International Journal of
Occupational Safety and Health

ISSN: 2091-0878 (Online) ISSN: 2738-9707 (Print)

Original Article

Factors affecting risk level of work postures of durian farmers during pesticide spraying in southern peninsular Thailand: A cross-sectional study

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Date of submission: 15.01.2026
Date of acceptance: 01.04.2026
Date of publication: 15.04.2026
Conflicts of interest: None
Supporting agencies: Prince of Songkla University
DOI:https://doi.org/10.3126/ijosh.v16i1.89360

ABSTRACT

Introduction: Work-related musculoskeletal disorders (WMSDs) are a major occupational health problem among farmers in Thailand. The purpose of this study was to evaluate the risk level and risk factors in work posture of durian farmers during pesticide spraying.

Methods: This cross-sectional study was carried out among 82 durian farmers (n = 82) in southern peninsular Thailand. A questionnaire was used to collect data on socio-demographics and work characteristics. The posture analysis during pesticide spraying was done using Rapid Entire Body Assessment (REBA). The Chi-squared test was applied to find associations between socio-demographics or work characteristics with the risk level according to REBA assessments, with statistical significance requiring $p<0.05$.

Results: REBA assessments indicated that most work postures during pesticide spraying by durian farmers had a high risk. Ergonomic risk factors for durian farmers involved prolonged work while standing in awkward postures, including bending the neck with more than 20° extension, bending the trunk with 0°-20° extension, raising and abducting the shoulder, both hands holding spray handles all the time, or carrying backpack pesticide sprayers with weights from 8 to 22 kg. Season, age, monthly income, pesticide spraying experience, pesticide spraying on other plants, pesticide spraying method, frequency of spraying pesticide, and durian tree height were statistically significantly associated with risk levels of work postures during pesticide spraying by durian farmers.

Conclusion: Therefore, regular ergonomic training accompanied by modifications to the workstations and to tools for pesticide spraying are essential in improving work postures during pesticide spraying by durian farmers.

Keywords: durian farmer, ergonomics, pesticide spraying, work posture

Introduction

Thailand is an agricultural country, where the majority of people are farmers. Thailand is the largest producer of durian and has the largest annual durian exports. The area of durian production has significantly increased from 838,714 rai in 2017 to 1,069,668 rai in 2020 (one rai equals 1,600 square meter area).[1] The durian production in the southern peninsular region has reached 47.4 percent of the total durian production in Thailand. In addition, most durian farmers are in this southern region (65.6 percent) and they produce durian both in its peak season

and out of season.[1] Based on the statistics provided by the Bureau of Occupational and Environmental Diseases (BOED), farmers are the category with the most prevalent musculoskeletal disorders. The number of farmers in Thailand who suffer from musculoskeletal disorders has increased steadily: 38,793 (2016), 62,806 (2017) and 70,184 (2018).[2] Many studies that relate to work posture and musculoskeletal disorders of farmers in Thailand have been published. A study of rice farmers during rice field preparation in Khon Kaen province found that experience and age were significantly associated with body pain and cramping. The most complaints of work-related musculoskeletal disorders (WMSDs) among more experienced farmers concerned their legs.[3] A study on Cambodian fruit farm workers in eastern Thailand indicated that the operations of mixing and of spraying pesticides, and of harvesting fruits, pose very high risks according to the Rapid Upper Limb Assessment (RULA) method. The body parts with the most discomfort to workers in a Cambodian fruit farm were lower back, neck, and shoulders. Risk factors for work related discomforts were age, length of work history, plantation area, and unhealthy work postures.[4] The organic farmers from Yasothorn province showed significantly more pain, numbness, or weakness in the wrists/hands, fingers, upper back, hips and ankles/feet than conventional farmers using pesticides from Nakorn Sawan and Phitsanulok provinces. Organic farmers do not use pesticides and take care of plants by sitting or squatting near the plants and removing weeds by hand.[5] The three top ranked risk factors to WMSDs of elderly farmers in Pathumthani province were bending trunk forward, bending the neck, and twisting the trunk. The Rapid Entire Body Assessment (REBA) indicated that most elderly farmers had a high risk level.[6] Lower back pain was the most prevalent musculoskeletal disorder in rubber farmers of southern Thailand, followed by hip/thigh and ankle/foot pains. RULA method reported that postures during tapping rubber trees and collecting rubber latex had a medium risk.[7]

