Factors that contribute to insecticide poisoning among immigrant agricultural workers in Thailand

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ABSTRACT

Background: There has been a strong increase in the international movement of workers during the last few decades. As Thailand's economy has rapidly developed during the past 20 years, it has attracted growing numbers of laborers from the bordering countries of Myanmar, Lao PDR, and Cambodia. Numbers of migrant workers in Thai agriculture have risen to the extent that the sector's continued growth has become increasingly dependent on migrant workers.

Objective: The purpose of this study was to explore the factors that contribute to the development of symptoms of insecticide poisoning among immigrant agricultural workers in the eastern region of Thailand.

Methods: Data were collected via interviews ($N = 891$), and the levels of cholinesterase activity in the workers' blood were tested using reactive test strips.

Results: Only 4.4% of the workers had normal levels of cholinesterase activity and 75.1% had levels that were abnormal. Regarding factors that affect gastrointestinal symptoms of poisoning, being aged 45 to 50 increased the risk of developing gastrointestinal symptoms (odds ratio (OR): 2.51; 95% CI: 1.41–4.46), as did using a backpack spraying technique (OR: 3.74; 95% CI: 2.16–6.49) and having only moderate levels of self-protection behavior while spraying the insecticides (OR: 2.23; 95% CI: 1.16–4.29). Having an at risk level of cholinesterase activity increased the risk of gastrointestinal symptoms (OR: 3.25; 95% CI: 1.05–10.04) and the risk of respiratory symptoms (OR: 2.75; 95% CI: 1.17–6.44).

Conclusion: It is recommended that insecticide self-protection measures should be promoted and health monitoring should be implemented for migrant workers affected by high-risk insecticide use.

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Introduction

The number of migrant workers in Thailand has increased in recent years [1,2]. In 2004, the Office of Migrant workers allowed approximately 850,000 workers from Myanmar, Laos, and Cambodia in Thailand. In 2012, the number of migrants had reached approximately 1.1 million of whom 940,531 were legal migrants and 193,320 were in the country illegally. By 2016, the total number of migrant workers has grown to 1,564,106 [1,2]. No verifiable estimate of migrant workers in the agricultural sector is available. Reasons for migration to Thailand include its proximity to countries with large unemployed or underemployed populations, unrest in the country of origin, and a favorable economic climate, in Thailand, including labor shortages [3].

Traditionally, the Thai economy was largely rural, but increasing urbanization in the previous decades has resulted in increased urban employment in the industrial and services sector. As a result, the agricultural sector

requires migrant workers to fill labor shortages [4]. In Eastern Thailand, which is a major producer of fruits, agricultural employment of migrant workers includes permanent and seasonal employees [5]. Most migrant workers work in agriculture permanently.

In economically developing countries like Thailand, organophosphates (OPs) and carbamates (CMs) are widely used as pesticides among fruit farmers [6]. Serious intoxication and other poor health repercussions resulting from the inappropriate use of insecticides are frequently reported. Due to the type of work performed, immigrant agricultural workers are at an especially high risk of being exposed to insecticides [7–9], a problem also reported in Kenya and Nicaragua [10,11] and in other areas of Thailand where insecticides are widely used in farming [6].

OP and CM insecticide poisoning in humans is caused by the inhibition of the cholinesterase enzyme [12]. Acute poisoning can occur immediately after exposure [13,14]. Symptoms include stomach pain, nausea,

vomiting, headaches, rashes, respiratory problems, eye irritation, congested nose, and loss of consciousness [14,15]. The consequences of chronic insecticide poisoning include dermatitis, asthma, endocrine disruption, immunotoxicity, neurobehavioral disorders such as Parkinson's disease, cancer, reproductive dysfunction, and birth defects [16–20].

The World Health Organization (WHO) and the United Nations Environment Program (UNEP) have estimated that one case of insecticide poisoning occurs every 2–3 min and each year, the effects of insecticide exposure cause 100,000 deaths worldwide [21,22]. Data from hospitals in Thailand indicate that 7500 persons are admitted to hospitals each year due to acute insecticide poisoning [23].

There are several studies on insecticide poisoning among non-immigrant agricultural workers in Thailand. One that included exposure screening in 582 Hmong farmers found that 20–69% had risky or unsafe levels of cholinesterase inhibition, an indicator of exposure to OP and CM insecticides [24]. A second study with chili farm workers [25] found a 32% prevalence of abnormal levels of serum cholinesterase (SChE) activity. Finally, another Thai study found that 34.3% of 317,051 screened farmers had unsafe SChE levels due to the inappropriate use of insecticides [7].

While there has been some research with Thai agricultural workers, little is known about the health of migrant agricultural workers in Thailand. Apart from the health check introduced by the Ministry of Health in 2003 for the purpose of disease screening (which migrants undergo at the beginning of their employment), the health of migrants is not monitored and no health surveillance of migrant workers takes place [26]. There are no guidelines to screen migrant farmers as part of surveillance implemented among Thai farmers regarding health risks from pesticide exposure.

The purpose of this study was to explore contributing factors associated with symptoms of OPs and CM poisoning among migrant workers in the eastern region of Thailand. The results can be used to inform health policy, including health monitoring for migrant workers in Thailand exposed to OP and CM insecticides.

