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The Impact of Harvesting Height on Farmers' Musculoskeletal Tissue

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Abstract: This study aimed to examine whether different agricultural work patterns may cause MSDs in different body areas and assess their severity. In previous studies, musculoskeletal disorders (MSDs) have been recognized as an occupational disease in agricultural workers. However, not all MSDs resulting from agriculture occur in the same body areas or have similar severity. This study conducted a questionnaire survey to inquire about the body areas and severity of MSDs among fruit farmers. A total of 212 valid answers were collected. Subsequently, their main harvesting postures were classified into three groups to examine the differences in MSD occurrence and severity among those groups. The results indicate that the harvesting posture did result in different severities of MSDs in certain body areas. Raising hands above the shoulders caused significantly higher MSD severity in the neck, shoulder, upper back, and elbows despite the same standing posture. Additionally, those who squatted, bent, or kneeled had a significantly higher severity of MSDs in the shoulders compared to those who stood but did not raise their hands above their shoulders. This study confirmed that the different harvesting heights of fruits can affect farmers' posture, leading to differences in the body areas affected by, and severity of, MSDs.

Keywords: agriculture; occupational diseases; musculoskeletal disorders; harvesting height; harvesting posture

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1. Introduction

Musculoskeletal disorders (MSDs) have been identified as one of the most common occupational diseases affecting agricultural workers in previous relevant studies [1–5]. In related studies, the incidence of MSDs among farmers was indeed significantly higher than that of non-farmers [6–8]. In agricultural operations, there are significant amounts of potential risk factors that may contribute to the occurrence of occupational diseases, physical factors being the most common among them [6,9]. The physical factors include prolonged heavy lifting [3,10–13], improper posture [3,11–15], vibration from operating agricultural machinery [11,16,17], and high-frequency repetitive motions [1,3,10–12,17,18]. These risk factors are present in many tasks carried out during agricultural operations, increasing the likelihood of agricultural workers developing MSDs.

MSDs directly harm the health and occupational safety of agricultural workers. Depending on the severity and areas of the MSDs, they may cause short-term or long-term effects on agricultural workers. Regardless of the duration of the MSDs' impact, they inevitably indirectly affect agricultural productivity and output [19–22]. Relevant studies

have found that workers who take a break due to MSDs have a significant decrease in productivity even after returning to their positions [21]. To address this problem, relevant government agencies or international organizations have published research and warnings. There are lists of common work-related musculoskeletal disorders, potential reasons for those disorders, and methods for their prevention or improvement [6,12,23–25]. They aim to increase farmers' awareness of occupational risks, improve occupational safety, and address MSDs among agricultural workers. However, MSDs is only a general term that includes several conditions that affect the joints, bones, muscles, and multiple body areas or systems. For joints, specific examples include osteoarthritis and spondyloarthritis [1]. For bones, a specific example would be traumatic fractures. In multiple body areas or systems, there may be regional (e.g., back and neck pain) and widespread (e.g., fibromyalgia) pain conditions [6]. And not all agricultural workers are susceptible to suffering from MSDs in the same body areas, at the same severity, or under the same conditions [1,2,13,16].

