

Relationship Between Pesticide Exposure Factors and Health Symptoms Among Chili Farmers in Northeast Thailand

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Objectives: The unsafe use of pesticides in agriculture represents a major hazard to human health. This study was conducted to investigate the association between pesticide exposure and health symptoms among chili farmers in northeast Thailand.

Methods: This cross-sectional analytic study included 141 chili farmers in Sakon Nakhon Province, in northeast Thailand. Data regarding health symptoms were gathered using a self-report questionnaire. A medical technician tested blood cholinesterase activity using an erythrocyte method, and an occupational medicine specialist at Ramathibodi Hospital in Bangkok, Thailand reviewed the results. Associations between personal characteristics, pesticide exposure factors, and health symptoms were analyzed using multiple logistic regression.

Results: Of the 141 chili farmers studied, 66.7% experienced pesticide poisoning, as indicated by below-normal cholinesterase levels. Fatigue was the most frequently reported symptom associated with pesticide exposure, affecting 37.6% of participants. This was followed by nausea and vomiting (31.9%), dizziness (14.9%), and dry throat (14.9%). Multivariate logistic regression analysis revealed that several factors were significantly associated with adverse symptoms: amount of work experience, volume of pesticides used, use of chemical pesticides, use of leaking containers during spraying, direct pesticide exposure while working, contact with pesticide-soaked clothing, consumption of food and drinks in the fields, and blood cholinesterase level indicating risk.

Conclusions: This study suggests potential health risks for chili farmers stemming from exposure to and contamination by pesticides used in agricultural practices. To mitigate these risks, it is essential to supply personal protective equipment and to implement educational programs aimed at improving protective behaviors among farmers.

Key words: Pesticide exposure factors, Blood cholinesterase level, Health symptoms, Acetylcholinesterase erythrocyte activity, Chili farmer

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INTRODUCTION

Agriculture is a vital sector in Thailand, providing much of the population with both food and a livelihood. Rice, along with chilies and maize, plays a key role in the Thai economy and labor force. Pesticides are commonly used in Thailand's agricultural regions to enhance crop yields and food production. Farmers employ these substances to control crop diseases and pests. Thailand's annual pesticide imports have been

on the rise [1]. The increase in pesticide usage can be attributed to several factors, including insect resistance and pest resurgence, the industrialization of agricultural practices, and the need to switch crop types from season to season in response to market demands, despite varying weather conditions [2]. In 2019, the majority of agricultural chemicals imported into Thailand were insecticides [3]. The most popular families of pesticides are organophosphates (OPs) and carbamates (CAs) [4-6]. Pesticides are most heavily utilized within the subsector of smallholder agricultural production systems.

Farm workers constitute a high-risk group for agrichemical poisoning exposure [7,8]. Serious health effects are facilitated by the unregulated environment, inadequate use of personal protective equipment, and limited awareness regarding pesticide application [9]. Moreover, the excessive and unsafe use of pesticides poses a major threat to human health, environmental integrity, and food quality [10]. Pesticide applicators, in particular, have grown increasingly concerned about the potential acute and long-term health consequences associated with intensive pesticide use [4,11]. The most pressing issue facing farm workers is exposure to pesticides. The majority of agricultural activities, including pesticide mixing, spraying, harvesting, and cultivation, are conducted manually, which subjects farm workers to dangerous agricultural chemicals [12].

Most farmers are exposed to pesticides that are absorbed through the skin and inhaled, leading to health issues [13]. This exposure is often due to improper chemical handling and a heavy reliance on pesticides like OPs and CAs to enhance agricultural yields. Such practices can have both immediate and long-term health consequences, including the impact on blood cholinesterase levels from pesticides absorbed through the skin or through breathing [14]. In the present research, pesticide use among chili farmers was monitored by screening blood cholinesterase levels, specifically using the standard method for erythrocyte acetylcholinesterase (AChE). This screening approach is a novel and localized method that has not been previously examined. Moreover, few studies have analyzed the laboratory confirmation of unusual blood cholinesterase levels in Thailand. Consequently, this study aimed to examine the prevalence of health symptoms and their relationship with factors of pesticide exposure and occupational blood cholinesterase levels among chili farmers in Sakon Nakhon Province, Thailand.