Methods

Participants

This cross-sectional study included male and female Cambodian migrant workers, both authorized and unauthorized, working on Thai fruit plantations. The study was conducted in an area of concentrated tropical fruit production in three adjacent coastal provinces (Chonburi, Rayong, and Chanthaburi) in the eastern region of Thailand. Migrant workers received a daily wage for their work. The annual agricultural cycle of the fruit plantations involves two annual harvests. Large quantities

of insecticides are applied in December/January for the first harvest and again in June/July for the second harvest.

Of the 2185 fruit farms across the three provinces, we calculated the number of fruit farms by province. Informal documents related to the number of orchards in the three provinces were collected from the Provincial Health Office or the Health Promoting Hospital in each district. We then conducted a simple random sampling of 78 fruit farms from this sample.

For the randomly selected farms, workers were included in the study if they were immigrants of Cambodian nationality, employed as permanent daily paid employees in the fruit-farms, and if they had been employed as such for at least one year. Furthermore, eligibility was limited to migrant workers who self-reported pesticide exposure and whose employer confirmed OP and/or CM insecticides use on the farm. All respondents voluntarily participated and permission from the employer was obtained beforehand. All participants were permitted to decline or withdraw at any time from the study without penalty. Those who agreed to participate provided written informed consent. The Institutional Review Board of Burapha University provided ethical approval for the study protocol.

Sample size was determined using a technique developed by Hsieh et al. [27]. The adjusted size of sample was 888, and 891 workers were recruited.

Research tools and data collection

Data were collected via interviews and finger stick blood samples.

Interview questions

An interview questionnaire was used for data collection. The interview questions were divided into six parts, with a total of 86 questions. Part 1 involved five questions on demographic and socioeconomic information. Part 2 consisted of six questions on current or past cigarette smoking and alcohol consumption. Part 3 consisted of nine interview questions on employment history. Part 4 comprised 23 questions on self-protection behavior associated with insecticide preparation, insecticide spraying, and post-insecticide spraying. When interpreting these practices, answers were divided into three levels using a range to compute the difference between the highest score to lowest score. Self-protection behavior scores were classified into three groups based on Best theory [28] –1) low (score <23), 2) moderate (23–45), and 3) high (>45). Part 5 included 12 questions on knowledge of appropriate personal protective equipment use. Knowledge scores were classified into three groups based on Blooms theory [29].

The final section of the survey included 31 questions on self-reported health effects of insecticide exposure, including symptoms caused by the exposure to OPs and

CMs insecticides. The symptoms were classified according to the five physiological systems affected (central nervous system (CNS), respiratory, eye, gastrointestinal, and dermatological systems) and classified by the level of severity of the reported symptoms (mild, moderate, and severe), as detailed in Table 1.

Quality control of the questionnaire was carried out to ensure the validity of the data that were to be gathered. After reviewing suggestions from reviewers, the questionnaire was modified, and translated from Thai into Khmer, and were translated back from Khmer to Thai to check for accuracy.

Data collection

Before conducting the interviews, an informational and request letter was sent to employers, and arrangements for interviews were made by telephone. Interviews were conducted in the presence of a translator. Both the translator and the Thai interviewers were trained before data collection commenced. Migrant workers were interviewed by a Khmer-speaking interpreter and a Thai researcher together at the end of their work shift. Interviews took on average 10–15 min and were conducted at the sub-district health promoting hospital.

Collection of blood samples

Fingertip blood samples for cholinesterase activity were drawn after cleaning the finger with alcohol and following standard protocol [30]. Each sample was collected in a capillary tube and spun in a centrifuge until the red blood cells separated from the plasma. Then, a reactive test strip was placed on a slide and one drop of the plasma was placed on the paper, covered with another slide, and incubated for approximately seven minutes.

The results were interpreted according to a colorimetric chart as follows: yellow represents normal activity (≥ 100 units/mL), yellow-green represents a safe level of activity (87.5–99.9 units/mL), green represents a risky level of activity (75.0–87.4 units/mL), and blue represents an unsafe level of activity (< 75.0 units/mL). The results were further classified into two categories: category A (yellow or yellow-green), considered normal, and category B (green or blue), considered abnormal [30]. The data from the two categories were used in statistical analysis.

Blood sample screening

After interviewing each worker, a fingertip blood sample was obtained using standard techniques. Each blood sample was tested for acetylcholinesterase (AChE) activity using a reactive test strip for qualitative analysis (a simple method for early screening for exposure to OP and some CM insecticides) [31], with materials obtained from the Government Pharmaceutical Organization of

Thailand [30]. The sensitivity, specificity, and positive predictive values of the blood test were 77, 90, and 85%, respectively [31].

Data analysis

The data were analyzed using Statistical Package for the Social Sciences (SPSS) software version 20. The analysis was divided into two parts: (1) a descriptive analysis, with the data presented in tables (i.e. frequencies, percentages, means, standard deviations, medians, and minimum and maximum values) and (2) a referential analysis using multivariable logistic regression. In the regression analysis, the five dependent variables reflected the five physiological systems affected by poisoning symptoms (listed above). The independent variables were age, cigarette smoking habits, alcohol consumption habits, duration of employment, the size of the plantation, the number of insecticide spraying sessions per week, the daily duration of the spraying, the assigned tasks related to insecticides usage, the method of spraying, the most recent exposure to insecticides, the use of PPE, self-protection behavior while spraying, knowledge of appropriate insecticide usage, and the level of cholinesterase activity in the blood sample.