Through relevant previous studies, it was found that the variety of crops and types in agriculture can cause MSDs in different areas of the body, with varying levels of severity [10,26–32]. Additionally, there are different possible MSDs that agricultural workers may suffer from, even in the same areas of the body. Taking the lower back as an example, among numerous studies focusing on agriculture, the lower back has been identified as one of the most common areas for MSDs to occur [1,16–18,33–36]. However, in a study specifically targeting the tobacco cultivation industry, it has been found that lower back pain accounted for only 9% of the reported MSD cases. This is lower than the 25% reported for lower limb pain, indicating that it is not a major area for MSDs in this particular industry [26]. Similarly, studies with different research targets have produced varying results regarding the prevalence of MSDs in different body areas. For example, research conducted among farmers in Thailand who grow cassava, vegetables, and sugarcane found that their knees and calves were the body areas most commonly affected by MSDs. In contrast, farmers also in Thailand who grow rice and tobacco reported a lower incidence of MSDs in these body areas [27]. Furthermore, even within the same industry, the specific crop being cultivated can result in differences in the possibility and severity of MSDs. Some studies have found that fruit farmers primarily report MSDs in the upper limbs, such as the arms, elbows, and shoulders, with crops including apples, grapes, lychees, longans, and oil palms [19,28–30,37]. However, other studies have reported that the main areas for MSDs were the back [10,28,29,31,32] and lower limbs [26,27]. This study examined past research on MSDs in specific crops and found that there was a relative lack of analysis of the probability of and body areas affected by MSDs between different crops. Through a literature review, this study hypothesized that one of the key factors causing the variation in the probability and severity of MSDs in different crops is the harvesting height. Different harvesting heights can affect the posture required, thereby changing the possible areas, probability, and severity of MSDs. For example, when the harvesting height is higher and requires the hands to be raised above the shoulders, there may be a higher probability of more severe upper limb MSDs [10,29,30,38]. Therefore, this study focused on the fruit cultivation industry as the main research target. However, instead of targeting specific fruit types, several fruit types were collected and then divided by their primary harvesting height. Statistical analysis was conducted to examine whether agricultural workers who cultivate crops at different heights have differences in terms of the affected body areas and the severity of the MSDs. This study aimed to identify the key influencing factors for the incidence areas and severity of MSDs. The results lie in the extension of previous research by investigating the differences in the occurrence of MSDs in different body areas and the severity among different crops in agriculture. It could facilitate the development of more precise prevention and improvement recommendations in the future for MSDs in agricultural workers who plant specific crops, as well as provide a reference for related research.

2. Materials and Methods

2.1. Design and Participants

This study had a population-based cross-sectional design. It used a questionnaire survey to investigate the different areas and severities of MSDs at different harvesting heights. According to other kinds of fruit planting, fruit farmers have to harvest the fruit at different heights and keep themselves in different positions for a long time. Moreover, this study was designed to investigate numerous kinds of farmers who plant different kinds of fruit. The questionnaire survey targeted farmers whose main crop is fruit or whose primary income depends on the fruit.

We referred to questionnaires from related research in the past and made adjustments based on the needs of this study [39]. After the adjustments were completed, we submitted the questionnaire to experts and scholars in agricultural and occupational safety and health for review to ensure the validity of the questionnaire.

The questionnaire included demographic data, working conditions, healthy lifestyle, MSDs situation, the main kind of fruit they plant, and the main harvesting posture they adopt. Then, because the identification of MSDs is relatively complex and requires expertise, this study questionnaire included a question asking the participants whether they had been diagnosed by a doctor to confirm that they have MSDs. Only questionnaires with affirmative answers to this question would be considered valid for this study. However, the severity of MSDs (as determined by the number of sick leave days taken) was within the scope of the participants' self-assessment.

2.2. Procedure

Data collection was carried out between June and September 2022. Regarding the sampling procedure, we first selected 7 main agricultural counties and cities. Though this study did not cover most of the cities in Taiwan, those 7 cities are the main agriculture cities that have high a percentage of GPD depending on agriculture, such as Yulin and Pintung. In the next step, we used stratified sampling to ensure that the sample size of each main agricultural county and city matched the distribution of the national population. Next, we listed all Farmers' Association (FA) branches that deal with general farmers' affairs, like agricultural training, farmers' financial services, and insurance, in those cities or counties as a sampling framework, and randomly selected some from the list. We determined the number of FA branches to be randomly sampled and the number of questionnaires to be distributed based on the proportion of agricultural workers in each selected county or city to the national total. Then, finally, we distributed questionnaires through those associations to volunteers.

We mailed questionnaires to 18 local FA branches in main agricultural cities and asked for their help to recruit voluntary fruit farmers. We also asked the local FA branches to ensure that they recruited farmers who were actually engaged in agriculture and whose main crops were indeed fruits. In some branches, because the climate, soil, and topography of the area favored planting specific kinds of fruits, most farmers affiliated with those branches mainly grew fruits. However, in contrast, some branches were located in areas where fruit cultivation was not prevalent, but rather other crops such as rice, vegetables, tea, etc. Therefore, we specifically emphasized to them that only farmers who primarily grew fruits were invited to complete the questionnaire. Besides screening the eligibility of the participants when distributing the questionnaires, this study also verified the main crops in the questionnaires after collecting them. If the respondents' answers were not fruits, those questionnaires were also considered invalid.

