B978-0-444-62627-1.00019-6.

[2] J. I. Minshew, 32 - Ergonomics, in: J. D. Bancroft, M. Gamble (Eds.), Theory and Practice of Histological Techniques (Sixth Edition), Churchill Livingstone, Edinburgh, 2008, pp. 661–671. doi:10.1016/B978-0-443-10279-0.50039-7.

[3] N. N. Byl, M. F. Barbe, C. B. Dolan, G. Glass, Chapter 27 - repetitive stress pathology: Soft tissue* the authors, editors, and publisher wish to acknowledge ann barr for her contributions on this topic in the previous edition, in: D. J. Magee, J. E. Zachazewski, W. S. Quillen, R. C. Manske (Eds.), Pathology and Intervention in Musculoskeletal Rehabilitation (Second Edition), W.B. Saunders, 2016, pp. 938–1004. doi:10.1016/B978-0-323-31072-7.00027-0.

[4] D. Fels, A. Blackler, D. Cook, M. Foth, Ergonomics in apiculture: A case study based on inspecting movable frame hives for healthy bee activities, Heliyon 5 (7) (2019) e01973.

[5] R. H. Rautiainen, S. J. Reynolds, Mortality and morbidity in agriculture in the United States, Journal of Agricultural Safety and Health 8 (3) (2002) 259–276. doi:10.13031/2013.9054.

[6] H. Naeini, K. Karuppiah, S. B. Tamrin, K. Dalal, Ergonomics in agriculture: an approach in prevention of work-related musculoskeletal disorders (wmsds), undefined 3 (2) (2014) 33–51.

[7] Barbour EHS, Msds in the agriculture sector: From identifying the risks to adopting preventive measures (oct 2020).
URL https://www.shponline.co.uk/ergonomics/msds-in-the-agriculture-sector-from-identifying-the-risks-to-adopting-preventive-measures/

[8] H. H. Harith, M. F. Mohd, S. Nai Sowat, A preliminary investigation on upper limb exoskeleton assistance for simulated agricultural tasks, Applied Ergonomics 95 (2021) 103455. doi:10.1016/j.apergo.2021.103455.