METHODS

Study Design and Participants

A cross-sectional analytical study was conducted from September 2021 to March 2022 in northeast Thailand. Three rural communities in Sakon Nakhon Province were selected as the study area because the main occupation in that region is chili farming (Figure 1). Using a purposive sampling method, 47 households from each of the 3 villages were randomly chosen. If a household was unoccupied at the time of the visit, the next nearest household was selected. Within each household, 1 chili farmer was chosen based on convenience. Eligible chili farmers were those over 30 years of age, registered as chili farmers for more than a year, literate, and willing to participate in the study. Health volunteers received training to conduct face-to-face interviews with a structured questionnaire. The sample size was calculated using the formula for the proportion of the population in cases where the entire population is known [15], with a 95% confidence interval (CI). This calculation was informed by the finding that 27.8% of chili farmers reported health symptoms associated with pesticide exposure [15], and the desired precision of the estimate was set at 8%. To account for potential loss or incomplete data, we increased the sample size by at least 20%. In total, 141 chili farmers were included in the study.

Questionnaire

Demographic information

Data were gathered through the use of questionnaires and the Health Risk Assessment Form for Pesticide Exposure (NGP 1-56), developed by the Division of Occupational and Environmental Diseases, Department of Disease Control, Ministry of Public Health, Thailand [14]. These instruments were administered during interviews that utilized self-reports to assess health-related issues. The questionnaire was divided into 5 sections. The first section collected demographic information, including sex, age, marital status, congenital diseases, use of pain relievers or muscle relaxants after a long workday, experience in chili cultivation, smoking habits, alcohol consumption, practices of combining chemicals, the likelihood of remaining in areas where chemicals had been sprayed, pesticide application practices, use of chemical pesticides, and chemical usage. The second section focused on the types of work and pesticides employed. The third section addressed the knowledge of pesticide use and the self-protective measures chili farmers