Each participant filled out the questionnaire by himself/herself or with FA officers' help (if they cannot understand the question or even if they cannot read or write). Each respondent was provided with an informed consent form written in Chinese establishing the objective of this study, their rights, and guarantees of anonymity and confidentiality. This study excluded any personal identifiers in the questionnaires to ensure anonymity

and the exclusion of any possible harm to their physical, mental, or reputational well-being. The application took about 6 to 8 min.

This study distributed 250 questionnaires to 18 local FA branches in main agriculture cities, and a total of 212 valid questionnaires were returned after excluding the invalid ones, for an effective response rate of 84.8%. Additionally, there were ten kinds of fruits the participants mainly planted: sugar apple, pear, wax apple, banana, lemon, orange, pineapple, melon, watermelon, and strawberry.

2.3. Measurements

The primary purpose of this study was to investigate whether different harvesting heights affect the areas and severity of MSDs in farmers. However, we also wanted to know whether other factors may contribute to the severity of MSDs, such as gender, age, body mass index (BMI), agricultural seniority, working hours each day, and healthy lifestyle.

2.3.1. Basic Information Collection

The basic information consisted of three sections: demographic data, working conditions, and healthy lifestyle. Demographic data included age, gender, educational level, and BMI (the questionnaire only asked for participants' weight and height, BMI was calculated after this study collected the respondents' forms back). Working conditions were composed of agricultural seniority, working hours each day, and working days each week. Healthy lifestyle questions asked respondents to rate their frequency of smoking, alcohol drinking, and betel nut chewing, and to report their sleeping hours and quality.

2.3.2. Group of Harvesting Height

This study tried to explore the relationship between harvesting height and the areas and severity of MSDs. This study did not just focus on a single kind of fruit like the related previous study; we tried to compare different kinds of fruit instead. In the previous study, the researchers asked the participants to harvest apples at four fixed harvest heights (500 mm, 1000 mm, 1500 mm, and 2000 mm) [40]. However, in this study, we classified different harvesting heights by position.

In the questionnaire design, participants were asked about the main fruit they plant. Then, we divided all categories of fruits participants reported into three groups by evaluating their harvesting height: high harvesting height (HHH), middle harvesting height (MHH), and low harvesting height (LHH). HHH refers to when farmers are harvesting their fruits and they often have to spread out their arms above their shoulders to harvest the fruits. MHH means that the farmers' harvesting height is mainly between their shoulders and waist in a standing position. Therefore, the farmers who belonged to MHH did not have to spread their hands above their shoulders or bend/kneel to harvest. Finally, LHH refers to farmers needing to kneel, take a squatting position, or bend over at their waist when harvesting.

In HHH, there were four kinds of fruits: sugar apple, pear, wax apple, and banana. Then, for lemon and orange, these two kinds of fruits were classified into MHH. Additionally, LMM included four kinds of fruits: pineapple, melon, watermelon, and strawberry.

2.3.3. Evaluation of MSDs

In a related study, MSD-affected areas were divided into nine areas: the neck, shoulder, elbow, wrist/hand, upper back, lower back, knees, hip/thighs, and ankle/feet [36]. This study followed this division for the body areas affected by MSDs. In our questionnaire, we divided MSDs into nine areas like the related study, and asked participants about the severity of MSDs that they suffered from in each area.

Regarding the severity of MSDs, we used their sick leave days caused by MSDs to measure. Comparing the reporting rates of MSDs, this measurement method may also be able to evaluate the economic costs or productivity lost due to MSDs. The severity of MSDs was divided into 5 levels: no effect, one day of sick leave, two days, three days, and four days and above.