The variables age, cigarette smoking habits, and alcohol consumption habits were considered confounders in the regression model. The stepwise selection, with p -value < 0.05 to enter and p -value > 0.10 to remove was a technique for determining the variables that affect the outcome.

Results

Demographics, cigarettes smoking, and alcohol consumption

The majority of survey respondents were male (57.7%), young (30.3 years), and without formal education (55.2%) (See Table 2).

Employment history and the use of PPE

The majority of migrant workers (51.9%) had been employed between one and five years. The mean duration of employment was 4.26 years (SD: 3.75 years). Regarding insecticides types, 26.6% of the workers reported using several types of insecticides (OPs, CMs, and Cypermethrin) concurrently and 73.4% reported the use of a single insecticide. Regarding the duration of insecticide spraying, 42.1% of the sample spent 4–5 h per day spraying insecticides. Nearly half (45.7%) of the workers reported exposure to insecticides in the previous 3–7 days (Table 3). The majority of the workers (67.6%) wore boots, although fewer (43.3%) used face-masks (Table 4).

Insecticide self-protection behaviors and personal hygiene

Insecticide preparation

Regarding self-protection behaviors from insecticide exposure during the preparation stage, 35.5% of the workers did not follow all of the steps on the instructions on the packaging, 28.1% reported occasionally rechecked equipment before use.

Insecticide spraying

Regarding self-protection behavior while spraying the insecticides, 34.9% reported hand washing before drinking water and 39.2% reported standing upwind while spraying.

Post-insecticide spraying

Regarding post-spraying behavior, 33% of the workers reported never cleaning the insecticide containers before reusing them and 25.6% reported never cleaning or washing the clothes that they wore while spraying the insecticides.

Knowledge of appropriate insecticide usage

Regarding the knowledge of appropriate insecticide usage among the workers, the majority (45.7%) had moderate levels of knowledge, followed by 36.4% with low levels of knowledge, as shown in Table 5.

Results of blood sample screening

Based on blood sample testing according to Division of Occupational Health, Ministry of Public Health [30], approximately 59% of workers had levels of cholinesterase activity that put them at risk for cholinesterase activity: 20.5% had higher-than-normal but still safe levels, 16.6% had unsafe levels, and 4.4% had normal levels (Table 6).

Health effects associated with exposure to insecticides

The most frequently reported mild health symptoms were headaches (34.1%), dizziness, coughing, and dry or sore throats (19.5%). Regarding moderate symptoms, 24.6% had chest pain or tightness of the chest, 23.9% experienced nausea or vomiting, and 17.4% had stomach pain, as shown in Table 7.

Physiological health effects associated with exposure to insecticides

The health effects reported among workers who exposed to insecticides were CNS symptoms (64.9%), respiratory symptoms (58.2%), eye symptoms (27.2%) gastrointestinal symptoms (21.2%), and dermatological symptoms (18.4%).

Factors associated with symptoms of OPs and CM poisoning among migrant workers

Workers 45–50 years old had a greater risk of gastrointestinal symptoms compared to workers 18–28 years

old (OR: 2.51, 95% CI: 1.41–4.46). For workers on plantations 40 acres or larger, there was a greater risk of dermatological symptoms compared to small plantations (x acres or smaller) (OR: 2.24, 95% CI: 1.27–3.95). Workers who sprayed three or more times per week had a greater risk of developing CNS symptoms compared to workers who sprayed once per week (OR: 2.55, 95% CI: 1.05–6.16). Workers who sprayed more than eight hours per day spraying had a greater risk of developing gastrointestinal symptoms compared to workers who sprayed one to three hours per day (OR: 2.56, 95% CI: 1.23–5.32).

Workers who mixed the insecticides had an increased risk of eye symptoms compared to workers who did not mix the insecticides (OR: 2.53, 95% CI: 1.73–3.70). In addition, workers who had been exposed to insecticides in the previous 1–2 days had a greater risk of CNS symptoms (OR: 2.18, 95% CI: 1.27–3.76). Regarding self-protection behavior while spraying the insecticides, workers who had moderate levels of self-protection behavior had a greater risk of developing gastrointestinal symptoms compared to workers who had high levels of self-protection behavior (OR: 2.23, 95% CI: 1.16–4.29), as shown in Table 8.

Discussion

The main health effects from insecticide exposure among the migrant workers on Thai fruit farms were CNS symptoms, respiratory symptoms, eye symptoms, gastrointestinal symptoms, and dermatological symptoms. Most migrants reported more than one symptom (74.3%). The study found that several factors contributed to the incidence of poisoning symptoms among migrant workers exposed to insecticide.

The mean age of migrant workers was associated with gastrointestinal symptoms, which corresponds to another study that showed that workers over 45 years had an increased risk of gastrointestinal symptoms [32]. Workers with a longer history of spraying insecticides likely have more exposure to insecticides, explaining the increased risk of developing gastrointestinal symptoms.

