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Serum Cholinesterase Levels of Thai Chilli-Farm Workers Exposed to Chemical Pesticides: Prevalence Estimates and Associated Factors

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Abstract: Serum Cholinesterase Levels of Thai Chilli-Farm Workers Exposed to Chemical Pesticides: Prevalence Estimates and Associated Factors: Prasit KACHAIYAPHUM, *et al*. Faculty of Public Health, Mahidol University, Thailand—Objective: To estimate the prevalence of, and factors associated with, abnormal serum cholinesterase (SChE) levels among chilli-farm workers in Chatturat District, Chaiyaphum Province. **Methods:** A total of 350 chilli-farm workers aged 18–60 yr were randomly sampled and interviewed. A reactive-paper finger-blood test was used to assess SChE levels. **Results:** The prevalence of abnormal SChE levels was 32.0%. The most common pesticide-related symptoms were dizziness (38.0%), headache (30.9%), nausea/vomiting (26.9%), and fever (26.9%). Multiple logistic regression analysis revealed 7 factors were independently associated with abnormal SChE level: male gender, single/separated/divorced, being a permanent worker, spraying pesticide more than 3 times per month, having moderate or poor pesticide-use behaviors, and low perceived susceptibility and severity of pesticide use. **Conclusions:** The prevalence of abnormal SChE levels among chilli-farm workers was quite high. It would be beneficial to decrease pesticide use and encourage alternative measures. Effective preventive interventions to increase correct perceptions of pesticide use, the use of personal protective measures and continuing monitoring for blood cholinesterase, especially for male permanent farm workers, are recommended.
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Key words: Chemical pesticides, Chilli-farm workers, Pesticide-related symptoms, Serum cholinesterase, Thailand

Farm workers are a high risk group for exposure to agrichemical poisoning[1, 2]. In Thailand, chemical pesticides containing hazardous compounds used in the agricultural sector can be classified into 4 main types: organophosphates, carbamates, organochlorines, and pyrethroids. Organophosphates and carbamates are the predominant types of pesticide used and are of specific concern due to their highly toxic impact on humans and other organisms[3, 4]. Exposure to organophosphate and carbamate pesticides is the major cause of cholinesterase depression and plasma cholinesterase has been used as an exposure index, to assess low-level, chronic residue exposures among field workers[5–7].

Although agrichemicals are important for food hygiene, by preventing mould damage, flies, and other insects from contaminating food, their potential hazardous effects on humans makes their inappropriate use worrisome[8]. In 2007, data from the Bureau of Epidemiology showed public hospitals and health centers reported 1,452 pesticide-poisoning incidents, or 2.3 per 100,000 population; of these, 52.8% were farmers and 16.9% farm laborers. The northern region was ranked first in pesticide-poisoning incidents, followed by the north-east, with peaks in the rainy season (June/July), when farmers begin to cultivate their crops[9, 10]. The Bureau of Occupational and Environmental Disease, Thai Ministry of Public Health launched a nation-wide cholinesterase-activity screening test using a reactive-paper finger-blood test to determine farmers' exposure to cholinesterase-inhibiting pesticides, organophosphates, and carbamates. Data collected in 2006 indicated 27.6% of those tested had risky or unsafe cholinesterase depression[11].

Chilli is one of Thailand's economic crops. In 2003, the estimated value of chilli-farm production was US$136

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million, and the retail value of chilli and chilli products was US$276 million[12]. The total area under chilli cultivation in Thailand was estimated at 720 sq km, with 117.5 sq km (16.3%) in Chaiyaphum Province, second among the 76 provinces of Thailand[13]. Insects and diseases are a major constraint for chilli farmers. Despite the high use of chemicals, annual losses due to insects and diseases average 24 and 31%, respectively[12].

Chaiyaphum is a northeastern Province of Thailand. In 2005, data from a cholinesterase-activity screening-test survey in Chaiyaphum showed that 8.4% of those tested had risky or unsafe cholinesterase depression levels[14]. In addition, data from the Bureau of Epidemiology (2005) showed public hospitals and health centers reported 41 pesticide-poisoning incidents or 3.7 per 100,000 population[15]. However, the true extent of the problem is difficult to determine, because data derived from health facilities only represent cases requiring medical treatment. Farm laborers with mild pesticide poisoning often do not present for treatment, since treatment services are costly, or for fear of drawing attention to themselves, resulting in loss of employment[16].