[9] P. Hurst, Health, safety and environment: a series of trade union education manuals for agricultural workers, no. 184, International Labor Organization (ILO), 2006.
[10] E. Topal, A. Atayoğlu, M. Kösoğlu, A. Atayoğlu, Occupational health and safety risk factors in beekeeping (may 2016).
[11] E. Topal, M. Strant, C. Pocol, M. Kösoğlu, A Critical Point in Beekeeping: Beekeepers' Health, Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Food Science and Technology-Publisher: AcademicPres Publishing House (2019).
[12] Agricultural Marketing Resource Center, Bees profile (2021). URL `https://www.agmrc.org/commodities-products/livestock/bees-profile`
[13] I. Kuorinka, B. Jonsson, A. Kilbom, H. Vinterberg, F. Biering-Sørensen, G. Andersson, K. Jørgensen, Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms, Applied Ergonomics 18 (3) (1987) 233–237. doi:10.1016/0003-6870(87)90010-x.
[14] M. Gomez-Galan, J. Perez-Alonso, A.-J. Callejon-Ferre, J. Lopez-Martinez, Musculoskeletal disorders: OWAS review, Industrial Health 55 (4) (2017) 314–337. doi:10.2486/indhealth.2016-0191.
[15] UN, Department of Economic and Social Affairs, food security and nutrition and sustainable agriculture (2023). URL `https://shorturl.at/uDZ24`
[16] S. R. Kirkhorn, G. Earle-Richardson, R. J. Banks, Ergonomic risks and musculoskeletal disorders in production agriculture: recommendations for effective research to practice, Journal of Agromedicine 15 (3) (2010) 281–299. doi:10.1080/1059924X.2010.488618.
[17] Food and Agriculture Organization of the United Nations, Bees and Their Role in Forest Livelihoods: A Guide to the Services Provides by Bees and the Sustainable Harvesting, Processing and Marketing of Their Products, Food & Agriculture Org, Rome, 2009.
[18] A. Osborne, C. Blake, B. M. Fullen, D. Meredith, J. Phelan, J. McNamara, C. Cunningham, Prevalence of musculoskeletal disorders among farmers: A systematic review, American Journal of Industrial Medicine 55 (2) (2012) 143–158. doi:10.1002/ajim.21033.
[19] A. Calvo, E. Romano, C. Preti, G. Schillaci, R. Deboli, Upper limb disorders and hand-arm vibration risks with hand-held olive beaters, International Journal of Industrial Ergonomics 65 (2018) 36–45. doi:10.1016/j.ergon.2018.01.018.
[20] E. Romano, L. Caruso, D. Longo, E. Vitale, G. Schillaci, V. Rapisarda, Investigation of hand forces applied to a pruning tool – pilot study, Annals of Agricultural and Environmental Medicine 26 (3) (2019) 472–478. doi:10.26444/aaem/109751.
[21] S. Gallagher, J. R. Heberger, Examining the Interaction of Force and Repetition on Musculoskeletal Disorder Risk: A Systematic Literature Review, Human factors 55 (1) (2013) 108–124.
[22] M. Rasoulivalajoozi, M. Rasouli, Prevalence of musculoskeletal Disorders and analysis of working postures by (owas) among saffron harvesters, Iranian Journal of Health Sciences 8 (4) (2020) 28–36, publisher: Iranian Journal of Health Sciences. doi:10.18502/jhs.v8i4.4792.
[23] F. A. Fathallah, B. J. Miller, J. A. Miles, Low back disorders in agriculture and the role of stooped work: scope, potential interventions, and research needs, Journal of Agricultural Safety and Health 14 (2) (2008) 221–245. doi:10.13031/2013.24352.
[24] F. A. Fathallah, Musculoskeletal disorders in labor-intensive agriculture, Applied Ergonomics 41 (6) (2010) 738–743. doi:10.1016/j.apergo.2010.03.003.
[25] L. Benos, D. Tsaopoulos, D. Bochtis, A review on ergonomics in agriculture. part II: Mechanized operations, Applied Sciences 10 (10) (2020) 3484. doi:10.3390/app10103484. URL `https://doi.org/10.3390/app10103484`
[26] R. Vyas, Mitigation of musculoskeletal problems and body discomfort of agricultural workers through educational intervention, Work 41 (Supplement 1) (2012) 2398–2404, publisher: IOS Press.
[27] A. Pal, P. C. Dhara, Work-related musculoskeletal disorders and postural stress of the women cultivators engaged in uprooting job of rice cultivation, Indian Journal of Occupational and Environmental Medicine 22 (3) (2018) 163–169. doi:10.4103/ijoem.IJOEM_104_18.
[28] B. Das, S. Gangopadhyay, Prevalence of musculoskeletal disorders and physiological stress among adult, male potato cultivators of west bengal, india, Asia Pacific Journal of Public Health 27 (2) (2015) NP1669–NP1682, publisher: SAGE Publications Inc. doi:10.1177/1010539511421808.