Workers who mixed insecticides had a 2.53-fold increase in the risk of having eye symptoms, in agreement with a study by Wilaiwan and Siriwong [33] that showed that Thai workers with direct contact with insecticides had a tendency to have more eye symptoms. Migrant workers who mixing insecticides, and the employers supervising them, should therefore be encouraged and trained to use goggles to protect workers from insecticide exposure to their eyes.

This study did not find that the occurrence of CNS symptoms to be associated with insecticide mixing. This is in contrast to the findings of a study by Sapbamrer [34], Banerjee et al. [35], and Manyilizu et al. [36] which found that workers in charge of spraying and mixing insecticides had increased risk of CNS symptoms.

Table 1. Heath effect caused by insecticide classified by the severity of poisoning symptoms and by the physiological system affected.

Insecticide poisoning symptoms	Male <i>n</i> = 514(57.7)		Female <i>n</i> = 377(42.3)		Total <i>n</i> = 891(100)	
	No symptoms	Symptoms	No symptoms	Symptoms	No symptoms	Symptoms
	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)
<i>The severity of poisoning symptoms</i>						
No symptoms	59(11.5)	–	49(13.0)	–	108(12.1)	–
Symptoms	–	455(88.5)	–	328(87.0)	–	783(87.9)
1 Symptoms	–	74(14.4)	–	47(12.5)	–	121(13.6)
>1 Symptoms	–	381(74.1)	–	281(74.5)	–	662(74.3)
<i>Mild symptoms</i>						
Coughing	377(73.3)	137(26.7)	259(68.7)	118(31.3)	636 (71.4)	255 (28.6)
Nose irritation	413(80.4)	101(19.6)	294(78.0)	83(22.0)	707 (79.3)	184 (20.7)
Dry or sore throat	424(82.5)	90(17.5)	293(77.7)	84(22.3)	717 (80.5)	174 (19.5)
Difficulty breathing	442(86.0)	72(14.0)	318(84.4)	59(15.6)	760 (85.3)	131 (14.7)
Dizzy	338(65.8)	176(34.2)	252(66.8)	125(33.2)	590 (66.2)	301 (33.8)
Headache	332(64.6)	182(35.4)	255(67.6)	122(32.4)	587 (65.9)	304 (34.1)
Sleep disturbance	471(91.6)	43(8.4)	340(90.2)	37(9.8)	811 (91.0)	80 (9.0)
Dry skin and scaling	477(92.8)	37(7.2)	337(89.4)	40(10.6)	820 (92.0)	71 (8.0)
Rashes, blistering, itching skin	496(96.5)	18(3.5)	346(91.8)	31(8.2)	800 (89.8)	91 (10.2)
Burning pain	499(97.1)	15(2.9)	359(95.2)	18(4.8)	821 (92.1)	70 (7.9)
Red-eye / itching eyes.	488(94.9)	26(5.1)	313(83.0)	64(17.0)	750 (84.2)	141 (15.8)
Tiredness	489(95.1)	25(4.9)	348(92.3)	29(7.7)	837 (93.9)	54 (6.1)
Numbness	502(97.7)	12(2.3)	366(97.1)	11(2.9)	868 (97.4)	23 (2.6)
Heart palpitation	502(97.7)	12(2.3)	364(96.6)	13(3.4)	866 (97.1)	26 (2.9)
Sweating	482(93.8)	32(6.2)	345(91.5)	32(8.5)	827 (92.8)	64 (7.2)
Eye watering	490(95.3)	24(4.7)	359(95.2)	18(4.8)	849 (95.3)	42 (4.7)
Excessive saliva	497(96.7)	17(3.3)	368(97.6)	9(2.4)	865 (97.1)	26 (2.9)

An increased number of insecticide spraying sessions per week can increase the risk of CNS symptoms. A similar finding was reported by Mancini [37] and Lee [38], and the California Department of Food and Agriculture [37] who all found that workers using insecticides more frequently were more likely to report CNS symptoms.

Workers exposed to insecticides during the previous one to two days had 1.85-fold increase in the risk of developing respiratory symptoms compared to those unexposed to insecticides in the past two weeks [39]. This corresponds to studies by Fenske et al. [40], Yassin et al. [41] and Farahat et al. [42] that found that workers exposed to insecticides in the previous 1–7 days experienced negative health effects. OPs and CMs insecticides are known to cause respiratory symptoms [43].

The size of the plantation's area was also a factor that was associated with poisoning symptoms. Migrant workers spraying insecticide in larger area are likely to carry and use more insecticides, and therefore they would be more exposed, resulting in more severe symptoms. This corresponds to a study by Kim et al. [44] that found that workers on plantations larger than three acres had an increased risk of developing acute respiratory symptoms compared to workers on plantations smaller than three acres (OR: 1.49; 95% CI: 1.17–1.88).

The number of hours spent to spray insecticide in a working day also was a factor related to respiratory symptoms. Again, spending more time spraying increases exposure, hence making the risk of poisoning greater. This corresponds to a study by Wilaiwan, Siri Wong [31] that found that workers forced to inhale insecticides while working had an increased risk of developing asthma, dry coughing, and difficulty breathing [38] Kishi

et al. [45] also found that the number of spray operations per week was significantly and independently associated with a number of respiratory signs and symptoms.