WMSDs are a major occupational health problem for farmers worldwide. In Malaysia, REBA method revealed that most of the postures during harvesting and collecting fresh fruit bunches of oil palm were in the very high-risk level. The main types of activities inducing WMSDs were holding and swinging chisel and sickle, and these required further investigation and changing the action soon.[8] Another study from Malaysia showed that the most complaints of WMSDs among oil palm fresh fruit harvesters were from lower back pain, followed by knee, shoulder and neck regions. Musculoskeletal symptoms in the past 12 months were significantly associated with duration of employment, and daily work and rest durations.[9] Conventional method of maize seeding in Malaysia is related to an awkward posture with repetitive movements, sit squatting, bending the knee, and digging a hole. REBA and RULA methods indicate the conventional method as having a high risk, whereas lightweight motorized maize seeder had a low risk. Moreover, the lightweight motorized maize seeder was faster than the conventional method in seeding maize.[10] In Indonesia, the highest prevalences of disorders for rice farmers in Bantul province from manually planting rice in the rice field were in waist, right and left shoulder, and back. REBA method showed the manual method as having a high risk with a score of 10, but a rice planter tool gave a medium risk with a score of 4. Rice planter tool increased the productivity twofold and reduced the risk of WMSDs.[11] The 9 activities of rice farmers in West Java province are use of a hoe manually for land clearing, grass cutting, planting the rice, manual plowing, applying fertilizer, harvesting, threshing, cleaning the rice from the straw, and sun-drying of rice. REBA method reported that the four activities manual plowing, manual use of hoe for land clearing, grass cutting, and threshing, were of a high risk. Most rice farmers suffered from musculoskeletal disorders in shoulder and lower back. Risk factors for work related discomforts were lifting and carrying heavy loads, repeated whole body bending, and highly repetitive handwork.[12] Another study on rice farmers in Central Java showed that neck and

lower back pain were the most prevalent musculoskeletal disorders. REBA method indicated that most rice farmers had a medium risk with a score of 7, and RULA method showed a high risk with a score of 7. The three top-ranked risk factors associated with WMSDs were heavy loads, bending the back, and sitting position.[13] The most suffered WMSD symptom of elderly farmers was lower back pain, and these musculoskeletal disorders were significantly associated with work position. The main types of activities inducing lower back pain were prolonged standing, body bending and body rotation approximately 4 times per minute.[14] In Iran, the main types of activities in manual sesame seed harvest were mowing, tying, and shaking. Ovako work posture analysis system (OWAS) indicated that stooped and squatting postures and heavy lifting were the dominant risk factors associated with lower back pain.[15] The 5 tasks of a pistachio farmer were picking pistachios from trees, carrying cloth wrappers for loading, shoveling pistachios into a hulling machine, washing pistachios, and transferring bags to a warehouse; and these were identified as high risk. Shoulder pain was the most prevalent musculoskeletal disorder, followed by lower back and wrist/hand pains. Musculoskeletal disorders were associated with repetitive motions, excessive force, awkward postures, and prolonged sitting and standing.[16] In Colombia, the 4 activities of natural rubber tappers were latex tapping, latex collection, mixing in two-roll mills, and metallic mold operations. The major risk factors were awkward posture, repetitive movements, and manual handling of heavy loads, which caused back and leg disorders.[17] In Spain, the normal work in melon cultivation involves transplanting, manual spraying, tractor spraying, leaf removal, harvesting, and cleaning. OWAS indicated that melon cultivation was dominantly of medium risk (47.57%), followed in rank by high risk (14.32%) and very high risk (0.47%). Mostly the posture has bent back, holding both arms below shoulder level, standing on two straight legs, and with a work load of less than 10 kg.[18]

Many studies have been performed on work posture, risk factors, and musculoskeletal disorders associated with rice, fruit, rubber, and organic farming, and associated with elderly farmers in Thailand. Additionally, there are many studies relevant to WMSDs among oil palm, maize, rice, sesame, pistachio, rubber, and melon farmers, and on elderly farmers worldwide. Limited studies have included durian farmers. Therefore, this study focused on factors affecting risk level of work postures of durian farmers during pesticide spraying in southern peninsular Thailand.