Some factors in human poisoning, such as lack of knowledge among users and handlers about the effects of pesticides and of the safety precautions to minimize or prevent negative environmental and health effects[17] must also be considered. Currently, little is known about the actual handling and personal-protective-equipment (PPE) practices of applicators, or about the knowledge and perceptions that may influence the pesticide-use behaviors of chilli-farm workers in Chaiyaphum Province. This study aimed to estimate the prevalence of, and factors associated with, abnormal serum-cholinesterase (SChE) levels among chilli-farm workers in Chatturat District, Chaiyaphum Province.

Material and Methods

This study was conducted in Chatturat District, Chaiyaphum Province, 342 km northeast of Bangkok, where chilli is a major product. Chatturat District was selected because most people in the area are chilli-farm workers. The famous chilli variety grown in this area is "Yod-son", and it is used to produce a spicy-hot and fragrant dried chilli. Farm workers begin sowing in March and transplant the seedlings 67 days later. The first harvest takes place in October, and a total of 6 harvests are common. Anthracnose, a disease of chilli plants caused by different *Colletotrichum* species, is the most serious problem for chilli growers[18].

In 2007, Chatturat District had 9 sub-districts, with an estimated population of 75,948 people living in 22,401 households. Five of the 9 sub-districts were selected for the study area, since most of the people were chilli growers. Seventy of the 75 villages were recruited into the study; 5 small villages had no chilli growers. Five households were randomly selected from each village. If no one was home, the next nearest household was selected. When a household had more than one eligible subject, only one subject was chosen at random. Sample size was estimated using the single proportion formula, with a 95% confidence interval. The sample-size calculation was based on an 8.4% abnormal SChE level[14]. Precision was set at 3.0%, and the sample size was calculated as 329. This study recruited 350 respondents to allow for approx. 6% of non-respondents. Inclusion criteria were: chilli farmers and farm workers aged 18–60 yr who lived in the study area, and had handled pesticides regularly, or worked in a sprayed field in the study area for at least 3 mo prior to conduct of the survey. This included eligible persons in the study area during the survey, although their names were not listed in the house registration. Those with a history of liver disease, diabetes, cardiovascular disease, anemia, taking anti-malarial drugs, or malnutrition, were excluded.

Interview data and blood samples were collected by the first author and 4 well-trained research assistants. The Ethics Committee of Mahidol University approved the research protocol. The Chief of Chatturat District Health Office, Chaiyaphum Province, gave permission to conduct the study. All participating subjects gave their verbal informed consent.

Instrumentation

1) Questionnaire

The survey instrument was a 4-part questionnaire. Part 1 consisted of 7 items about the respondent's demographic data and 12 dichotomous items regarding pesticide-related symptoms. Part 2 dealt with type of work, duration of exposure to pesticide, frequency of pesticide use per month, trade name of the pesticide used most frequently, and 33 items on pesticide-use behaviors, covering practices before preparing pesticide, use of PPE while spraying pesticide, re-entry interval, and dealing with empty containers. Responses were noted on a 3-point rating scale, with scores being 2= always, 1=sometimes, and 0=never. A reverse score was given for negative items. Cronbach's alpha was 0.815. Part 3 dealt with knowledge of pesticide use, covering route of pesticide absorption, pesticide-related symptoms, pesticide residues, alternative pest-control methods, self-protection, and pesticide storage sites. There were 31 dichotomous items. A score of '1' was given for a correct answer and '0' for an incorrect answer. Cronbach's alpha was 0.731. Part 4 comprised perceptions of pesticide use, covering perceived susceptibility, severity, benefits, and barriers related to pesticide use. There were 8 items, and a 3-point rating scale: 3=high, 2=moderate and 1=low. Cronbach's alpha was 0.767. Possible scores and cut-off points for all study scales are shown in Table 1.

Table 1. Possible scores and cut-off points for all study scales

Scale (No. of items)	Possible score	Poor/Low	Moderate	Good/High
Pesticide-use behaviors (33)	0–66	0–44	45–53	54–66
Pesticide-use knowledge (31)	0–31	0–18	19–24	25–31
Perceived susceptibility (2)	2–6	2–4	–	5–6
Perceived severity (2)	2–6	2–4	–	5–6
Perceived benefits (2)	2–6	2–4	–	5–6
Perceived barriers (2)	2–6	2–4	–	5–6

2) Blood test

The finger-blood of the respondents was collected by capillary tube and centrifuged onsite. Then, the serum was tested using reactive-paper, to determine the cholinesterase level. The test kit was produced by the Government Pharmaceutical Organization of Thailand. The sensitivity, specificity, and positive predictive values of this test were 77, 90, and 85%, respectively[19]. Four levels of colors were used to determine the magnitude of change in cholinesterase activity through the production of acetic acid, as follows[19]:

Reactive paper color	*Health status*	*SChE level (units/ml)*
Yellow	Normal	≥100
Yellow-green	Safe	87.5–99.9
Green	Risky	75.0–87.4
Blue	Unsafe	<75.0

SChE levels were further grouped into 2 groups. A cholinesterase value of ≥87.5 units/ml was considered ‘normal’ and <87.5 units/ml ‘abnormal’. Samples were collected from October to December 2007, the harvesting and spraying period. Usually, farm workers spray their crops about one week before harvest.