The application method of insecticides was a found to be a factor associated with respiratory symptoms. Workers who used cars or motorcycles to spray the insecticides had a 1.57-fold increase in the risk of developing respiratory symptoms compared with those who placed the insecticide containers on the ground. It might be that the car or motorcycle method caused the insecticides to be dispersed more widely, leading to more exposure. This would correspond to a study by Pathak et al. [46] that stated that agricultural workers who sprayed insecticides using tractor-mounted sprayers had an increased risk of developing respiratory symptoms compared to those using a different method. Kim et al. [44] also found that workers who used speed sprayers with air blasts had a 1.32-fold increase in the risk of developing respiratory symptoms. Sapbamrer [34] noted that using two or more types of insecticides in insecticide spraying can cause difficulty in breathing and chest pain or tightness in the chest, respectively.

This study found that workers who sprayed insecticides using a backpack sprayer were more likely to have skin symptoms, which corresponds to a study by Wang et al. [47] that indicated that exposure to chlorpyrifos caused symptoms similar to dermatitis. Furthermore, Lu [46] conducted a study on insecticide exposure among workers who grew vegetables, which revealed that 31.8% of the workers who used a backpack sprayer experienced insecticide leakages that contaminated their hands; 58% of the workers in the study by Lu [48] stood upwind while spraying the insecticides.

Table 2. Subject characteristics.

Subject characteristics	Male <i>n</i> = 514(57.7)		Female <i>n</i> = 377(42.3)		Total <i>n</i> = 891(100)	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Age (Years) Mean (SD)	30.66(8.39)		29.79(8.59)		30.29(8.48)	
Median (Min, Max)	30(18,61)		29(18,62)		30(18,62)	
<i>Education level</i>						
No formal education	281	54.7	211	56.0	492	55.2
Primary level	204	39.7	156	41.4	360	40.4
High school or equivalent	29	5.6	10	2.7	39	4.4
Income (USD) Mean (SD)	216(61)		204(60)		211(61)	
Median (Min, Max)	200(86,514)		171(60,514)		171(60–514)	
<i>Smoking</i>						
<i>Smoking duration (Years)</i>						
1–5	119	57.5	15	75.0	134	59.0
>5–10	47	22.7	3	15.0	50	22.0
>10	41	19.8	2	10.0	43	18.9
Mean (SD)	7.73(7.62)		6.65(8.03)		7.19(7.83)	
Median (Min, Max)	1.00(1,40)		1.00(1,30)		1.00(0,40)	
<i>Current drinking history</i>						
Never alcohol usage	249	48.4	328	87.0	577	64.8
Ex- alcohol usage	15	2.9	4	1.1	19	2.1
Current alcohol usage	250	48.6	45	11.9	295	33.1

Table 3. Work characteristics.

Work characteristics	Male <i>n</i> = 514(57.7)		Female <i>n</i> = 377(42.3)		Total <i>n</i> = 891(100)	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
<i>Duration of insecticide use (years)</i>						
≤1	86	16.7	86	22.8	172	19.3
1–5	304	59.1	220	58.4	524	58.8
6–10	114	22.2	57	15.1	171	19.2
>10	10	1.9	14	3.7	24	2.7
Mean(SD)	4.43(3.43)		4.05(4.14)		4.26 (3.75)	
Median (Min, Max)	4(0.50,30)		3(0.33,31)		3 (0.33,31)	
<i>The total space of plantation</i>						
≤19.76 Acres	256	49.8	209	55.4	465	52.2
20.16–39.52 Acres	177	34.4	108	28.6	285	32.0
39.52 Acres	81	15.8	60	15.9	141	15.8
Mean(SD)	57.69(121.90)		59.99(135.12)		148.37(322.71)	
Median (Min, Max)	23.72(1.98,988.42)		19.76(0.40,988.42)		50(4,2500)	
<i>Frequency of spraying (time(s)/week)</i>						
1	232	45.1	182	48.3	414	46.5
2	210	40.9	158	41.9	368	41.3
3	21	4.1	16	4.2	37	4.2
>3	51	9.9	21	5.6	72	8.1
<i>Duration of insecticide spraying (Hours)</i>						
1–3	176	34.5	143	38.5	319	35.8
4–5	223	43.7	152	41.0	375	42.1
6–8	66	12.9	47	12.7	113	12.7
>18	45	8.8	29	7.8	74	8.3
<i>Most recent spraying session (days)</i>						
1–2	82	16.1	53	14.4	135	15.2
3–7	243	47.3	164	44.6	407	45.7
>7–14	61	12.0	46	12.5	107	12.0
>14	122	24.0	105	28.5	227	25.5
<i>Type of insecticide used</i>						
OPs	127	24.7	110	29.2	237	26.6
OPs and CMs Cypermethrin	387	75.3	267	70.8	654	73.4

Note: Organophosphate (OPs): Chlorpyrifos, Omethoate, Ethion, Tetradifon.
Carbamate (CMs): Fenobucarb, Methomyl, Carbofuran.
Pyrethroid: cypermethrin.