Methods

A cross-sectional study was conducted in durian farmers of southern peninsular Thailand, from November 2019 to September 2021. Durian farmers in this region prefer to grow durian because of its high sales price, while the price of rubber is relatively depressed. As a result, the agricultural area to grow durian has expanded in some areas. The areas for rubber trees, or fruits such as rambutan, have transitioned to growing durian instead. Durian is grown both in-season and out of season. In-season for durian is from July to August, while its off-season is from December to March. In this study, the top 2 areas in the southern region with the highest durian yield (kg) per rai were selected, namely Nakhon Si Thammarat and Surat Thani provinces. To sample in Nakhon Si Thammarat province, Tha Sala district was selected because it has the most durian cultivation and is a high yielding area. Moreover, most of the durian farmers are mainly producing durian out of season. In Surat Thani province, Na San district was chosen because of the highest durian yield per rai, and most of the durian farmers producing durian in-season. The sample size was determined using the Krejcie and Morgan table with an acceptable margin of error of 5% and a confidence level of 95%. According to the Krejcie and Morgan table, from a population of 101 individuals, a minimum sample size of 80 participants was required. Lists of registered durian farmers in the selected districts were obtained from local agricultural offices. Eligible

farmers were assigned identification numbers and selected using simple random sampling with a computer-generated random number list, resulting in a total of 82 participants being recruited for the study. All those randomly selected durian farmers aged from 20 to 60 years who had been spraying pesticide for one year or more and were still spraying pesticide in durian farm when they were invited to participate, were included in the study. An informed consent was obtained from each of the durian farmers, and the study was approved by the Health Science Human Research Ethics Committee, Prince of Songkla University (HSc-HREC-60-005-10-1).

The questionnaires collected data on demographics and work characteristics, including gender, weight, height, age, marital status, highest education level, monthly income, pesticide spraying experience (years), spraying pesticide on other plants, pesticide spraying method, frequency of spraying pesticide (days/year), duration of pesticide spraying (h), and durian tree height. All questions were multiple-choice type or open ended.

Work postures of individual durian farmers during pesticide spraying were captured by using a video camera and cropped to produce snapshots. Video recordings were reviewed frame-by-frame. The most frequent posture was defined as the posture maintained for the longest cumulative duration during pesticide spraying. The worst posture was defined as the posture exhibiting the greatest degree of joint deviation from neutral position and highest biomechanical load, based on Rapid Entire Body Assessment (REBA) scoring criteria (Table 1). REBA was designed by MacAtamney and Hignett, and this method is divided into 2 sections, of which section A includes neck, trunk, and legs, and section B covers upper arms, lower arms and wrists. This method also evaluates force and load, coupling, and muscle activity. Scores are calculated for the posture during each task, and these are classified into five risk levels: very low risk (score 1), low risk and change may be needed (score 2-3), medium risk, further investigation and change soon (score 4-7), high risk, investigate and implement change (score 8-10), and very high risk and implement change (score $\geqslant$ 11).[19] REBA scoring was conducted independently by two trained assessors with experience in ergonomic evaluation. The inter-rater reliability was assessed using Cohen's kappa coefficient, with a value of 0.89 indicating substantial agreement between the raters.

Descriptive analysis was used to determine the frequencies and percentages of risk levels from REBA assessments. The Chi-squared test was applied to find associations between socio-demographics or work characteristics with risk level according to REBA assessments, with statistical significance requiring $p<0.05$. In addition to Chi-square tests, effect size was calculated using Cramer's V to assess the magnitude of associations between categorical variables and risk level of work postures. The magnitude of association was interpreted according to conventional benchmarks, where values of approximately 0.10, 0.30, and 0.50 indicate small, moderate, and large effect sizes, respectively. Effect size measures were reported to complement p-values and provide information on the strength of associations. Because multiple associations were examined, the likelihood of type I error due to multiple comparisons may have increased. No formal adjustment for multiple testing was applied; therefore, the findings should be interpreted cautiously.

Results

In this study involving 82 durian farmers, there were mainly males (73.2%) with a male to female ratio of 3:1. The participants ranged in age from 20 to 59 years with average age of 38.0±12.4 years. Most of them were married (91.5%).

Table 1. REBA methods.

Part of body/ Activity	REBA method
Neck	score 1: 0°-20° flexion
	score 2: > 20° flexion or > 20° extension
	+1 score: twisting and side bending
Trunk	score 1: upright
	score 2: 0°-20° flexion or 0°-20° extension
	score 3: 20°-60° flexion
	score 4: > 60° flexion
	+1 score: twisting and side bending
Legs	score 1: bilateral weight bearing
	score 2: unilateral weight bearing or an unstable posture
	+1 score: knee between 30°-60° flexion
	+2 score: knee > 60° flexion
Upper arms	score 1: 20° extension to 20° flexion
	score 2: > 20° extension/20°-45° flexion
	score 3: 45°-90° flexion
	score 4: > 90° flexion
	+1 score: arm is abducted or rotated/shoulder is raised
	-1 score: supporting weight of arm
Lower arms	score 1: 60°-100° flexion
	score 2: 0°-60° flexion or > 60° flexion
Wrists	score 1: 0°-15° flexion or 0°-15° extension
	score 2: >15° flexion or >15° extension
	+1 score: deviated or twisted
Force and Load	score 0: load <11 lbs
	score 1: load 11-22 lbs
	score 2: load >22 lbs
	+1 score: rapid built up of force
Coupling	score 0: fitting handle and mid rang power grip
	score 1: acceptable but not ideal hand hold or coupling
	score 2: hand hold not acceptable but possible
	score 3: no handles
Muscle Activity	score 1: static/dynamic