[29] R. Wilsonn, Apitherapy: Benefits, risks, and more (Mar. 2022). URL `https://www.medicalnewstoday.com/articles/apitherapy`
[30] Agricultural Marketing Resource Center, Report (2021). URL `https://www.agmrc.org/media/cms/AgMRC_OctDec_2021_Report_CA9351CFB5844.pdf`
[31] M. K. Rahimi, E. Abbasi, M. Bijani, G. Tahmasbi, A. A. Azimi Dezfouli, Sustainability criteria of apicultural industry: evidence from Iran, Ecosystem Health and Sustainability 6 (1) (2020) 1818630, publisher: Taylor & Francis. doi:10.1080/20964129.2020.1818630.
[32] Iran Beekeeping Industry News, food security and nutrition and sustainable agriculture (2022). URL `https://shorturl.at/jmp19`
[33] Iran open data, The bonyad eiko has turned beekeeping into a $533 million business (2023). URL `https://shorturl.at/apHRV`
[34] K. G. Davis, S. E. Kotowski, Understanding the ergonomic risk for musculoskeletal disorders in the United States agricultural sector, American Journal of Industrial Medicine 50 (7) (2007) 501–511. doi:10.1002/ajim.20479.
[35] A. A. Aiyeloja, G. A. Adedeji, E. A. Emerhi, Impacts of beehive stands' heights and hives' types on the ergonomics of honey harvesting in Port Harcourt, Nigeria, New York Science Journal 08 (04) (2015) 23–27.
[36] G. Maina, F. Rossi, A. Baracco, How to Assess the Biomechanical Risk Levels in Beekeeping, Journal of Agromedicine 21 (2) (2016) 209–214. doi:10.1080/1059924X.2016.1141132.
[37] A. M. Alkhateeb, N. S. Daher, B. J. Forrester, B. D. Martin, H. M. Jaber, Effects of adjustments to wheelchair seat to back support angle on head, neck, and shoulder postures in subjects with cerebral palsy, Assistive Technology 33 (6) (2021) 326–332, publisher: Taylor & Francis. doi:10.1080/10400435.2019.1641167.
[38] K. Masumi, R. E. Kenari, M. K. Motamed, Investigation of technological gap ratio and factors affecting the technical efficiency of beekeeping units, Animal Production Research (jun 2022). doi:10.22124/ar.2022.20703.1650.
[39] A. F. Ferenczi, I. Szűcs, A. B. Gáthy, Economic sustainability assessment of a beekeeping farm in hungary, Agriculture 13 (6) (2023) 1262. doi:10.3390/agriculture13061262.
[40] K. S. Rani, S. Saha, A. J. Reddy, Migratory beekeeping: a boon to both farmer and beekeeper, Insect Environment (mar 2023). doi:10.55278/SHDH7874. URL `https://shorturl.at/oqtJ1`
[41] J. O. Crawford, The Nordic Musculoskeletal Questionnaire, Occupational Medicine, 57 (4) (2007) 300–301. doi:10.1093/occmed/kqm036.
[42] A. Descatha, Y. Roquelaure, J.-F. Chastang, B. Evanoff, M. Melchior, C. Mariot, C. Ha, E. Imbernon, M. Goldberg, A. Leclerc, Validity of Nordic-style questionnaires in the surveillance of upper-limb work-related musculoskeletal disorders, Scandinavian Journal of Work, Environment & Health 33 (1) (2007) 58–65.
[43] M. Motamedzadeh, M. Jalali, R. Golmohammadi, J. Faradmal, H. R. Zakeri, I. Nasiri, Ergonomic risk factors and musculoskeletal disorders in bank staff: an interventional follow-up study in Iran, Journal of the Egyptian Public Health Association 96 (2021) 34. doi:10.1186/s42506-021-00097-8.
[44] C. C. Ngatcha Tchounga, M. Azabji Kenfack, W. R. Guessogo, J. Mekoulou Ndongo, E. C. Bika Léle, C. N. Ayina Ayina, A. Temfemo, B. Bongue, S. H. Mandengue, L. S. Etoundi Ngoa, P. B. Assomo Ndemba, Prevalence of musculoskeletal disorders among taxi drivers in Yaoundé, Cameroon: preventive effect of physical activity, BMC Musculoskeletal Disorders 23 (1) (2022) 1018.
[45] P. Chandoo Musango, D. K. Kimwetich, D. Nzioka Mutisya, Assessment of body mass index (bmi) among members of staff of kenya medical training college nakuru, International Journal of Advances in Scientific Research and Engineering (IJASRE) 5 (7) (2019).
[46] N. Brace, R. Kemp, R. Snelgar, SPSS for Psychologists: A Guide to Data Analysis Using Spss for Windows, 3rd Edition, Palgrave Macmillan, Basingstoke, 2007.
[47] D. Kee, Comparison of OWAS, RULA and REBA for assessing potential work-related musculoskeletal disorders, International Journal of Industrial Ergonomics 83 (2021) 103140. doi:10.1016/j.ergon.2021.103140.
[48] E. OCCHIPINTI, Ocra: a concise index for the assessment of exposure