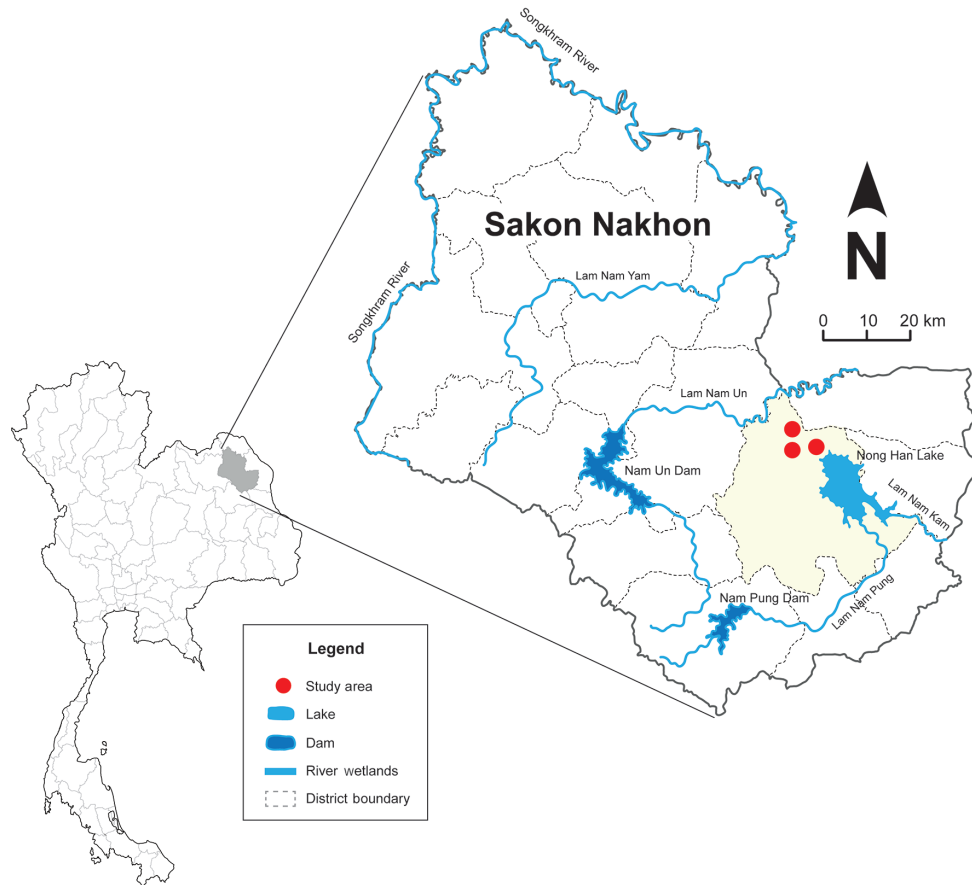


Figure 1. Map of the study area, providing an overview of the chili farming region within the Mueang Sakon Nakhon district of Sakon Nakhon Province, located in northeast Thailand.

take when using pesticides. The fourth section explored behaviors related to pesticide use and prevention strategies, while the fifth section inquired about health symptoms or conditions that arose following pesticide use or exposure.

Health symptoms

The health symptoms reported following pesticide use or exposure within the past month were categorized into 5 groups: (1) nervous system symptoms, which encompass nausea, vomiting, dizziness, headaches, excessive sweating, watery eyes, palpitations, twitching eyelids, insomnia, red eyes, burning eyes, itchy eyes, numbness, drooling, blurred vision, chest pain, chest tightness, trembling hands, an unsteady walk, seizures, blackouts, and loss of consciousness; (2) muscular system symptoms, such as fatigue, muscle weakness, and cramps; (3) respiratory system symptoms, including a dry throat, a burning sensation in the nose, sore throat, cough, difficulty breathing, and nasal discharge; (4) integumentary system symptoms, which cover skin itching, dry or chapped skin, rashes, blisters,

and a sensation of burning pain; and (5) gastrointestinal system symptoms, namely stomach pain and diarrhea. Participants who reported experiencing at least one symptom from any of these categories were considered to have symptoms associated with that system. The reliability of the health symptoms questionnaire was tested with a pilot study involving 50 chili farmers from different regions. The results demonstrated reliability, as indicated by a Cronbach alpha coefficient of 0.75.

Measurement of Erythrocyte Acetylcholinesterase

A medical technologist performed blood collection to assess cholinesterase levels. The blood was drawn from the antecubital vein in a volume of 3 mL, with the collection process taking 5 minutes per individual, and the samples were kept at a temperature between 2°C and 8°C. To determine erythrocyte cholinesterase levels, we utilized either whole blood or washed erythrocytes. The washed erythrocytes were prepared by removing the plasma and washing the cells three times with an equal volume of saline solution. For the assay of erythrocyte

cholinesterase activity, we combined 10 μ L of whole blood with 820 μ L of a working buffer that included quinidine. Subsequently, 10 μ L of a 69 mmol/L acetylcholine solution (yielding a final concentration of 2.0 mmol/L) was added to initiate the reaction. The introduction of 10 μ L of a 275 mmol/L acetylcholine solution into the buffer resulted in a blank drift of 4×10^4 pH/min, whereas the addition of 10 μ L of the 69 mmol/L solution produced a drift of 1×10^4 pH/min [16]. The toxicology laboratory employed a standard method for measuring erythrocyte AChE activity. The reference range was set at 70% of an individual's sensitivity/detection baseline (per the American Conference of Governmental Industrial Hygienists 2019 guidelines) [17], with the normal range being 1.0 to 1.5. The analysis was carried out by a medical technologist in the toxicology laboratory of the Faculty of Medicine at Ramathibodi Hospital, Bangkok. Blood cholinesterase levels were categorized into two groups: at risk (levels below 1.30 U/g) and normal (levels at or above 1.30 U/g). This classification was based on the cut-off value for the enzyme, which is below the limit of detection value used for biomonitoring AChE among farmers in Bandung, Indonesia [18].