Score	Risk level
1	very low risk
2-3	low risk and change may be needed
4-7	medium risk, further investigation and change soon
8-10	high risk, investigate and implement change
≥ 11	very high risk and implement change

The participants' weight ranged mostly between 45 kg and 55 kg (39.0%). Most of them were in the 161-170 cm height range (41.5%). The mean weight and height of durian farmers were 61.0±10.1 kg and 163.5±9.0 cm. Monthly income was 5,000-10,000 Thai baht for the majority (59.8%), while 19.5% and 20.7% reported 10,000-15,000 and more than 15,000 Thai baht, respectively. Most of the durian farmers had received education up to high school or primary school level (83.0%). The majority of durian farmers reported spraying pesticide 2-4 hours per day (84.2%) and 20-40 days per year (90.2%). On an average pesticide spraying took 2.9±1.1 hours per day and 34.9±5.0 days per year. Most durian farmers reported having pesticide spraying experience of 1-5 years (56.1%) and no spraying of pesticide on other plants (65.9%). Stationary tank was used by 96.3% of durian farmers to spray pesticides, while 3.7% of them used backpacks. Most durian trees had more than 5 m height (78.1%) (Table 2).

Table 2. Socio-demographics and work characteristics of durian farmers (N = 82).

Characteristic	Durian farmers, n (%)
1. Gender	
Male	60 (73.2)
Female	22 (26.8)
2. Weight (kg)	
45-55	32 (39.0)
56-65	23 (28.0)
66-75	18 (22.0)
> 75	9 (11.0)
Average	61.0±10.1
3. Height (cm)	
141-150	8 (9.8)
151-160	24 (29.3)
161-170	34 (41.5)
> 170	16 (19.4)
Average	163.5±9.0
4. Age (year)	
21-30	27 (33.0)
31-40	23 (28.0)
41-50	16 (19.5)
51-60	16 (19.5)
Average	38.0±12.4
5. Marital status	
Single	7 (8.5)
Married	75 (91.5)
6. Highest education level	
No education	7 (8.5)
Primary school	40 (48.8)
High school	28 (34.2)
Diploma	7 (8.5)
7. Monthly income (Thai baht)	
5,000-10,000	49 (59.8)
10,000-15,000	16 (19.5)
> 15,000	17 (20.7)
8. Pesticide spraying experience (year)	
1-5	46 (56.1)
5-10	11 (13.4)
> 10	25 (30.5)
9. Spraying pesticides on other plants	
Yes	28 (34.1)
No	54 (65.9)
10. Pesticide spraying method	
Backpack	3 (3.7)
Stationary pesticide tank	79 (96.3)
11. Frequency of spraying pesticide (day/year)	
< 20	6 (7.4)
20-40	74 (90.2)
> 40	2 (2.4)
Average	34.9±5.0
12. Duration of pesticide spraying (h/day)	
< 2	5 (6.1)
2-4	69 (84.2)
5-6	7 (8.5)
> 6	1 (1.2)
Average	2.9±1.1
13. Durian tree height (m)	
<5	18 (21.9)
>5	64 (78.1)

A stationary tank or, alternatively, a backpack was used as pesticide sprayer equipment. Stationary tank sprayers are used to spray pesticides in a large durian farm or with durian trees with heights exceeding 5 m. Normally, a

durian farmer mixes pesticide and water in a 1,000 L stationary tank, which is placed on the ground (Figure 1A). Backpack pesticide sprayers are used to spray pesticides at small durian farms and for durian trees of height less than 5 m. The portable backpack pesticide sprayers have weights from 8 to 22 kg (Figure 1B). Posture risk for durian farmer during spraying pesticide was incurred by prolonged standing in awkward postures, including bending the neck with more than 20° extension, bending the trunk with 0°-20° extension, unilateral weight bearing and knee at 30°-60° flexion, raising and abducting the shoulder, upper arms in more than 90° flexion, lower arms in more than 100° flexion, wrist in 0°-15° flexion, or both hands holding sprayer handles all the time (Figure 1).

The REBA method indicated that no durian farmers during pesticide spraying were classified as having very low or low risk. Most work postures of durian farmers during pesticide spraying had a high risk (Table 3).