2.4. Statistical Analysis

In this study, we conducted three steps of statistical analysis: descriptive analysis, median test, and multiple linear regression. The first step was to use descriptive analysis to describe participants' demographic information, working conditions, and healthy lifestyle, which helped us obtain a general understanding of the data. Then, we applied the Shapiro–Wilk test and examined the kurtosis and skewness of the sample distribution to verify that the sample did not follow a normal distribution. Based on this verification, we conducted the median test instead of one-way ANOVA to test whether there were significant differences between the severity of MSDs and harvesting height. Finally, for each body area that showed a significant difference, we built a multiple linear regression model to measure the association between harvesting height and the severity of MSDs. Harvesting height was the key independent variable, while demographic information, working conditions, and healthy lifestyle were other independent variables or control variables. The severity of MSDs was the dependent variable. These steps allowed us to analyze the data rigorously and accurately.

In terms of the confidence level, we used a higher confidence level (99%) in our statistical analysis. We applied a higher confidence level to address the issue that our sample was not large enough. Although we met the statistical criteria for a large sample size after grouping according to the harvesting heights, our sample size still has room for improvement.

All statistical analyses were conducted using Stata software (StataCorp LLC, College Station, TX, USA), version 14.0 MP.

3. Results

3.1. Descriptive Analysis

A total of 212 fruit farmers were included in this study. Table 1 summarizes the basic information of the 212 fruit farmers. All of them were divided into the HHH group (n = 107), the MHH group (n = 41), or the LHH group (n = 64). The average age was 56.46 (SD = 13.28), and most of them were male (145, 68.4%). The main education level of the participants was high school (85, 40.09%), and the secondary was university level (71, 33.49%). Over half of them had normal BMI (115, 54.25%), but there were also a significant number of them who were overweight (69, 32.55%) or obese (17, 8.02%).

Table 1. Basic information of the participants (n = 212).

Variables	HHH (High Harvesting Height) (n = 107)	MHH (Middle Harvesting Height) (n = 41)	LHH (Low Harvesting Height) (n = 64)
Age	56.46 ± 13.28	54.83 ± 14.28	51.79 ± 14.68
Gender, *n* (%)			
Male	75 (70.1)	27 (65.85)	43 (67.19)
Female	32 (29.9)	14 (34.15)	21 (32.81)
Education level, *n* (%)			
Primary and under	14 (13.1)	3 (7.3)	6 (9.4)
Secondary	17 (15.9)	2 (4.9)	8 (12.5)
High	41 (38.3)	16 (39.0)	28 (43.7)
University	32 (29.9)	18 (43.9)	21 (32.8)
Graduate	3 (2.8)	2 (4.9)	1 (1.6)
BMI, *n* (%)			
Underweight	53 (49.53)	23 (56.10)	39 (60.94)
Normal	6 (5.61)	1 (2.44)	4 (6.25)
Overweight	35 (32.71)	16 (39.02)	18 (28.13)
Obese	13 (12.15)	1 (2.44)	3 (4.68)
Working days each week	5.20 ± 1.52	5.54 ± 1.42	5.63 ± 1.66
Working hours each day	6.70 ± 2.65	7.07 ± 3.2	7.55 ± 2.56

Table 1. *Cont.*

Variables	HHH (High Harvesting Height) (n = 107)	MHH (Middle Harvesting Height) (n = 41)	LHH (Low Harvesting Height) (n = 64)
Seniority	21.37 ± 13.72	18.24 ± 16.20	18.98 ± 16.36
Smoking [a]	0.63 ± 1.05	0.68 ± 1.04	0.98 ± 1.35
Alcohol drinking [a]	0.92 ± 0.99	0.76 ± 0.92	1.13 ± 1.11
Betel nut chewing [a]	0.27 ± 0.73	0.22 ± 0.53	0.11 ± 0.44
Sleep sufficiency [b]	3.12 ± 0.98	3.29 ± 0.84	3.09 ± 0.71
Sleep quality [b]	3.13 ± 0.92	3.32 ± 0.69	3.06 ± 0.69
Number of farmers of various fruit			
Sugar apple	16	0	0
Pear	46	0	0
Wax apple	35	0	0
Banana	10	0	0
Lemon	0	19	0
Orange	0	22	0
Pineapple	0	0	35
Melon	0	0	13
Watermelon	0	0	9
Strawberry	0	0	7

[a] This study used a scale of 0–4 to represent the frequency of smoking, alcohol drinking, and betel nut chewing. The value 0 means never and 4 means always. [b] This study used a scale of 1–5 to ask participants to evaluate if they get enough hours of sleep. The value 5 means more than enough, and 1 means totally not enough. Additionally, we also used a scale of 1–5 to ask participants to measure their sleeping quality. The value 5 means very good, and 1 means very poor.