Statistical Analysis

The association between personal characteristics, pesticide exposure factors, and health symptoms in chili farmers was examined using multiple logistic regression. In our analyses, the dependent variable was the presence of health effects, coded as 0 for 'no' if participants did not report any acute symptoms related to pesticide exposure, and as 1 for 'yes' if they reported one or more symptoms [12,15]. The potential confounding factors in the model, namely age and sex, were adjusted based on the recommended factor effect for health symptoms [12,15]. Adjusted odds ratios (aORs) and 95% CIs were reported to describe the strength of the association between the determinants and health symptoms.

A *p*-value of less than 0.05 was considered to indicate statistical significance. Analyses were performed using SPSS version 26 (IBM Corp., Armonk, NY, USA).

Ethics Statement

Ethical approval for this research was granted by Kasetsart University, Sakon Nakhon, and the accredited human ethics committee approved the research study protocol (Kucsc.HE-64-022). Written informed consent was obtained from all study participants, who voluntarily agreed to take part in the research.

RESULTS

Demographic Information

Of the 141 chili farmers surveyed, 62.4% were female, and the mean \pm standard deviation was 51.43 ± 9.49 years. Among the participants, 24.1% had comorbidities. A majority did not smoke (73.8%), abstained from alcohol (80.1%), and did not use muscle relaxants after a long day of work (68.1%). Most of the farmers had over five years of experience in chili cultivation (80.9%) and were accustomed to using pesticides (83.7%). Of these, 62.4% mixed chemicals themselves, 92.9% remained in the vicinity where chemicals were sprayed, 46.8% personally applied pesticides, and 65.2% used less than 100 L of chemicals per application. The mean activity level of AChE was 1.25 ± 0.08 U/g, with participants divided into 2 categories: 66.7% were considered at risk (with levels below 1.30 U/g), while 33.3% fell within the normal range with levels of 1.30 U/g or higher (Table 1).

Health Symptoms Among Chili Farmers

Table 2 reveals that 119 farmers (84.4% of participants) reported experiencing at least 1 symptom of acute pesticide poisoning following the use or handling of pesticides. In contrast, 15.6% of the respondents did not attribute any health issues they experienced to pesticide exposure. The most frequently reported symptoms associated with pesticide exposure were fatigue (37.6%), nausea and vomiting (31.9%), dizziness (14.9%), and dry throat (14.9%), in that order. Additional symptoms identified by respondents included headaches, nasal irritation, itchy skin, sore throat, excessive sweating, dry or chapped skin, watery eyes, heart palpitations, eyelid twitches, cough, skin rashes with itching, blisters, stomachache, and diarrhea.

Relationships Between Pesticide Exposure Factors and Pesticide-related Symptoms Among Chili Farmers

Multiple logistic regression models suggest an association between factors related to pesticide exposure and the occurrence of health symptoms in chili farmers. When the models were adjusted for age and sex, a strong positive association was observed between pesticide exposure and health symptoms. The likelihood of developing health symptoms was higher in association with the chili farmers' work experience (aOR, 4.54; 95% CI, 1.43 to 14.38; *p* < 0.01), the volume of pes-

Table 1. Demographic information of chili farmers in north-east Thailand (n=141)