Data analysis

The general characteristics and study variables are described by percentage, median, and mean. In bivariate analysis, the chi-square test was used to compare two proportions for category data. Multiple logistic regression was used in multivariate analysis to obtain odds ratios (ORs) and 95% confidence intervals, to determine the association between study factors and SChE levels. The significance level was chosen as $p \leq 0.05$.

Results

General characteristics and pesticide use

Of the 350 chilli-farm workers, 62.0% were male. The mean age was 43.6 yr (range 29–60), 92.9% were married, 73.2% had finished elementary school, 92.9% were chilli farmers (38.8%, or 126/325, were chilli farmers’ wives) and 7.1% were seasonal chilli farm workers. The median income was 3,500 baht (range 1,000–15,000, 1US$–35 baht), and 78.3% had monthly incomes ≤5,000 baht. In relation to pesticide use, 95.1% of chilli farmers used a pesticide hand-sprayer and 4.9% a speed-sprayer; 51.1% were exposed to, or sprayed, pesticides by themselves. The proportion of married permanent farm workers was higher than the proportion of married non-permanent farm workers (92.3%; 303/325 vs. 88.0%; 22/25). About 58.6% reported that their work had exposed them to chemical pesticides for more than 5 yr. The mean number of working years was 5.3 (range 1–20). Around 28.9% used pesticides more than 3 times per month, with a mean of 2.9 times (range 1–10). The generic names of 3 of the most frequently used organophosphate pesticides were Cypermethrin (40.3%), Methoxychlor (23.4%), and Dimethoate (14.6%), whereas the general names of the 3 most frequently used carbamate pesticides were Carbaryl (41.4%), Methomyl (35.4%), and Carbosulfan (28.3%).

Behaviors, knowledge and perceptions of pesticide use

1) Behaviors of pesticide use

Overall, only 28.3% had good pesticide-use behaviors, followed by 60.6% moderate, and 11.1% poor. Table 2 shows that 62.0% of respondents always carefully read and understood all of the instructions. Only 1.4% always mixed with other pesticides, and 0.3% mixed with herbs. Three of the most frequently used PPE by farm workers while preparing pesticide, were long-sleeved shirt and trousers (60.2%), hat (40.9%), and mask (36.6%). Only 10.9% reported that they always wore gloves, and 69.7% always correctly followed the directions for use on the label affixed to the pesticide container. Three of the most frequently used PPE while spraying pesticide were long-sleeved shirt and trousers (86.6%), hat (68.3%), and mask (67.4%). Meanwhile, 19.1% reported that they always wore gloves. About 3.2%, 2.3%, and 0.6% reported always smoking, drinking, and eating, while spraying insecticide, respectively.

After spraying pesticide, 50.6% reported always immediately taking a shower using soap or bath cream,

Table 2. Pesticide-use behaviors among 350 chilli-farm workers, by item (%)