Among the 212 participants, the average times spent farming were 5.20 (SD = 1.52) days each week and 6.70 (SD = 2.65) hours each day. The average agricultural seniority of the participants was 21.37 (SD = 13.72) years.

Regarding the participants' healthy lifestyles, the frequencies of smoking (0.75, SD = 1.15), alcohol drinking (0.95, SD = 1.02), and betel nut chewing (0.21, SD = 0.62) were all low. Additionally, the average sleep sufficiency and quality participants reported were 3.12 (SD = 0.98) and 3.13 (SD = 0.92). This meant that the participants had a positive opinion of their sleeping time and quality.

3.2. Difference between the Severity of MSDs and Harvesting Height

Due to the severity of MSDs in different body areas not following a normal distribution, we used the Kruskal–Wallis Test (one type of median test) to replace the one-way ANOVA. The Kruskal–Wallis Test compares two or more group samples by ranking the combined samples. It assigns a rank of 1 to n (number of all observations) to all observations, the smallest observation is assigned a rank of 1, the second one is assigned a rank of 2, and so on. It will assign an average rank to each tied observation if two or more observations are tied. The result of the Kruskal–Wallis Test use rank means difference to replace means difference in one-way ANOVA.

Table 2 shows the difference between the severity of MSDs and harvesting height. With a 99% confidence level, different harvesting heights had different severities of MSDs, but this correlation merely existed in certain body areas: the neck, shoulder, upper back, and elbow. Most of the differences existed between HHH and MHH/LHH. There were no significant differences between MHH and LHH in the severity of MSDs in any body area, and the gap in the severity of MSDs between MHH and LHH in any area was not significant. We still found that the severity of MSDs of LHH was higher than those of MHH in most areas except the neck and ankle/feet by comparing their rank means. Then, we obtained a preliminary outcome, according to which fruit farmers whose main harvesting height is over the shoulders may have a higher severity of MSDs than others.

Table 2. Different severity of MSDs at different harvesting heights.

Areas	Group A	Group B	Rank Mean Difference (A–B)	Critical Value	*p*-Value
Neck	HHH	MHH	30.59 *	26.97	0.003
		LHH	19.84	23.21	0.020
	MHH	HHH	−30.59 *	26.97	0.003
		LHH	10.75	29.38	0.191
	LHH	HHH	−19.84	23.21	0.020
		MHH	−10.75	29.38	0.191
Shoulder	HHH	MHH	58.74 *	26.97	0.000
		LHH	33.18 *	23.21	0.000
	MHH	HHH	−58.74 *	26.97	0.000
		LHH	−25.56	29.38	0.019
	LHH	HHH	−33.18 *	23.21	0.000
		MHH	25.56	29.38	0.019
Upper Back	HHH	MHH	32.78 *	26.97	0.002
		LHH	17.02	23.21	0.040
	MHH	HHH	−32.78 *	26.97	0.002
		LHH	−15.77	29.38	0.099
	LHH	HHH	−17.02	23.21	0.040
		MHH	15.77	29.38	0.099
Elbow	HHH	MHH	28.09 *	26.97	0.006
		LHH	12.45	23.21	0.100
	MHH	HHH	−28.09 *	26.97	0.006
		LHH	−15.64	29.38	0.101
	LHH	HHH	−12.45	23.21	0.100
		MHH	15.64	29.38	0.101
Lower Back	HHH	MHH	25.54	25.31	0.068
		LHH	8.65	27.12	0.084
	MHH	HHH	−25.54	25.31	0.068
		LHH	−16.89	29.85	0.107
	LHH	HHH	−8.65	27.12	0.084
		MHH	16.89	29.85	0.107
Wrist/ Hand	HHH	MHH	22.66	26.97	0.022
		LHH	16.80	23.21	0.042
	MHH	HHH	−22.66	26.97	0.022
		LHH	−5.86	29.38	0.316
	LHH	HHH	−16.80	23.21	0.042
		MHH	5.86	29.38	0.316
Hip/ Thigh	HHH	MHH	23.37	26.97	0.019
		LHH	23.77	23.21	0.007
	MHH	HHH	−23.37	26.97	0.019
		LHH	0.41	29.38	0.487
	LHH	HHH	−23.77	23.21	0.007
		MHH	0.41	29.38	0.487
Knee	HHH	MHH	21.19	26.97	0.030
		LHH	20.35	23.21	0.018
	MHH	HHH	−21.19	26.97	0.030
		LHH	−0.84	29.38	0.473
	LHH	HHH	−20.35	23.21	0.018
		MHH	0.84	29.38	0.473
Ankle/ Feet	HHH	MHH	19.10	26.97	0.045
		LHH	22.19	23.21	0.011
	MHH	HHH	−19.10	26.97	0.045
		LHH	3.09	29.38	0.401
	LHH	HHH	−22.19	23.21	0.011
		MHH	−3.09	29.38	0.401