Characteristics	n (%)
Sex	
Male	53 (37.6)
Female	88 (62.4)
Age, mean ± SD (y)	51.43 ± 9.49
Marital status	
Single/divorced	4 (2.8)
Married	137 (97.2)
Comorbid disease (answer more than 1 underlying disease)	34 (24.1)
Hypertension	22 (15.6)
Diabetes	12 (8.5)
Liver and kidney	3 (2.1)
Cancer	2 (1.4)
Other; asthma, stroke, SLE	7 (5.0)
Used pain relievers or muscle relaxants after a long day at work	
Yes	45 (31.9)
No	96 (68.1)
Experience in planting chilies (y)	
<5	27 (19.1)
>5	114 (80.9)
Smoking status	
Yes	37 (26.2)
No	104 (73.8)
Alcohol consumption status	
Yes	28 (19.9)
No	113 (80.1)
Related to chemicals (more than one answer)	
Combine chemicals	
Yes	88 (62.4)
No	53 (37.6)
Stay in the area where chemicals are sprayed	
Yes	131 (92.9)
No	10 (7.1)
Spraying pesticides	
Yes	66 (46.8)
No	75 (53.2)
Use of chemical pesticides (y)	
<5	23 (16.3)
>5	118 (83.7)
Chemical consumption (L/time)	
<100	92 (65.2)
>100	49 (34.8)
Blood cholinesterase level	
Risk level (<1.30 U/g)	94 (66.7)
Normal level (≥1.30 U/g)	47 (33.3)
Mean ± SD (Min-Max)	1.25 ± 0.08 (1.06-1.45)

SD, standard deviation; SLE, systemic lupus erythematosus; Min, minimum; Max, maximum.

Table 2. Prevalence of health symptoms among chili farmers in northeast Thailand (n=141)

Health symptoms	n (%)
Nervous system	
Nausea and vomiting	45 (31.9)
Dizziness	21 (14.9)
Headache	20 (14.2)
Excessive sweating	6 (4.3)
Watery eyes	3 (2.1)
Heart palpitations	2 (1.4)
Eyelid twitches	1 (0.7)
Muscular system	
Fatigue	53 (37.6)
Respiratory system	
Dry throat	21 (14.9)
Nasal irritation	20 (14.2)
Sore throat	10 (7.1)
Cough	1 (0.7)
Integumentary system	
Itchy skin	12 (8.5)
Dry/chapped skin	6 (4.3)
Itchy skin rash	1 (0.7)
Blister	1 (0.7)
Gastrointestinal system	
Stomachache	1 (0.7)
Diarrhea	1 (0.7)

ticides used (aOR, 4.15; 95% CI, 1.15 to 14.93; $p < 0.05$), the use of chemical pesticides (aOR, 15.14; 95% CI, 3.09 to 74.21; $p < 0.001$), spraying using a leaking chemical container (aOR, 8.98; 95% CI, 1.95 to 41.44; $p < 0.01$), pesticide exposure during work (aOR, 3.50; 95% CI, 1.23 to 9.94; $p < 0.05$), wearing clothes soaked with pesticides (aOR, 2.93; 95% CI, 1.06 to 8.11; $p < 0.05$), consuming food and drinks in the workplace (aOR, 4.16; 95% CI, 1.12 to 15.35; $p < 0.05$), and blood cholinesterase levels (aOR, 3.36; 95% CI, 1.28 to 8.82; $p < 0.05$). However, the analysis revealed no significant associations between the pesticide-related health symptoms and variables such as sex, age, the area of chili production, and the number of days worked per month (Table 3).

Relationships Between Health Effects and Blood Cholinesterase Levels in Chili Farmers

Table 4 presents the multiple logistic regression models that demonstrate a link between health outcomes, occupational characteristics, and blood cholinesterase levels among chili farmers. When the model was adjusted for age and sex, a posi-

Table 3. Relationship between determinants and health symptoms resulting from pesticide exposure among chili farmers in Sakon Nakhon Province, northeast Thailand (n=141)