to repetitive movements of the upper limbs, Ergonomics 41 (9) (2010) 1290–1311. doi:10.1080/001401398186315.

[49] D. Roman-Liu, A. Groborz, T. Tokarski, Comparison of risk assessment procedures used in ocra and ulra methods, Ergonomics 56 (10) (2013) 1584–1598. doi:10.1080/00140139.2013.829923.

[50] D. Kee, Systematic comparison of owas, rula, and reba based on a literature review, International Journal of Environmental Research and Public Health 19 (1) (2022) 595, publisher: Multidisciplinary Digital Publishing Institute. doi:10.3390/ijerph19010595.

[51] M. Hita-Gutiérrez, M. Gómez-Galán, M. Díaz-Pérez, A.-J. Callejón-Ferre, An overview of reba method applications in the world, International Journal of Environmental Research and Public Health 17 (8) (2020). doi:10.3390/ijerph17082635.

[52] Middlesworth, Mark, A step-by-step guide to the REBA assessment tool (2012).
URL https://ergo-plus.com/reba-assessment-tool-guide/

[53] Correcting working postures in industry: A practical method for analysis, Applied Ergonomics 8 (4) (1977). doi:doi.org/10.1016/0003-6870(77)90164-8.

[54] M. Iqbal, L. Angriani, I. Hasanuddin, F. Erwan, H. Soewardi, A. Hassan, Working posture analysis of wall-building activities in construction works using the OWAS method, IOP Conference Series: Materials Science and Engineering 1082 (1) (2021) 012008, publisher: IOP Publishing.

[55] M. Nakhaei, Z. FaragZadeh, S. Tabiei, S. A. Saadatjoo, G. Mahmoodi Rad, M. H. Hoseini, Evaluation of ergonomic position during work in nurses of medical and surgical wards in Birjand University of Medical Sciences hospitals, Journal of Birjand University of Medical Sciences 13 (2) (2006) 9–15, publisher: Journal of Birjand University of Medical Sciences.

[56] A. Tajvar, N. Hashemnezhad, A. Jalali, H. Ghashghavi, Evaluation of risk factors causing work-related musculoskeletal disorders (wmsds) in kerman bakery workers by ocra index method, Iran Occupational Health Journal 6 (3) (2009) 41–46, publisher: IRAN OCCUPATIONAL HEALTH JOURNAL.

[57] UN, Sustainable Development Goals, Take action for the sustainable development goals (2023).
URL https://shorturl.at/sDQX3

[58] F. Kang, Z. He, B. Feng, W. Qu, B. Zhang, Z. Wang, Prevalence and risk factors for MSDs in vegetable greenhouse farmers: a cross-sectional survey from Shandong rural area, China, La Medicina Del Lavoro 112 (5) (2021) 377–386. doi:10.23749/mdl.v112i5.11490.

[59] V. C. Hoe, D. M. Urquhart, H. L. Kelsall, E. N. Zamri, M. R. Sim, Ergonomic interventions for preventing work-related musculoskeletal disorders of the upper limb and neck among office workers, The Cochrane Database of Systematic Reviews 10 (2018) CD008570. doi:10.1002/14651858.CD008570.pub3.

[60] A. A. Aiyeloja, G. A. Adedeji, E. A. Emerhi, Impacts of beehive stands' heights and hives' types on the ergonomics of honey harvesting in Port Harcourt, Nigeria, New York Science Journal 8 (4).