* $p < 0.01$.

By using the median test, we verified that there were significantly different severities of MSDs at different harvesting heights.

3.3. Regression Results of the Severity of MSDs

By comparing the median, we established that there were different severities of MSDs at different harvesting heights. Then, multiple linear regression analysis was conducted to examine the association between the severity of MSDs and related factors, especially harvesting height. However, the dependent variable (MSDs) does not follow a normal distribution. Although the sample size of this study meets the standard of a large sample, the study still took the logarithm of the variable before analysis to reduce possible analysis errors. Therefore, the results obtained are based on the logarithmic transformation of MSDs. The results are shown in Table 3. The results show that harvesting height and BMI have a significant linear relationship, affecting the severity of MSDs in four body areas: the neck, shoulder, upper back, and elbow.

Table 3. Association between the severity of MSDs and related influencing factors in different body areas.

Variable	Neck		Shoulder		Upper Back		Elbow	
	β	SE	β	SE	β	SE	β	SE
Constant	0.118	0.137	0.240	0.113	0.196	0.136	0.225	0.134
Age	0.002	0.002	0.001	0.001	0.002	0.002	0.002	0.002
Gender	−0.006	0.040	−0.035	0.033	−0.022	0.038	−0.008	0.037
Education	0.034	0.018	0.031	0.017	0.025	0.019	0.014	0.020
BMI								
Normal	0		0		0		0	
Underweight	0.187 *	0.059	0.190 *	0.052	0.265 *	0.043	0.240 *	0.054
Overweight	−0.029	0.036	−0.003	0.030	0.027	0.034	0.001	0.034
Obese	0.053	0.055	0.044	0.051	0.078	0.062	0.032	0.065
Working days each week	0.001	0.011	0.016	0.008	0.014	0.011	0.016	0.011
Working hours each day	0.000	0.007	0.001	0.005	0.003	0.006	0.004	0.006
Seniority	0.001	0.001	0.001	0.001	0.000	0.002	0.001	0.002
Smoking	0.016	0.015	0.000	0.014	0.006	0.015	0.008	0.014
Alcohol drinking	0.020	0.016	0.020	0.013	0.009	0.017	0.021	0.016
Betel nut chewing	0.005	0.028	0.031	0.017	0.039	0.023	0.007	0.028
Sleep sufficiency	0.055	0.033	0.024	0.030	0.046	0.033	0.055	0.032
Sleep quality	−0.055	0.034	−0.051	0.029	−0.033	0.035	−0.075	0.033
Harvesting height								
High	0		0		0		0	
Middle	−0.136 *	0.045	−0.216 *	0.039	−0.123 *	0.041	−0.098 *	0.042
Low	−0.102 *	0.038	−0.130 *	0.034	−0.069	0.038	−0.057	0.038
R^2	0.172		0.251		0.192		0.158	
Adj R^2	0.153		0.218		0.173		0.134	
F	3.48		4.97		5.17		3.52	

* $p < 0.01$.