Item	Always	Sometimes	Never
Carefully read and understand all instructions	62.0	33.7	4.3
Concentration of pesticide used			
Only one, not mixed	88.9	9.1	2.0
Mixed with other pesticides*	1.4	14.3	84.3
Mixed with herbs*	0.3	2.0	97.7
Preparing pesticide: personal protective equipment			
Wearing long-sleeved shirt and trousers	60.2	30.9	8.9
Wearing a hat	40.9	35.4	23.7
Wearing nasal mask	36.5	42.3	21.2
Wearing special boots	33.4	42.0	24.6
Using goggles	17.8	28.9	60.3
Wearing gloves	10.8	28.9	60.3
Follow directions on label affixed to pesticide container	69.7	28.3	2.0
Practices while spraying pesticide			
Wearing long-sleeved shirt and trousers	86.6	12.3	1.1
Wearing a hat	68.3	26.6	5.1
Wearing nasal mask	67.4	26.3	6.3
Wearing special boots	66.9	30.0	3.1
Using goggles	33.7	26.3	40.0
Wearing gloves	19.1	36.0	44.9
Wiping face with hand when wearing glove*	3.7	28.9	67.4
Smoking*	3.2	7.4	89.4
Drinking*	2.3	3.7	94.0
Eating*	0.6	1.4	98.0
Chewing gum*	0.3	6.9	92.8
Practices after spraying			
Immediately washing hands in clean water	67.7	29.4	2.9
Immediately washing hands with soap or bath cream	63.1	33.4	3.4
Immediately taking a shower	50.6	44.0	5.4
Immediately taking a shower using soap or bath cream	50.6	46.9	2.6
Returning to the field after spraying pesticide*	8.9	30.1	61.0
Dealing with empty pesticide container			
Discard on the garbage dump	44.2	28.9	26.9
Burying	25.2	27.4	47.4
Burning*	6.6	14.0	79.4
Storage water*	0.3	0.3	99.4
Storage foodstuffs*	0.0	5.1	94.9
Reaping crops during safe period after last spraying	85.1	12.3	2.6

*: Negative item.

and 63.1% reported always immediately washing hands with soap or bath cream. 8.9% reported always, and 30.1% reported sometimes, returning to the field immediately after spraying pesticides. About 44.2% always discarded pesticide containers at a garbage dump, and 25.1% always buried them. About 5.1% said that they sometimes used the empty pesticide containers to store foodstuffs. In addition, 2.6% reported that they never reaped crops during the safety period after the previous spraying.

2) Knowledge of pesticide use

About 31.1% had high knowledge of pesticide use, 50.9% moderate pesticide-use knowledge and 18.0% low pesticide-use knowledge. Table 3 shows that over 75% of respondents had correct knowledge about the entry routes of pesticide into the body. Three well know symptoms were sore eyes (81.4%), headache/dizziness (78.6%), and weakness (76.9%), while the symptoms not so well known were excessive sweating (47.7%) and infertility/miscarriage (38.3%). About 42.0% and 66.6%,

Table 3. Knowledge of pesticide use among 350 chilli-farm workers, by item

Variable	Number	%
Route of entry into body		
Mouth	335	95.7
Skin	299	85.4
Inhalation	264	75.4
Pesticide-related symptoms		
Sore eyes	285	81.4
Headache / dizziness	275	78.6
Weakness	269	76.9
Nausea and vomiting	271	77.4
Fever	252	72.0
Skin rash	218	62.3
Abdominal pain / diarrhea	216	61.7
Itching / skin irritation	194	55.4
Forgetfulness	194	55.4
Cough / chest pain / breathlessness	182	52.0
Excessive sweating	167	47.7
Infertility / miscarriage	134	38.3
Risk of get disease due to long-term expose to pesticide		
Respiratory disease	268	76.6
Dermatological disease	247	70.6
Neurological disease	233	66.6
Cancer	147	42.0
Places of pesticide residues exist		
Soil	333	95.1
Ground water	312	89.1
Fruit, seeds, and leaves of vegetables	312	89.1
Air	147	52.6
Alternative pest control to chemical pesticide		
Biological control e.g., effective microorganisms (EM)	338	96.6
Natural pest control	294	84.0
Traditional ways of controlling pests (by burning weeds or ploughing them)	250	71.4
Checking spraying equipment conditions before using	340	97.1
Do not spray against the wind	344	98.3
Place to store empty pesticide containers		
In specific storage in on the farm	348	99.4
In the home	283	80.9

respectively, knew that long-term exposure to pesticides put them at higher risk of cancer and neurological diseases. Only 52.6% knew that pesticide residues can persist in the air. Over 70% had correct knowledge of alternative methods to chemical pesticides to control pests. About 80.9% answered that they stored empty pesticide containers at home.

3) Perceptions of pesticide use

Approximately 25.1% had low perceived susceptibility, 46.0% low perceived severity, 40.6% low perceived benefits, and 6.3% high perceived barriers. Table 4 shows that more than 60% of respondents perceived those workers in agricultural occupations and their family members were at high risk of suffering negative effects from chemical pesticides. About 40% perceived that long-term exposure to pesticide and pesticide toxicity put them at high risk of death. Less than 50% perceived that using protective equipment against chemicals while spraying or adhering strictly to pesticide-use instructions, had moderate or low protective capacity or reduced the risks and dangers of pesticide use. Less than 10% perceived that using protective equipment against chemicals while spraying increased the expense of

Table 4. Perceptions of pesticide use among 350 chilli-farm workers, by item (%)