In this current study, knowledge about appropriate insecticide usage was also found to be a factor associated with respiratory symptoms. This corresponds to a study that indicated that a lack of knowledge about PPE is the main factor that causes insecticide poisoning [9]. Therefore, it is essential to provide workers with information on the methods of protection from insecticide exposure. Education and poisoning prevention materials

should be developed and distributed, taking into account that many migrant workers are unable to read Thai; the materials should be developed in the Cambodian language (or, for other groups of migrants, in their respective languages).

Plasma cholinesterase is one such marker of poisoning symptoms by acute OP or CM insecticide poisoning. Both insecticides are powerful inhibitors of plasma

Table 4. Use of personal protective equipment.

	Male		Female		Total	
	<i>n</i> = 514(57.7)		<i>n</i> = 377(42.3)		<i>n</i> = 891(100)	
	No	Yes	No	Yes	No	Yes
Use of personal protective equipment	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)
PPE used	85(16.5)	429(83.5)	96(25.5)	281(74.5)	181(20.3)	710(79.7)
Goggles	456(88.7)	58(11.3)	321(85.1)	56(14.9)	777(87.2)	114(12.8)
Facemask	266(51.8)	248(48.2)	239(63.4)	138(36.6)	505(56.7)	386(43.3)
Gloves	202(39.3)	312(60.7)	180(47.7)	197(52.3)	382(42.9)	509(57.1)
Boots	160(31.1)	354(68.9)	129(34.2)	248(65.8)	289(32.4)	602(67.6)
Body cloth	445(86.6)	69(13.4)	325(86.2)	52(13.8)	770(86.4)	121(13.6)
Gloves and Boots	279(54.3)	235(45.7)	220(58.4)	157(41.6)	499(56.0)	392(44.0)
Gloves, Boots, Facemask	389(75.7)	125(24.3)	292(77.5)	85(22.5)	681(76.4)	210(23.6)
Gloves, Boots, Facemask, goggle	487(94.7)	27(5.3)	359(95.2)	18(4.8)	846(94.9)	45(5.1)
Gloves, Boots, Facemask goggle, Body cloth	507(98.6)	7(1.4)	372(98.7)	5(1.3)	879(98.7)	12(1.3)

Notes: Farmers could select more than one type of PPE. Bold significance represents the total number of farmers who replied as yes (he or she used PPE).

Table 5. Personal hygiene and knowledge scores for insecticide use of fruit farmers (*N* = 891).

	Male	Female	Total
	<i>n</i> = 514(57.7)	<i>n</i> = 377(42.3)	<i>n</i> = 891(100)
Personal hygiene and knowledge scores for insecticide use	<i>n</i> (%)	<i>n</i> (%)	
<i>Personal hygiene for prevention of pesticide exposure</i>			
High (>45)	42(8.2)	25(6.6)	67(7.5)
Moderate (23–45)	406(79.0)	278(73.7)	684(76.8)
Low (< 23)	66(12.8)	74(19.6)	140(15.7)
<i>Knowledge score</i>			
High (>9.60)	82(16.0)	78(20.7)	160(18.0)
Moderate (7.30–9.59)	234(45.5)	173(45.9)	407(45.7)
Low (< 7.30)	198(38.5)	126(33.4)	324(36.4)

Note: Self-protection and personal hygiene behavior score were classified into three groups – high (>45), moderate (23–45), and low (score <23); Knowledge scores from 12 questions were classified into 3 groups :high (>80%;>9.60 scores), moderate (60–80%; 7.30–9.59 scores), and low (score <60 %,< 7.30 scores).

Table 6. The result of the blood screening of cholinesterase enzyme level by reactive paper.

Result	Male		Female		Total	
	<i>n</i> = 514(57.7)		<i>n</i> = 377(42.3)		<i>n</i> = 891(100)	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Group A: Normal	109	21.2	113	30.0	222	24.9
Normal (Yellow)	22	4.3	17	4.5	39	4.4
Safe (Yellow green)	87	16.9	96	25.5	183	20.5
Group B: Abnormal	405	78.8	264	70.0	669	75.1
At risk (Green)	314	61.1	207	54.9	521	58.5
Unsafe (Blue)	91	17.7	57	15.1	148	16.6

Note: The results were further classified into two categories: category group A: Normal (yellow or yellow-green), which was considered to be normal, and category B: Abnormal (green or blue), which was considered to be abnormal.

cholinesterase; consequently, the reduced level of this biochemical marker has been used in the diagnosis of cases of acute poisoning [49]. In this current study, abnormal cholinesterase levels were a factor associated with respiratory, gastrointestinal tract, and eye symptoms. Workers who had safe levels of cholinesterase activity had a 2.75-fold increase in risk of respiratory symptoms compared with workers whose levels were normal, which corresponds to a study by Chakraborty et al. [50] that stated that the insecticides that suppressed cholinesterase for an extended period were associated with disorders of the respiratory system. However, measuring red blood cell cholinesterase with an EQM test kit (EQM Research, Inc.) or laboratory analysis would provide more reliable test results than the rapid screening test used in this study.

A study by Ming et al. [51] also indicated that levels of cholinesterase activity were associated with disorders of the respiratory system in a study that compared people occupationally exposed to pesticides who had high levels of cholinesterase activity with a control group that had normal levels of cholinesterase activity. This corresponds to studies by Wilaiwan and Siri Wong [35] that noted that workers who had decreased levels of plasma cholinesterase (PChE) activity were more likely to have respiratory symptoms. In addition, two studies highlighted that standing upwind while spraying insecticides facilitates the inhalation and absorption of the insecticides into the workers' bodies [52,53].