Table 3. Frequency distribution and percentage of risk according to REBA assessment in work posture of durian farmers (N = 82) during pesticide spraying.

Risk level	Frequency (%)
Very low	0 (0%)
Low	0 (0%)
Medium	13 (15.9%)
High	62 (75.6%)
Very high	7 (8.5%)

(A) **(B)**

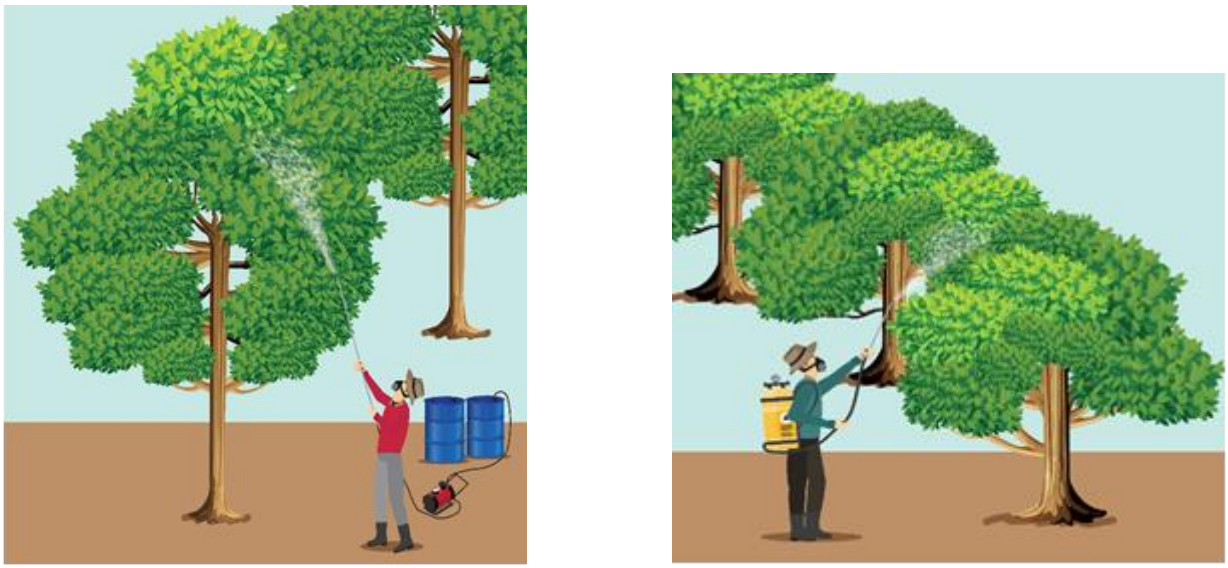

Figure 1. Work postures of durian farmers during pesticide spraying. Stationary pesticide tank (A), and backpack sprayer (B)

Durian farmers producing durian in-season are classified as having very high risk more often (17.7%) than those producing out of season (2.1%). Females were exposed to high and very high risk less than males. Weight range 66-75 kg is categorized more often as very high risk (16.7%) than the others, whereas 45-55 kg was indicated as high risk (87.5%) more often than the others. Rank order for body height by very high risk was: >170 cm (18.8%) > 151-160 cm (8.3%) > 161-170 cm (5.9%). Durian farmers in age range 41-50 years were not exposed to very high risk, whereas 51-60 years range had the most very high risk. Durian farmers that were single were not exposed to very high risk while most of these had high risk. Those with no education were classified as high (85.7%) and very high risk (14.3%) more often than others. In the very high risk category, monthly income > 15,000 Thai baht (17.6%) was 1.5 and 4-fold more often than 10,000-15,000 (12.5%) and 5,000-10,000 (4.1%) Thai baht incomes. Most durian farmers having

pesticide spraying experience for more than 10 years are classified as having very high risk (12.0%) but those with 5-10 years had no very high risk. Durian farmers spraying pesticide on other plants were classified as having very high risk (14.3%) more than those not spraying pesticide on other plants (5.5%). Durian farmers using backpack to spray pesticides (n = 3) were categorized as having high and very high risk more often than those using a stationary tank. This subgroup had small cell counts, Fisher's exact test was not applied, which may affect the stability of the estimates. However, this finding should be interpreted cautiously due to the small sample size. Only spraying pesticide 20-40 days per year was indicated as high (16.2%) and very high risk (1.4%). Durian farmers spraying pesticide 2-4 h/day (7.2%) were categorized as having very high risk less than those spraying for 5-6 h/day (28.6%). Durian trees of height more than 5 m incurred high and very high risk more often than trees of height less than 5 m. Chi-square analysis identified statistically significant associations between risk level and season ($p = 0.007$), age ($p = 0.017$), monthly income ($p = 0.000$), pesticide spraying experience ($p = 0.007$), spraying pesticide on other plants ($p = 0.019$), pesticide spraying method ($p = 0.000$), frequency of spraying pesticide ($p = 0.000$), and durian tree height ($p = 0.010$). Effect size analysis using Cramer's V indicated moderate associations for most significant factors ($V = 0.29–0.41$), while pesticide spraying method demonstrated a strong association with risk level ($V = 0.59$) (Table 4).