Variable	High	Moderate	Low
Agricultural occupations are at risk of negative effects from chemical pesticides	67.1	29.1	3.7
Agricultural family members are at risk of negative effects from chemical pesticides	62.3	30.6	7.1
Long-term exposure to pesticide may cause diseases such as leukemia	35.4	31.1	33.4
The toxicity of pesticides may cause death	43.7	41.1	15.1
Using chemo-protective equipment while spraying can protect you against exposure to chemicals	53.7	42.0	4.3
Strictly adhering to chemical use instructions can reduce the risks and dangers of chemical use	50.3	44.3	5.4
Using chemo-protective equipment while spraying increases costs	5.4	32.9	61.7
Using chemo-protective equipment causes difficulty and feeling uncomfortable while working	3.1	24.3	72.6

Table 5. Self-reported pesticide-related symptoms among chilli-farm workers, by serum cholinesterase (SChE) levels

Pesticide-related symptoms[a]	Abnormal SChE (%) n=112	Normal SChE (%) n=238	Total (%) n=350
Dizziness[b]	60.7	27.3	38.0
Headache[b]	47.3	23.1	30.9
Nausea and vomiting[b]	40.2	20.6	26.9
Fever[b]	39.3	17.2	24.3
Weakness[c]	30.4	17.6	21.7
Eye irritation[d]	23.2	13.4	16.6
Excessive sweating[c]	28.6	9.2	15.4
Itching/ skin irritation[b]	23.2	8.4	13.1
Abdominal pain/ diarrhea[b]	17.9	5.0	9.1
Cough/ breathlessness/ chest pain[c]	14.3	5.5	8.3
Burning sensation on skin[d]	10.7	4.6	6.6
Burning on face[e]	3.6	2.1	2.6

[a]: multiple responses, [b]: Chi-square test $p<0.001$, [c]: $p<0.01$, [d]: $p<0.05$, [e]: $p>0.05$.

spraying markedly or caused difficulties working.

Prevalence of abnormal SChE and pesticide-related symptoms

Overall, the prevalence of abnormal SChE levels was 32.0% (11.1% unsafe and 20.9% risky) and the remainder were normal (29.7% safe and 38.3% normal). Table 5 shows the common pesticide-related symptoms were dizziness (38.0%), headache (30.9%), nausea/vomiting (26.9%), and fever (24.3%). The prevalence of pesticide-related symptoms among the chilli farmers with abnormal SChE levels was significantly higher than the normal group ($p<0.05$), except for burning on the face ($p>0.05$).

Factors associated with abnormal SChE

In the multivariate analysis, 14 variables with $p<0.05$ in the bivariate analyses were simultaneously analyzed by multiple logistic regression analysis. Table 6 shows 7 variables were significantly associated with abnormal serum cholinesterase levels. They were: being male (adjusted OR=5.80, 95%CI 1.79–18.83), being single/ separated/divorced (adjusted OR=4.00, 95%CI 1.03–

Table 6. Crude and adjusted odds ratios (ORs) for abnormal serum cholinesterase levels among 350 chilli-farm workers, by logistic regression analysis

Variable	Crude		Adjusted*		*p*-value
	OR	95%CI	OR	95%CI	
Sex					0.003
Female	1.00		1.00		
Male	8.62	4.50–16.52	5.80	1.79–18.83	
Age (yr)					0.773
≤34	1.00		1.00		
35–44	3.98	1.44–10.95	1.73	0.36–8.33	
≥45	2.52	1.56–4.06	1.21	0.55–2.68	
Marital status					0.045
Married	1.00		1.00		
Single/separated/divorced	2.47	1.09–5.61	4.00	1.03–15.48	
Education					0.953
Secondary or higher	1.00		1.00		
Illiterate/ primary	1.77	1.03–3.05	1.03	0.42–2.54	
Main occupation					0.541
Chilli farmer	1.00		1.00		
Seasonal farm worker	2.99	1.27–7.06	1.66	0.33–8.45	
Spraying pesticide					0.415
No	1.00		1.00		
Yes	2.33	1.46–3.71	1.50	0.56–4.02	
Type of work					<0.001
Seasonal farm worker	1.00		1.00		
Permanent	9.60	5.55–16.62	4.32	1.96–9.54	
Pesticide use per month					<0.001
1–3 times	1.00		1.00		
>3 times	12.01	6.98–20.66	6.31	2.84–14.05	
Pesticide-use knowledge (score)					0.266
High (25–30)	1.00		1.00		
Moderate (19–24)	1.44	0.80–2.56	1.46	0.55–3.88	
Low (11–18)	2.66	1.35–5.21	2.38	0.80–7.09	
Pesticide-use behaviors (score)					<0.001**
Good (54–62)	1.00		1.00		
Moderate (45–53)	0.30	0.14–0.65	4.24	1.05–17.16	
Poor (30–44)	1.99	1.18–3.33	5.42	2.35–12.54	
Perceived susceptibility (score)					<0.001
High (5–6)	1.00		1.00		
Low (2–4)	5.21	3.11–8.73	6.19	2.44–15.70	
Perceived severity (score)					0.037
High (5–6)	1.00		1.00		
Low (2–4)	2.34	1.46–3.74	2.34	1.05–5.19	
Perceived benefits (score)					0.076
High (5–6)	1.00		1.00		
Low (2–4)	2.74	1.72–4.34	1.95	0.93–4.09	
Perceived barriers (score)					0.064
Low (2–4)	1.00		1.00		
High (5–6)	25.65	5.88–111.95	5.61	0.91–34.65	