Factors	No. of examined	Health symptoms, n (%)		cOR (95% CI)	aOR (95% CI)
		Yes	No		
Sex ¹					
Female	88	74 (84.1)	14 (15.9)	1.08 (0.43, 2.70)	1.03 (0.40, 2.63)
Male	53	44 (83.0)	9 (17.0)	1.00 (reference)	1.00 (reference)
Age (y) ²					
≤40	17	16 (94.1)	1 (5.9)	5.33 (0.58, 49.18)	6.45 (0.67, 62.42)
41-50	48	42 (87.5)	6 (12.5)	2.33 (0.66, 8.22)	2.31 (0.64, 8.32)
51-60	52	42 (80.8)	10 (19.2)	1.40 (0.44, 4.43)	1.45 (0.45, 4.63)
>60	24	18 (75.0)	6 (25.0)	1.00 (reference)	1.00 (reference)
Work experience (y) ³					
>5	114	99 (86.8)	15 (13.2)	2.78 (1.03, 7.47)*	4.54 (1.43, 14.38)**
≤5	27	19 (70.4)	8 (29.6)	1.00 (reference)	1.00 (reference)
Chili production area (ha) ³					
>1	46	40 (87.0)	6 (13.0)	1.45 (0.53, 3.97)	1.41 (0.51, 3.91)
≤1	95	78 (82.1)	17 (17.9)	1.00 (reference)	1.00 (reference)
No. days per month work ³					
>7	12	11 (91.7)	1 (8.3)	2.26 (0.28, 18.43)	2.12 (0.26, 17.50)
≤7	129	107 (82.9)	22 (17.1)	1.00 (reference)	1.00 (reference)
Volume of pesticides usage (L) ³					
>100	49	46 (93.9)	3 (6.1)	4.26 (1.20, 15.15)*	4.15 (1.15, 14.93)*
≤100	92	72 (78.3)	20 (21.7)	1.00 (reference)	1.00 (reference)
Chemical pesticide usage ³					
Yes	132	115 (87.1)	17 (12.9)	13.53 (3.09, 59.23)***	15.14 (3.09, 74.21)***
No	9	3 (33.3)	6 (66.7)	1.00 (reference)	1.00 (reference)
While spraying, use a leaking chemical container ³					
Yes	55	53 (96.4)	2 (3.6)	8.56 (1.92, 38.18)**	8.98 (1.95, 41.44)**
No	86	65 (75.6)	21 (24.4)	1.00 (reference)	1.00 (reference)
Pesticide exposure while working ³					
Yes	117	102 (87.2)	15 (12.8)	3.40 (1.24, 9.31)*	3.50 (1.23, 9.94)*
No	24	16 (66.7)	8 (33.3)	1.00 (reference)	1.00 (reference)
Clothes soaked with pesticides ³					
Yes	113	99 (87.6)	14 (12.4)	3.35 (1.27, 8.84)*	2.93 (1.06, 8.11)*
No	28	19 (67.9)	9 (32.1)	1.00 (reference)	1.00 (reference)
Consume food and drinks in the workplace ³					
Yes	47	44 (93.6)	3 (6.4)	3.96 (1.11, 14.11)*	4.16 (1.12, 15.35)*
No	94	74 (78.7)	20 (21.3)	1.00 (reference)	1.00 (reference)
Blood cholinesterase level ³					
Risk level (<1.30 U/g)	95	84 (88.4)	11 (11.6)	2.69 (1.09, 6.70)*	3.36 (1.28, 8.82)*
Normal level (≥1.30 U/g)	46	34 (73.9)	12 (26.1)	1.00 (reference)	1.00 (reference)

The data presented were analyzed using a logistic regression model.
cOR, crude odds ratio; aOR, adjusted odds ratio; CI, confidence interval.

¹aOR adjusted for age.

²aOR adjusted for sex.

³aOR adjusted for age and sex.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4. Health effects associated with cholinesterase levels among chili farmers in Sakon Nakhon Province, northeast Thailand (n=141)