Discussion

Most work postures of durian farmers during pesticide spraying in this study had a high risk according to REBA method, whereas earlier reports indicated 'very high risk' to Cambodian and to vegetable greenhouse farmers in China, assessed by RULA method.[4,20] Numerous factors could have caused these differences, including assessment method, sample size, task distribution, length of work day, pesticide sprayer equipment used, and personal characteristics of the farmers such as height, age, and BMI. The RULA method weighs the scores for neck, lower arms, wrists, wrist twist, and force and load more than the REBA method. The RULA method is used in ergonomic investigations of workplaces with work related upper limb disorders, whereas the REBA method is used to investigate work postures of the upper limbs as well as the lower limbs along with coupling.

Posture risk for durian farmer during spraying pesticide was from prolonged standing, repetitive movements of shoulders, arms and wrists, and also from work with their hands above their shoulders. This is similar to the work posture of fresh fruit bunch cutters at oil palm plantations, usually working standing and holding a chisel or sickle overhead to cut the oil palm fruit for a prolonged period of time. Accordingly, work posture of fresh fruit bunch cutters indicates high risk and very high risk by both REBA and RULA assessments.[8,9,21,22,23,24] Furthermore, pesticide spraying was associated with neck and shoulder pain among female farmers in India,[25] and also male farmers in India reported very moderate to severe pain in neck, shoulder, upper arm, lower arm, and palm/fingers while spraying pesticide.[26]

The result of this study showed a significant correlation of risk level from work postures of durian farmers during spraying pesticide with season, age, monthly income, pesticide spraying experience, spraying pesticide on other plants, pesticide spraying method, frequency of spraying pesticide, and durian tree height.

Table 4. Factors associated with risk level of work postures of durian farmers (N = 82) during spraying pesticide.

Factor	Frequency (%)			Chi-square	P	Cramer's V
	Medium	High	Very high			
1. Season				9.971	0.007*	0.35
In season (n = 34)	8 (23.5)	20 (58.8)	6 (17.7)			
Out of season (n = 48)	5 (10.4)	42 (87.5)	1 (2.1)			
2. Gender				1.490	0.475	0.13
Female (n = 22)	5 (22.7)	16 (72.7)	1 (4.6)			
Male (n = 60)	8 (13.3)	46 (76.7)	6 (10.0)			
3. Weight (kg)				6.978	0.323	0.21
45-55 (n = 32)	4 (12.5)	28 (87.5)	0 (0)			
56-65 (n = 23)	3 (13.0)	17 (73.9)	3 (13.0)			
66-75 (n = 18)	4 (22.2)	11 (61.1)	3 (16.7)			
> 75 (n = 9)	2 (22.2)	6 (66.7)	1 (11.1)			
4. Height (cm)				3.423	0.754	0.14
141-150 (n = 8)	1 (12.5)	7 (87.5)	0 (0)			
151-160 (n = 24)	4 (16.7)	18 (75.0)	2 (8.3)			
161-170 (n = 34)	6 (17.6)	26 (76.5)	2 (5.9)			
> 170 (n = 16)	2 (12.5)	11 (68.7)	3 (18.8)			
5. Age (year)				15.460	0.017*	0.31
21-30 (n = 27)	1 (3.7)	24 (88.9)	2 (7.4)			
31-40 (n = 24)	2 (8.3)	20 (83.4)	2 (8.3)			
41-50 (n = 15)	4 (26.7)	11 (73.3)	0 (0)			
51-60 (n = 16)	6 (37.5)	7 (43.8)	3 (18.7)			
6. Marital status				0.769	0.681	0.10
Single (n = 7)	1 (14.3)	6 (85.7)	0 (0)			
Married (n = 75)	12 (16.0)	56 (74.7)	7 (9.3)			
7. Highest education level				3.793	0.705	0.15
No education (n = 7)	0 (0)	6 (85.7)	1 (14.3)			
Primary school (n = 40)	9 (22.5)	28 (70.0)	3 (7.5)			
High school (n = 28)	3 (10.7)	23 (82.1)	2 (7.2)			
Diploma (n = 7)	1 (14.3)	5 (71.4)	1 (14.3)			
8. Monthly income (thai baht)				24.258	0.000*	0.38
5,000-10,000 (n =49)	2 (4.1)	45 (91.8)	2 (4.1)			
10,000-15,000 (n =16)	8 (50.0)	6 (37.5)	2 (12.5)			
> 15,000 (n =17)	3 (17.6)	11 (64.8)	3 (17.6)			
9. Pesticide spraying experience (year)				14.133	0.007*	0.29
1-5 (n =46)	2 (4.4)	40 (86.9)	4 (8.7)			
5-10 (n =11)	5 (45.5)	6 (54.5)	0 (0)			
> 10 (n =25)	6 (24.0)	16 (64.0)	3 (12.0)			
10. Spraying pesticide other plants				7.902	0.019*	0.31
Yes (n =28)	8 (28.6)	16 (57.1)	4 (14.3)			
No (n =54)	5 (9.3)	46 (85.2)	3 (5.5)			
11. Pesticide spraying method				28.045	0.000*	0.59
Backpack (n =3)	1 (33.3)	1 (33.3)	1 (33.3)			
Stationary tank (n =79)	68 (86.0)	11 (14.0)	0 (0)			
12. Frequency of spraying pesticide (day/year)				26.992	0.000*	0.41
< 20 (n =6)	6 (100.0)	0 (0)	0 (0)			
20-40 (n =74)	61 (82.4)	12 (16.2)	1 (1.4)			
> 40 (n =2)	2 (100.0)	0 (0)	0 (0)			
13. Duration of pesticide spraying (h/day)				5.792	0.447	0.19
< 2 (n =5)	0 (0)	5 (100.0)	0 (0)			
2-4 (n =69)	12 (17.4)	52 (75.4)	5 (7.2)			
5-6 (n =7)	1 (14.3)	4 (57.1)	2 (28.6)			
> 6 (n =1)	0 (0)	1 (100.0)	0 (0)			
14. Durian tree height (m)				9.186	0.010*	0.34
< 5 (n =18)	7 (38.9)	10 (55.5)	1 (5.6)			
> 5 (n =64)	6 (9.4)	52 (81.2)	6 (9.4)			