According to the outcome of the median test, changing harvesting height affected the severity of the MSDs ($p < 0.01$). The differences between HHH and MHH were significant in all four models. When switching harvesting height from high to middle, the logarithm of severity of the MSDs significantly decreased by 0.136 in the neck, 0.216 in the shoulder, 0.123 in the upper back, and 0.098 in the elbow. Comparatively, the difference between HHH and LHH was only significant in the model of the neck and shoulder. When changing the harvesting height from high to low, the logarithm of severity of MSDs significantly decreased by 0.102 in the neck and 0.550 in the shoulder. These outcomes almost matched the median test.

Regarding BMI, it is the only related factor that had a significant association with the severity of MSDs, excluding harvesting height. All four multiple linear regression models indicated that individuals whose BMI was underweight were more likely to have more severe MSDs ($p < 0.01$) than normal-weight people.

4. Discussion

In previous studies, MSDs have been identified as common occupational diseases among agricultural workers, especially the elderly. However, there appear to be notable differences in the occurrence and severity of MSDs affecting specific areas of the body across various types of agriculture or crops. This implies that there is still much to be explored in terms of the impact of MSDs on farmers.

This study examines whether farmers experience different severities of MSDs across specific areas of the body as a result of varying fruits and harvesting heights. We conducted a questionnaire survey on farmers who mainly plant fruits to evaluate the severity of MSDs across various body areas. Subsequently, we utilized median tests and multiple linear regression to examine whether the different harvesting heights of fruits affect the severity of MSDs. In conclusion, this study found that different fruits with varying harvesting heights had significantly different effects on the severity of MSDs in four body areas: neck, shoulders, upper back, and elbows. The effects were observed after controlling for other potential influencing factors such as age and working hours.

In this study, the main postures adopted by farmers during harvesting were divided into three groups: HHH, MHH, and LHH. These three groups were analyzed for the severity of MSDs in various areas of the body.

Firstly, the Kruskal–Wallis Test was used to compare the median of the severity of MSDs in different body areas among the three groups. The results show that there were significant differences in the severity of MSDs in the neck, shoulders, upper back, and elbows. In the neck, the severity of MSDs for HHH crops was significantly higher than for MHH crops (rank mean difference = 30.59), with a 99% confidence level. HHH also had a higher severity compared to LHH, although this difference was not statistically significant (rank mean difference = 10.75). In the upper back (rank mean difference = 32.78) and elbows (rank mean difference = 28.09), the outcome is similar to the neck, while the severity of HHH MSDs was significantly higher than those of MHH (99% confidence level). HHH MSDs are still more severe than those at LHHs in the upper back (rank mean difference = 17.02) and elbows (rank mean difference = 12.45), but their differences do not have significance. However, in contrast to the previous three, HHH has a significantly higher severity of MSDs of the shoulders compared to both MHH (rank mean difference = 58.74) and LHH (rank mean difference = 33.18).

After the first stage of the analysis, it can be observed that the severity of MSDs is greater in the neck, shoulders, upper back, and elbow regions in the order of HHH > LMM > MHH. Although this result is not statistically significant, it presents an overview of the correlation between different harvesting heights and the severity of MSDs. Among the different harvesting heights, MHH, which involves maintaining a standing posture during crop harvesting and minimal arm lifting, appears to have the lowest risk of experiencing MSDs. Conversely, HHH, which involves maintaining a standing posture and implies frequently lifting the arms over the shoulder during harvesting, has the highest risk of experiencing MSDs in the neck, shoulders, upper back, and wrist regions.

Secondly, this study built regression models for certain body areas exhibiting significant differences in the severity of MSDs at different harvesting heights. This study investigated the impact of various factors, including different harvesting heights, on the severity of MSDs. For each of the four body areas, four models were constructed and the results are similar to the outcome of the median test. The logarithms of severity of MSDs in four body areas all significantly increased when the harvesting height was changed from MHH to HHH. The increasing severities of MSDs in the neck, shoulders, upper back, and elbows are 0.14, 0.22, 0.12, and 0.01, respectively. In the case of the neck and shoulders, a significant increase in the logarithm of severity of MSDs was observed when the harvesting

height was changed from LHH to HHH while maintaining other factors constant. In addition to harvesting height, BMI was another significant factor affecting the severity of MSDs. Compared to the farmers with a normal BMI, the individuals whose BMI fell within the underweight range had higher severity of MSDs in the neck, shoulders, upper back, and elbows. The increasing logarithms of severity of MSDs in the neck, shoulders, upper back, and elbows are 0.19, 0.19, 0.27, and 0.24, respectively.