Health effects	No. of examined	Blood cholinesterase level, n (%)		cOR (95% CI)	aOR (95% CI) ¹
		Risk level (<1.30 U/g)	Normal level (≥1.30 U/g)		
Nervous system					
Yes	75	56 (74.7)	19 (25.3)	2.04 (0.99, 4.17)	2.22 (1.06, 4.64)*
No	66	39 (59.1)	27 (40.9)	1.00 (reference)	1.00 (reference)
Muscular system					
Yes	53	43 (81.1)	10 (18.9)	2.98 (1.33, 6.68)**	3.45 (1.48, 8.06)**
No	88	52 (59.1)	36 (40.9)	1.00 (reference)	1.00 (reference)
Respiratory system					
Yes	49	38 (77.6)	11 (22.4)	2.12 (0.96, 4.68)	2.24 (1.00, 5.04)
No	92	57 (62.0)	35 (38.0)	1.00 (reference)	1.00 (reference)
Integumentary system					
Yes	16	15 (93.7)	1 (6.3)	8.44 (1.08, 66.00)*	8.80 (1.10, 70.33)*
No	125	80 (64.0)	45 (36.0)	1.00 (reference)	1.00 (reference)
Gastrointestinal system					
Yes	2	1 (50.0)	1 (50.0)	0.48 (0.03, 7.83)	1.91 (0.11, 31.84)
No	139	94 (67.6)	45 (32.4)	1.00 (reference)	1.00 (reference)

The data presented were analyzed using a logistic regression model. cOR, crude odds ratio; aOR, adjusted odds ratio; CI, confidence interval. ¹aORs are adjusted for age and sex. * $p < 0.05$, ** $p < 0.01$.

tive association was observed between blood cholinesterase level and certain adverse health effects, namely those of the nervous (aOR, 2.22; 95% CI, 1.06 to 4.64; $p < 0.05$), muscular (aOR, 3.45; 95% CI, 1.48 to 8.06; $p < 0.01$), and integumentary systems (aOR, 8.80; 95% CI, 1.10 to 70.33; $p < 0.05$). However, no significant correlation was observed for the respiratory and gastrointestinal systems (Table 4).

DISCUSSION

This study explored the potential links between pesticide exposure and the occurrence of health symptoms. Our findings indicate that chili farmers are at an increased risk of experiencing health issues associated with pesticide exposure, particularly when considering blood cholinesterase levels. By employing the standard method for measuring erythrocyte AChE activity, we were able to more accurately assess the relationship between pesticide exposure and health symptoms. Consequently, we are confident in our results, which suggest that blood cholinesterase concentrations in chili farmers could influence the manifestation of health symptoms. These findings are consistent with research from Thailand, which reported average activities of AChE and plasma cholinesterase (PChE) at

2.73 ± 0.88 U/mL and 1.58 ± 0.56 U/mL, respectively. Notably, approximately 80% of the chili farmers had detectable OP residues on their hands, and half of the study participants reported experiencing acute health symptoms within 48 hours of pesticide application [15].

The prevalence of symptoms reported in the survey aligned with previous studies conducted in the Arusha region of Tanzania, where the most common health symptoms were neurological (57.1%), followed by perspiration and headache (40.7%), poor appetite and depression (29.3%), and irritation (26.4%) [19]. Studies from Thailand, Brazil, and Cameroon also indicated that among pesticide-related symptoms, the most frequent included dizziness, coughs, and headaches [20], dyspnea, wheezing, poor digestion, tiredness, and feelings of worthlessness [10], and weakness, itchiness, a burning sensation, sneezing, and vomiting [21]. Furthermore, a study in southern Thailand found that the most frequently self-reported symptoms were coughing (5.7%), tiredness (5.4%), dizziness (5.1%), and dry skin and irritation (4.8%) [22]. Similarly, in western Ethiopia, the prevalence of respiratory symptoms among small-scale farmers exposed to pesticide chemicals was 87.2%, with coughing, headaches, skin irritation, and inhalation and skin contact issues primarily attributed to inadequate knowledge, practic-

es, and education, as well as factors such as age, work, and low income [23]. Applicators were more likely than residents to report skin irritation, shortness of breath, coughing, and dizziness, which may be related to the perceived toxicity of the mixture of pesticides in use [11].