Workers who had unsafe levels of cholinesterase activity had a 5.78-fold, and an at-risk level of cholinesterase

Table 7. Health effect caused by insecticide exposure.

	Male		Female		Total	
	<i>n</i> = 514(57.7)		<i>n</i> = 377(42.3)		<i>n</i> = 891(100)	
	No symptoms	Symptoms	No symptoms	Symptoms	No symptoms	Symptoms
Insecticide poisoning symptoms	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)
Runny nose	498(96.9)	16(3.1)	367(97.3)	10(2.7)	865 (97.1)	26 (2.9)
<i>Moderate symptoms</i>						
Eyelid twitching	490(95.3)	24(4.7)	363(96.3)	14(3.7)	853 (95.7)	38 (4.3)
Blurred-vision	442(86.0)	72(14.0)	331(87.8)	46(12.2)	773 (86.8)	118 (13.2)
Chest tightness	381(74.1)	133(25.9)	291(77.2)	86(22.8)	972 (75.4)	219 (24.6)
Nausea/vomiting	382(74.3)	132(25.7)	296(78.5)	81(21.5)	678 (76.1)	213 (23.9)
Stomach pain	422(82.1)	92(17.9)	314(83.3)	63(16.7)	736 (82.6)	155 (17.4)
Diarrhea	472(91.8)	42(8.2)	346(91.8)	31(8.2)	818 (91.8)	73 (8.2)
Muscle weakness	505(98.2)	9(1.8)	369(97.9)	8(2.1)	874 (98.1)	17 (1.9)
Muscle cramping	498(96.9)	16(3.1)	365(96.8)	12(3.2)	863 (96.9)	28 (3.1)
Tremor	510(99.2)	4(0.8)	373(98.9)	4(1.1)	883 (99.1)	8 (0.9)
Ataxia	505(98.2)	9(1.8)	374(99.20)	3(0.8)	879 (98.7)	12 (1.3)
<i>Severe symptoms</i>						
Epilepsy	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
Coma	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
Loss of consciousness	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
<i>The physiological system affected</i>						
Central nervous system	172(33.5)	342(66.5)	141(37.4)	236(62.6)	313(35.1)	578(64.9)
Respiratory symptoms	213(41.4)	301(58.6)	159(42.2)	218(57.80)	372(41.8)	519(58.2)
Skin symptoms	414(80.5)	100(19.5)	313(83.0)	64(17.0)	727(81.6)	164(18.4)
Gastrointestinal tract system	402(78.2)	112(21.8)	300(79.6)	77(20.4)	702(78.8)	189(21.2)
Eyes	377(73.3)	137(26.7)	272(72.1)	105(27.9)	649(72.8)	242(27.2)

activity had a 6.69-fold increase in risk of eyes symptoms compared with workers whose levels were normal, which corresponds to a study by Safi [54] that stated that many symptoms were self-reported by farm workers. Certain symptoms, such as itching, skin irritation, and a burning sensation in eyes or face, were significantly associated with cholinesterase inhibition. Workers who had at risk levels of cholinesterase activity had a 3.25-fold increase in the risk of gastrointestinal symptoms, which conflicted with a study [55] of coffee workers in Tanzania that assessed the level of erythrocyte AChE activity due to OP insecticide spraying.

Workers who were in charge of the insecticide mixing had a 2.53-times increase in the risk of having eye symptoms, which corresponds to a study by Wilaiwan and Siritwong [33] that showed that workers who had direct contact with insecticides had a tendency to have more eye symptoms, which corresponds to a study by Boonyakawee [56] that found that workers who mixed insecticides in amounts exceeding 500 mL per 0.4 acre were more likely to have skin rashes compared with workers who used lower amounts of insecticides. This is because OPs and CM insecticides can be easily absorbed through the skin and the layer of fat under the skin [57].

Self-protection behavior is a factor associated with gastrointestinal symptoms. Workers who had moderate levels of self-protection behaviors while spraying insecticides had a 2.23-fold increase in the risk of gastrointestinal symptoms compared with workers who had high levels of self-protection behaviors. This corresponds to a study by Meggs [32], Kim et al. [44] that found that workers who did not have self-protection behaviors had an increased risk of developing gastrointestinal

disorders. The results also did not correspond to a study by Portilla-Portilla et al. [58] that indicated that workers who had inappropriate self-protection behavior while spraying insecticides developed symptoms of nausea and frustration. This current study found that most of them were wearing basic boots, gloves, and face masks (23.6%). With regard to face masks, most of them were wearing improper face masks, like those made of cloth. Despite the lack of confirmation for the effect of PPE, based on previous studies in other settings it is recommended that migrant workers increase their use of proper PPE.

Strengths and limitations

This research provides strong evidence on the factors that contribute to the negative health effects of insecticide usage. The quality of the research tools used in this study was verified by experts and the interviews were conducted via interpreters. However, a limitation of this study is that it focused on data collection during the spraying season without collecting data from the non-spraying season. In addition, the participants did not undergo formal medical evaluations to assess whether their symptoms were caused by the insecticide toxins or by other factors.