* Significant at $p < 0.05$

Work postures of durian farmers during pesticide spraying when producing durian in-season are classified as very high risk more than when producing out of season. This may be a result of the size of the durian plantation, which is larger for in-season than for out of season, leading to a high workload, long hours, and fatigue. This correlates with prior results, suggesting that farmers with large harvests often work longer hours and experience fatigue, especially during peak harvest and production seasons.[27]

This study found that durian farmers who were 51-60 years old had the highest risk. This matches prior study results, indicating that elderly farmers in Thailand and Indonesia have inappropriate work postures, causing high risk.[6,14] It is also consistent with a study conducted in Bangladesh, which found that agricultural workers who were 41-60 years old normally suffered from musculoskeletal disorders.[28] Moreover, for farmers over 45 years of age, a high frequency of musculoskeletal disorders is associated with back, shoulder and leg pains.[29,30,31,32] In addition, aging is a risk factor for work-related musculoskeletal disorders among farmers due to decreased functional capacity, reduced physical strength and endurance, and a comparatively limited range of joint motion.[5,14,33,34,35,36,37]

Durian farmers who had a comparatively high monthly income > 15,000 Thai baht had very high risk more frequently than those who had 5,000-10,000 baht incomes. This agrees with earlier study results, which found that a high salary was associated with musculoskeletal pain for manually harvesting farmers in India.[31]

Durian farmers who had pesticide-spraying experience of more than 10 years had a higher risk than those who had been spraying for 5-10 years or 1-5 years. Likewise, durian farmers who were spraying pesticides 20-40 days per year had a higher and very high risk than when spraying < 20 days per year. These results match a prior study, which found that fruit farm workers in Thailand who had been spraying pesticide for longer than 10 years had a 1.66-fold risk of neck pain relative to those who had sprayed for < 1 year.[4] This is also similar to various studies, which indicated that a longer work history in agriculture increases the risk of musculoskeletal disorders. [20,21,25,28,31,34,38,39,40]

Durian farmers spraying pesticides on other plants are at a very high risk from work posture, more so than those not spraying pesticides on other plants. This result agrees with a study conducted on Cambodian fruit farm workers and another on rice farmers in Thailand, which reported that a larger plantation area related to the amount of work and increased fatigue, causing more musculoskeletal disorders.[4,41]