This study demonstrates that different harvesting postures are needed for crops at different harvesting heights, and these postures can lead to varying locations and severities of MSDs. Subsequently, this outcome could be applied preliminarily to infer the types of MSDs that may occur in various agricultural activities and crops. This is consistent with previous research findings. As fruits are often located at higher positions, agricultural workers are forced to adopt inappropriate postures or frequently raise their arms above their shoulders or heads during harvesting. Such work patterns increase the risk of MSDs in their upper extremities and may result in higher severity levels compared to other individuals [14,29,30,38]. A study of fruit farmers in Thailand revealed that both male and female workers who had to raise their arms above their shoulders during harvesting had a higher incidence of neck MSDs, with odds ratios of 1.68 and 1.82, respectively [38]. A similar problem can also occur in the same crop, such as oil palm. Studies conducted on oil palm harvesting workers in Malaysia and Thailand found that workers harvesting oil palm did indeed have a considerable prevalence of lower back MSDs. However, the incidence of MSDs in the shoulder and neck areas was also significant. Particularly, workers responsible for higher fruit collection areas had to adopt more inappropriate postures or raise their arms, resulting in greater pressure exerted on their shoulder and neck areas throughout the harvesting process. The ultimate result is that palm oil harvesters, particularly those responsible for higher yield areas, are found to have a higher prevalence of MSDs in the neck and shoulders, as indicated by prior studies [14,29].

This study has several limitations that we have tried to emphasize as much as possible in the research discussion. First, we adopted a self-reported method to measure MSDs due to constraints such as time and budget, although we downsized where participants suffered from MSDs diagnosed by a doctor. This method may lack precision compared to examining official medical records or using professional medical evaluations. However, it also allows for collecting a relatively large amount of data and avoiding underestimating the severity of the condition, which are potential issues with the latter methods [41,42]. Therefore, we suggest using more professional evaluation methods in future studies if possible. Second, although we met the statistical criteria for a large sample size after grouping according to the harvesting heights, our sample size still has room for improvement. To address this issue, we used a higher confidence level (99%) in our statistical analysis. Third, we hypothesized that harvesting heights caused the differences in the occurrence and severity of MSDs among different crops. Although our results supported this hypothesis, other factors may also contribute to these differences. These factors may include harvested fruit weight, auxiliary equipment use, organizational factors, social context, external tolerance, etc. However, we did not fully explore these factors in our questionnaire design, and their effects were excluded from our analysis, which could bias our results. We only managed to exclude demographic data (such as sex and age), working conditions (such as daily working hours), and healthy lifestyles of participants, which could potentially cause bias as well. We should note that without comprehensive control of relevant confounding factors, our main finding—the impact of harvesting height on MSDs—could be subject to interference. We recommend taking these factors into account in future questionnaire designs by including them as much as possible and eliminating their confounding effects during analysis.

5. Conclusions

In conclusion, agricultural workers who frequently raise their arms above their shoulders or heads are more prone to suffering from MSDs, with a high prevalence in the neck,

shoulder, upper back, and elbow. Those who can maintain a standing posture, but with arm movements falling between the shoulders and waist, have a relatively lower MSD incidence rate. This can be considered a relatively appropriate and safe working posture. In the future, more attention should be paid to issues such as the harvesting posture required for a specific harvesting height. For now, some potential ways to improve that issue may be adjusting the environment in which farmers work. For example, some fruit farmers in certain areas have adjusted the height of fruit trees through planting techniques, such as using breeding or physical methods to limit the height of fruit trees. This way, they can keep the height of subsequent care and harvesting at a level that is convenient for farmers to work at (such as standing upright, without having to squat down, use a ladder, or lift their hands above their shoulders). Additionally, the occupational safety issues of agricultural workers should consider the resulting MSDs' morbidity rate.

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