Recommendations

A recommendation from this study is that health monitoring for migrant workers in Thailand be provided in the same manner as this is done for Thai workers, especially for migrant workers affected by high-risk

Table 8. Factors affecting poisoning symptoms caused by the insecticide exposure among immigrant workers.

Factor	Number	CNS			Respiratory tract			Eyes			GI tract			Skin		
		aOR	95%CI		aOR	95%CI		aOR	95%CI		aOR	95%CI		aOR	95%CI	
			Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Age (year)																
18–28	411(46.1)	1	–	–	1	–	–	1	–	–	1	–	–	1	–	–
–40–50	107(12.4)	2.55	1.05	6.16	1.20	0.74	1.95	0.54	0.30	0.97	2.51	1.41	4.46	0.82	0.43	1.56
The size of plantation (Acres)																
≤19.76	466(52.2)	1	–	–	1	–	–	1	–	–	1	–	–	1	–	–
–20.16–39.5	285(32.0)	0.89	0.63	1.27	0.92	0.66	1.30	1.72	1.19	2.49	0.80	0.52	1.22	1.10	0.70	1.73
–>39.5	141(15.8)	1.10	0.68	1.78	1.67	1.03	2.70	1.79	1.07	2.99	0.49	0.26	0.92	2.24	1.27	3.95
Workers who were in charge of mixing insecticides																
No	90(10.1)	1	–	–	1	–	–	1	–	–	1	–	–	1	–	–
Yes	801(89.9)	1.29	0.91	1.84	1.69	0.90	3.16	2.53	1.73	3.70	1.49	0.96	2.31	2.19	1.42	3.39
The spraying frequency																
1 sessions per week	414(46.5)	1	–	–	1	–	–	1	–	–	1	–	–	1	–	–
–3 sessions per week	37(4.2)	2.55	1.05	6.16	0.90	0.42	1.93	1.21	0.52	2.82	1.51	0.59	3.83	2.45	1.03	5.81
Spraying duration (hrs)																
1–3	319(36.2)	1	–	–	1	–	–	1	–	–	1	–	–	1	–	–
–4–5	375(42.6)	1.08	.75	1.57	2.00	1.40	2.86	1.10	.74	1.64	1.22	.87	2.85	.74	.44	1.16
–6–8	113(12.8)	.87	.52	1.44	1.88	1.14	3.08	1.27	.74	2.19	1.57	.87	1.94	1.28	.70	2.35
–>8	74(8.3)	1.15	0.60	2.22	1.69	.90	3.16	0.74	.35	1.55	2.56	1.23	5.32	2.31	1.14	4.71
The most recently exposure to insecticides –1–2 days	135(15.2)	2.18	1.27	3.76	1.85	1.11	3.08	1.11	0.63	1.96	1.30	0.68	2.50	0.61	0.32	1.18
–3–7 days	407(46.5)	1.30	.84	2.02	2.18	1.41	3.38	.94	.57	1.54	1.10	.63	1.92	.51	.29	.89
–7–14 days	107(12.2)	.87	.52	1.46	1.21	.72	2.05	.98	.54	1.78	.89	.46	1.76	1.11	.59	2.08
>14	227(25.9)	1	–	–	1	–	–	1	–	–	1	–	–	1	–	–
Methods used to spray insecticide																
–Back pack spraying	206(23.1)	0.89	0.55	1.44	1.38	0.88	2.17	0.89	0.55	1.44	3.74	2.16	6.49	1.85	1.02	3.36
–Car/motorcycle	421(47.3)	0.59	0.38	0.91	1.57	1.03	2.38	0.69	0.43	1.09	1.80	1.04	3.11	0.95	0.53	1.70
put container on the ground	251(28.6)	1	–	–	1	–	–	1	–	–	1	–	–	1	–	–
Insecticide exposure protection behavior																
–Moderate level	645(72.4)	1.06	0.58	1.93	1.00	0.62	1.62	.69	.42	1.13	2.23	1.16	4.26	1.90	0.92	–
High	102(11.4)	1	–	–	1	–	–	1	–	–	1	–	–	1	–	–
Level of knowledge																
–Low	324(36.4)	1.15	0.72	1.83	1.64	1.04	2.58	1.92	1.12	3.28	1.22	0.69	2.15	1.11	0.60	2.08
–Moderate	407(45.7)	1.21	0.72	2.03	1.65	1.08	2.53	1.50	0.90	2.50	0.60	0.35	1.04	1.56	0.88	2.76
High	160(18.0)	1	–	–	1	–	–	1	–	–	1	–	–	1	–	–
ChE level																
Normal	183(20.5)	1	–	–	1	–	–	1	–	–	1	–	–	1	–	–
–Safe	521(58.5)	1.61	.75	3.46	2.75	1.17	6.44	6.77	1.88	24.41	2.36	.72	7.8	1.67	.56	4.9
–At risk	148(16.6)	1.33	.61	2.93	1.04	.68	1.58	5.78	1.56	21.37	1.28	.37	10.04	1.51	.50	4.57

Note: Gender is not a factor that contributes to poisoning symptoms caused by insecticide exposure among immigrant workers.

insecticide use because these factors increase the risks of developing illnesses from exposure to insecticides.

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