Durian farmers used portable backpack sprayers weighing 8-22 kg to spray pesticides, resulting in higher and very high risk more often than with a stationary tank. This is similar to previous studies in which farmers in Thailand, Korea and Brazil had musculoskeletal problems from carrying heavy spray tanks.[42,43,44] It also matches a study that reported that fruit farm workers who had been backpack-spraying pesticides had a high risk of neck and shoulder pain.[4]

The height of a durian tree is correlated with its age. Durian farmers are exposed to ergonomic work conditions that depend on the height of their durian trees. The results from this study indicate that a durian tree with a height exceeding 5 m has 1.5 times the risk of a shorter tree (height < 5 m). When the durian tree grows taller, durian farmers, during pesticide spraying, usually work while standing and need to bend their necks and trunks upward while their arms are raised above shoulder height, with repeated movements and forceful gripping of spray handles for a prolonged time. Awkward postures of neck and trunk cause constant pressure on spine and neck muscles, and also stress and strain ligaments, increasing intervertebral disc pressure; potentially causing pains in upper back, lower back, neck and shoulders.[45] Awkward postures of wrists and

thumbs, repeated movements, and forceful gripping can cause inflammation and swelling in wrists and thumbs, which is called tendonitis.[46] The results of this study are in agreement with the results of other studies that have indicated risks from awkward postures during harvesting oil palm due to the height of oil palm trees (> 3 m).[20,21]

This study has several limitations. First, due to its cross-sectional design, the findings reflect associations rather than causal relationships. Second, data on work characteristics were collected using self-reported questionnaires, which may be subject to recall bias. Third, although posture assessment was conducted using a standardized REBA method, observer bias cannot be entirely excluded. In addition, some subgroup analyses involved small sample sizes, and Fisher's exact test was not performed. Furthermore, the relatively small sample size and recruitment from only two provinces in southern peninsular Thailand may limit the generalizability of the findings to other agricultural settings or durian farmers in different regions. Therefore, the results should be interpreted with caution, and longitudinal studies with larger and more diverse populations are warranted to confirm these findings.

The strength of this study lies in the ergonomic risk assessment using the REBA method among all 82 durian farmers. The findings show that most postures during pesticide spraying pose a high risk and may lead to awkward postures for farmers. The study recommends medical surveillance for musculoskeletal disorders in high-risk groups, particularly farmers aged over 50 years, with more than 10 years of spraying experience, frequent spraying (20–40 days/year), use of backpack sprayers, and working with durian trees taller than 5 m. Durian farmers often perform repetitive movements while firmly gripping spraying equipment, which may lead to tendonitis in the wrists and thumbs. Using support wraps, braces, and gentle stretching before and during spraying can help reduce musculoskeletal symptoms. When spraying trees taller than 5 m, prolonged standing and upward bending of the neck and trunk, with arms raised, increase the risk of pain in the back, neck, and shoulders. Backpack sprayers are typically used for trees under 5 m in height. Durian farmers carried backpack pesticide sprayers weighing 8 to 22 kg, which can cause neck and shoulder pain. The findings of this study have important practical ergonomic implications. Given the high prevalence of awkward postures and repetitive overhead activities during pesticide spraying, targeted ergonomic interventions should be implemented to reduce musculoskeletal strain. Engineering controls, such as lightweight backpack sprayers, adjustable harness systems, and telescopic spray wands, may help minimize sustained shoulder elevation and excessive neck extension. Administrative measures, including task rotation, scheduled rest breaks, and limiting prolonged spraying duration, could further reduce cumulative physical load. In addition, structured ergonomic training programs should be provided to farmers, particularly older workers and those with long spraying experience, to promote safe work techniques, stretching exercises, and early recognition of musculoskeletal symptoms. Community-based health promotion strategies may also enhance awareness and encourage sustainable adoption of ergonomic practices in agricultural settings.

Conclusion

This study suggests an extremely high risk from work postures of durian farmers during pesticide spraying. Awkward postures of durian farmers during pesticide spraying involve prolonged standing, carrying heavy loads, repeated movements, forceful gripping, bending neck and trunk upward, and raising shoulder. Moreover, the risk level associated with the work postures of durian farmers during pesticide spraying was correlated with season, age, monthly income, pesticide spraying experience,

spraying pesticides on other plants, pesticide spraying method, frequency of pesticide spraying, and durian tree height. The findings from this study suggest that guidelines and training on adopting exercise and appropriate work postures should be provided to durian farmers. In addition, ergonomically designed pesticide spraying tools should be developed to promote the health and safety of durian farmers.

Acknowledgements

The authors would like to thank the Prince of Songkla University, Grant number SIT6202003S, for financial support to this study. The authors thank Associate Professor Dr. Seppo Karrila for language revision.

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