[61] M. M. Cremasco, A. Giustetto, F. Caffaro, A. Colantoni, E. Cavallo, S. Grigolato, Risk assessment for musculoskeletal disorders in forestry: A comparison between RULA and REBA in the manual feeding of a wood-chipper, International Journal of Environmental Research and Public Health 16 (5) (2019) 793. doi:10.3390/ijerph16050793.

[62] W. Sc, H. Em, B. Nm, S. Jr, H. Ap, Musculoskeletal disorders associated with obesity: a biomechanical perspective, Obesity reviews : an official journal of the International Association for the Study of Obesity 7 (3), publisher: Obes Rev (aug 2006).

[63] X. Jin, Y. Dong, F. Wang, P. Jiang, Z. Zhang, L. He, M. Forsman, L. Yang, Prevalence and associated factors of lower extremity musculoskeletal disorders among manufacturing workers: a cross-sectional study in china, BMJ Open 12 (2) (2022) e054969, publisher: British Medical Journal Publishing Group.

[64] P. Bonato, G. R. Ebenbichler, S. H. Roy, S. Lehr, M. Posch, J. Kollmitzer, U. Della Croce, Muscle Fatigue and Fatigue-Related Biomechanical Changes During a Cyclic Lifting Task, Spine 28 (16) (2003) 1810–1820.

[65] C. E. Cook, T. Denninger, J. Lewis, I. Diener, C. Thigpen, Providing value-based care as a physiotherapist, Archives of Physiotherapy 11 (1) (2021) 12. doi:10.1186/s40945-021-00107-0.

[66] Q. Gasibat, N. B. Simbak, A. A. Aziz, Stretching Exercises to Prevent Work-related Musculoskeletal Disorders – A Review Article, American Journal of Sports Science and Medicine 5 (2) (2020) 27–37, publisher: Science and Education Publishing.

[67] H. A. Désiron, A. de Rijk, E. Van Hoof, P. Donceel, Occupational therapy and return to work: a systematic literature review, BMC Public Health 11 (2011) 615.

[68] M. N. Today, Physical therapy: Who can benefit, and how can it help? (jan 2022).
URL https://www.medicalnewstoday.com/articles/160645

[69] A. M. Montalvo, E. L. Cara, G. D. Myer, Effect of Kinesiology Taping on Pain in Individuals With Musculoskeletal Injuries: Systematic Review and Meta-Analysis, The Physician and Sportsmedicine 42 (2) (2014) 48–57, publisher: Taylor & Francis. doi:doi.org/10.3810/psm.2014.05.2057.

[70] Y.-C. Chiu, Y.-S. Tsai, C.-L. Shen, T.-G. Wang, J.-l. Yang, J.-J. Lin, The immediate effects of a shoulder brace on muscle activity and scapular kinematics in subjects with shoulder impingement syndrome and rounded shoulder posture: A randomized crossover design, Gait & Posture 79 (2020) 162–169. doi:10.1016/j.gaitpost.2020.04.028.

[71] T. J. Maurer, E. M. Weiss, F. G. Barbeite, A model of involvement in work-related learning and development activity: The effects of individual, situational, motivational, and age variables, Journal of Applied Psychology 88 (4) (2003) 707–724, place: US Publisher: American Psychological Association. doi:10.1037/0021-9010.88.4.707.

[72] I. M. Zeidi, H. Morshedi, B. M. Zeidi, The effect of interventions based on transtheoretical modelling on computer operators' postural habits, Clinical Chiropractic 14 (1) (2011) 17–28. doi:10.1016/j.clch.2010.07.001.

[73] Y. Darradi, E. Saur, R. Laplana, J.-M. Lescot, V. Kuentz, B. C. Meyer, Optimizing the environmental performance of agricultural activities: A case study in La Boulouze watershed, Ecological Indicators 22 (2012) 27–37. doi:10.1016/j.ecolind.2011.10.011.

[74] R. S. Bridger, Introduction to Ergonomics, McGraw-Hill College, New York, 1995.