Multiple logistic regression analysis revealed 8 factors independently associated with persistent health symptoms in chili farmers, even after adjusting for major confounders. These confounders included work experience, the volume of pesticide use, use of chemical pesticides, leakage from chemical containers during spraying, pesticide exposure while working, wearing clothes soaked with pesticides, consuming food and drinks in the workplace, and blood cholinesterase levels. The studies suggest that pesticide exposure in chili farmers is significantly linked to a higher prevalence of health symptoms. These findings echo research on rice farmers in Indonesia, which identified the frequency of pesticide spraying as the most critical factor in pesticide poisoning incidents. Other risk factors include the mixing dosage, frequency of spraying, working hours, and wind direction [24]. Additionally, research from the Chitwan District in Nepal reported acute symptoms in the prior 12 months among chemical pesticide users [25]. In the previously referenced study from Thailand, exposure to certain pesticides (OP, chlorpyrifos, and profenofos) on the hands was significantly associated with health symptoms in chili farmers [15]. Observations indicated inadequate pesticide handling and application practices, such as leaking spray tanks, smoking while working, and consuming food and alcohol in the work area [20]. The work experience of farmers, along with their level of knowledge and attitudes, may influence the occurrence of acute health symptoms [12]. These findings also suggest a link between blood cholinesterase levels and health symptoms, which is consistent with research from Tanzania that showed a correlation between self-reported fatigue symptoms and lower AChE levels [13]. In the study from southern Thailand, individuals with abnormal serum AChE levels were more likely to report dizziness as a primary symptom [22]. These studies propose that blood cholinesterase levels are related to health effects in chili farmers. Multiple logistic regression analysis also revealed health effects on the nervous, muscular, and integumentary systems associated with blood cholinesterase levels in chili farmers, after accounting for major confounders. This result is supported by the study from the Arusha Region, which found that the most frequently reported neurological symptom was fatigue (57.1%), and 27% of pesticide applicators had

AChE levels below the permissible limit [19]. AChE is a cholinergic enzyme primarily located at postsynaptic neuromuscular junctions, especially in nerves and muscles. The primary role of AChE is to terminate neuronal transmission and synaptic signaling to prevent AChE dispersal and the activation of nearby receptors. OPs and CAs can impact cholinesterase activity in both the central and peripheral nervous systems, potentially affecting various body systems, including the exocrine glands, eyes, gastrointestinal tract, respiratory tract, cardiovascular system, and skeletal muscles [26]. Symptoms such as confusion, headache, and impaired memory can arise from exposure to these substances, with repeated exposure leading to neurotoxic and neuromuscular effects. The prevalence of organophosphates in this study underscores the importance of monitoring cholinesterase activity as a primary test for pesticide poisoning.

Several limitations of this study should be considered when interpreting the results. First, the study relied on self-reported data collected during interviews, which may be subject to memory biases. Despite this, the data were gathered using a standardized questionnaire for health risk assessment from pesticide exposure in farmers (NGP 1-56), developed by the Division of Occupational and Environmental Diseases, Department of Disease Control, Ministry of Public Health, Thailand. In future research, blood AChE activity, in conjunction with the questionnaire on risk assessment from pesticide exposure, could be utilized to predict health impairments. Secondly, establishing a causal link between factors related to pesticide exposure and the blood cholinesterase levels of chili farmers, and their health symptoms, is challenging. This is due to the nature of cross-sectional analytic studies, which can only suggest potential associations among the 141 participants involved. Lastly, the study was conducted with a relatively small sample size as it was a preliminary investigation. Nevertheless, the findings demonstrate a significant association between factors related to pesticide exposure and health symptoms in rural community settings. Consequently, additional studies are required.

In conclusion, our findings revealed that various factors related to pesticide exposure and blood AChE levels are associated with a higher prevalence of health symptoms among chili farmers. These results indicate a need for targeted public health education and training programs for chili farmers, particularly emphasizing the importance of using appropriate personal protective equipment to minimize chemical exposure and en-

hance their proficiency in pesticide application. Furthermore, it is essential to conduct regular monitoring of blood cholinesterase levels and implement effective strategies to decrease pesticide exposure in order to safeguard the health of chili farmers.

NOTES

Conflict of Interest

The authors have no conflicts of interest associated with the material presented in this paper.

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Author Contributions

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