*: Adjusted for sex, age, marital status, education, occupation, spraying pesticide, type of work, monthly pesticide use, knowledge of pesticide use, pesticide-use behaviors, perceived susceptibility, perceived severity, perceived benefits, perceived barriers. **: *p* for trend.

15.48), being a permanent worker (adjusted OR=4.32, 95%CI 1.96–9.54), spraying pesticide more than 3 times per month (adjusted OR=6.31, 95%CI 2.84–14.05), having moderate pesticide-use behaviors (adjusted OR=4.24, 95%CI 1.05–17.16; *p* for trend <0.001), having low perceived susceptibility (adjusted OR=6.19, 95%CI 2.44–15.70) and having low perceived severity (adjusted OR=2.34, 95%CI 1.05–5.19).

Discussion

The prevalence of abnormal SChE levels in the study area was higher than those reported for the provincial level[14] (32.0% vs. 8.4%). The possible reasons were: 1) this survey covered only a high risk area of abnormal SChE in Chatturat District, whereas the provincial survey covered farm-worker samples from both high and lower risk areas; and 2) it is likely that different crops are associated with different levels of pesticide exposure, due to the different tasks associated with crops; those requiring more manual labor imply greater exposure[20]. The prevalence of abnormal SChE in this study was lower than previous studies conducted in high-risk areas for specific crops. For example, Chomthaisong *et al.*[21], reported that 66.2% (45.1% risky and 21.1% unsafe levels) of 71 tomato growers for seed production, and 48.1% (35.1% risky and 13.0% unsafe levels) of 77 tomato growers for consumption were found to have abnormal SChE levels. Srivirojana *et al.*[22] also found that 49.3% (24.6% risky and 24.7% unsafe levels) of 98 orchid farmers had abnormal SChE levels. The prevalence of abnormal SChE levels was generally lower if the study samples were drawn from a wider area and non-specific crops. Chumchuay[23] noted that the prevalence of abnormal SChE among 472 farmers from 10 districts of Phatthalung Province was 24.2% (risky and unsafe levels combined).

The present study found that the most common pesticide-related symptoms of chilli-farm workers were dizziness (38.0%), headache (30.9%), and nausea/ vomiting (26.9%). This result was similar to those of Chomthaisong *et al.*[21] and Yassin *et al.*[24], i.e., that dizziness and headache were the most common pesticide-related symptoms.

The results showed that male farm workers were more likely to develop abnormal SChE levels than females. This might be due to the fact that most farm workers were male and their work exposed them directly to pesticide mixing, loading, application and re-entering the sprayed field, resulting in abnormal SChE levels. Most chilli farmers' wives were not directly exposed to pesticides. When a speed-sprayer of pesticide was used, the females might manage the hose, while the males were spraying the pesticide. The result was consistent with Pornpanuwit[25], who found that the mean SChE level among male farmers was significantly lower than among female farmers, indicating that males were at higher risk of developing abnormal SChE levels than females.

This study also showed that single/separated/divorced farm workers were more likely to develop abnormal SChE levels than married farm workers. This may be due to married farm workers using PPE more effectively than single/separated/divorced farm workers. In addition, they might be given tasks that place them at a lower risk of exposure to pesticides.

Subjects who were permanent farm workers and sprayed pesticide more than 3 times per month were more likely to develop abnormal SChE levels than seasonal workers and day-laborers; this may be due to the fact that permanent farm workers had longer exposure and more frequent direct exposures to pesticide use. Longer periods of exposure to chemical pesticides without correct use of PPE resulted in a higher risk of developing abnormal SChE levels. This result corresponded with the reports of Pornpanuwit[25] and Singhaseni *et al.*[26], who found that longer exposure to chemical pesticides increased the risk of pesticide hazards. However, it was inconsistent with the findings of Quinlan *et al.*[27], who found pesticide exposure was likely to be greater among seasonal farm-workers or day-laborers. This may be because seasonal workers or day-laborers might be given tasks placing them at greater risk of exposure to pesticides. In this study, the majority of the married farmers were permanent farmers; the results for the odds ratios for abnormal SChE seem to opposite between married status and the work style. One possible explanation is that longer exposure and more frequent direct exposure to pesticides are more important risk factors for abnormal SChE than being single/separated/ divorced.

Chilli-farm workers with moderate/poor pesticide-use behaviors were more likely to develop abnormal SChE levels than those with good behaviors. This may be attributable to ineffective PPE use, e.g., not always using a mask, boots, long-sleeved shirt and trousers, always/ sometimes smoking while preparing and applying pesticide. In addition, after spraying pesticide, the same subjects did not immediately take a shower using soap or bath cream, frequently re-entered a sprayed field. This result confirmed previous studies' findings, that behavioral factors were directly related to pesticide exposure, such as the use of PPE and personal hygiene behaviors, including hand washing at work, and showering upon returning home from work[20, 25, 28].

Farm workers with low levels of perceived susceptibility and severity of pesticide use were more likely to develop abnormal SChE levels than those with high perception levels. This may be due to farm workers in this group perceiving that in an agricultural occupation, they and their family members were at low risk of suffering from chemical pesticides, and that long-term exposure to pesticides and their toxicity did not put them at high risk of death. Perceptions do influence human behaviors[29], as was the case in this study, in the decision to use or not use PPE during pesticide exposure; therefore, low perceived susceptibility and low perceived severity of pesticide use led to carelessness in the use of PPE, resulting in overexposure to pesticides and the development of abnormal SChE levels. This finding agrees with those of previous studies, where higher perceived pesticide risk increased farm workers' sense of control and willingness to practice safety behaviors to reduce pesticide exposure[30, 31].

This study had 4 limitations; 1) the modest sample size, which represented only a high-risk chilli-growing area in Chatturat District, Chaiyaphum Province; 2) the reactive paper finger-blood test is a screening test, which should be confirmed by the Biggs or Ellman methods. Ideally, the blood test should be performed twice; once for baseline testing to determine the body's normal cholinesterase level, and again within the first 3 days of pesticide spraying, or no later than 30 days after the spraying period[19]; 3) evidence of pesticide-related symptoms relied on self-reports without physical examinations or clinical interview; and 4) the cross-sectional study design was limited to determining the causal associations of significant predictors and abnormal SChE levels.

In conclusion, the prevalence of abnormal SChE levels among the chilli-farm workers in the study area was quite high. Encouraging the alternative use of biopesticides is one way to reduce harmful effects on humans, and negative environmental and economic consequences. Effective preventive interventions to increase correct perceptions of pesticide use, the use of PPE during exposure to pesticides, appropriate waste disposal and continuous monitoring of blood cholinesterase, especially for male, permanent farm workers, should be provided.

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References

1) McConnell R, Cedillo L, Keifer M, et al. Monitoring organophosphate insecticide-exposed workers for cholinesterase depression. New technology for office or field use. J Occup Med 1992; 34: 34–7.
2) Watterson A. Pesticide health and safety and the work and impact of international agencies: Partial successes and major failures. Int J Occup Environ Health 2001; 7: 339–47.
3) Singhaseni P. Pesticide toxicity to the users and environment. Bangkok: Chulalongkorn Publishing Company; 1997. p. 7 (in Thai).
4) Plianbangchang P, Jetiyanon K, Wittaya-Areekul S. Pesticide use patterns among small-scale farmers: A case study from Phitsanulok, Thailand. Southeast Asian J Trop Med Public Health 2009; 40: 401–10.
5) Mekonnen Y, Ejigu D. Plasma cholinesterase level of Ethiopian farm workers exposed to chemical pesticide. Occup Med (Lond) 2005; 55: 504–5.
6) Nouira S, Abroug F, Elatrous S, et al. Prognostic value of serum cholinesterase in organophosphate poisoning. Chest 1994; 106: 1811–4.
7) Nielsen JB, Andersen HR. Cholinesterase activity in female greenhouse workers—Influence of work practices and use of oral contraceptives. J Occup Health 2002; 44: 234–9.
8) Reigart JR, Roberts JR. Recognition and management of pesticide poisoning, 5th ed. Washington, DC: United States Environmental Protection Agency; 1999. p. 5–6.
9) Bureau of Epidemiology. Annual epidemiological surveillance report 2007. Ministry of Public Health. [Online]. 2008 [cited 2009 Feb 15]; Available from: URL: http://203.157.15.4/Annual/ ANNUAL2550/ Part1/5350_PesticidePoisoning.doc (in Thai).
10) Bureau of Epidemiology. Annual epidemiological surveillance report 2007. Ministry of Public Health. [Online]. 2008 [cited 2009 Feb 15]; Available from: URL: http://203.157.15.4/Annual/ ANNUAL2550/ Part2/Table/Table9_36.html.
11) Bureau of Policy and Strategy, Ministry of Public Health. Thailand health profile report 2005–2007. Bangkok: The War Veterans Organization of Thailand; 2008. p. 222.
12) Mustafa Y, Ali M, Satapornvorasak T, et al. Thailand. In: Ali M, editor. Chili (*Capsicum* spp.) Food Chain Analysis: Setting Research, 2006: p. 197–245. Priorities in Asia. -Shanhua, Taiwan: AVRDC—The World Vegetable Center, Tech Bull 38. [Online]. 2006 [cited 2007 Mar 10]; Available from: URL: http:// www.avrdc.org/pdf/TB38/TB38_Thailand.pdf
13) Official files of Department of Agricultural Extension (DOAE), Statistics of Individual Vegetable Growing for the Year 2001–2003. Bangkok: DOAE; p.199.
14) Chaiyaphum Provincial Health Office. Annual health service report 2005. Chaiyaphum (Thailand): CPHO; p.20 (in Thai).
15) Bureau of Epidemiology. Annual epidemiological surveillance report 2005. Ministry of Public Health. [Online]. 2008 [cited 2009 Feb 15]; Available from: URL: http://203.157.15.4/Annual/Annual48/Part2/ Table/Table9_36.html
16) Murphy H. A farmer self-surveillance system of pesticide poisoning. June 2002. [Online]. 2002 [cited 2007 Mar 1]; Available from: URL: http://thailand.ipm-info.org/ documents/Surveillance_manual_(English).pdf
17) Perry MJ, Marbella A, Layde PM. Association of pesticide safety knowledge with beliefs and intentions among farm pesticide applicators. J Occup Environ Med 2000; 42: 187–93.
18) Wangraha N, Martwanna N, Techawongstien S. Chilli production practices and problems of chilli growers in Northeastern Provinces. Agricultural Sci J 2006; 37 (Suppl): 321–4 (in Thai).
19) Division of Occupational Health. Sensitivity and specificity of reactive paper in screening the retention of organophosphate and carbamate pesticides in blood

serum. In: Occupational Health Problems in Thailand. Bangkok: The War Veterans Organization of Thailand; 1986. p. 69–78 (in Thai).

20) Quandt SA, Hernández-Valero MA, Grzywacz JG, et al. Workplace, household, and personal predictors of pesticide exposure for farmworkers. Environ Health Perspect 2006; 114: 943–52.

21) Chomthaisong C, Nathapindhu G, Settheetham D. Occupational health impact on tomato growers in Kutchap District and Nonwuaso District Udon Thani Province: A comparison of impact between production for seed and production for consumption. KKU Res J (GS); 7: 74–82 (in Thai).

22) Srivirojana N, Thepetepa T, Punppuing S, et al. Population pressure, utilization of chemicals in agriculture, health outcomes and solid waste management. Proceedings: International conference on integrated solid waste management in Southeast Asian Cities, 2005. [Online]. 2006 [cited 2007 Mar 7]; Available from: URL: http://www.sea-uema.ait.ac.th/ARL/Conf_July05_ISWM/ Proceedings Pg.html

23) Chumchuay S. Factors related to the level of risk blood result from insecticide among farmers in Phatthalung Province in the year 2000. J Health Promot Envi Health 2001; 24:1–7 (in Thai).

24) Yassin MM, Abu Mourad TA, Safi JM. Knowledge, attitude, practice, and toxicity symptoms associated with pesticide use among farm workers in the Gaza Strip. Occup Environ Med 2002; 59: 387–93.

25) Pornpanuwit C. Blood cholinesterase enzyme levels of the farmers using agricultural pesticide in Muang District, Phrae Province. [Online]. 2008 [cited 2009 Jan 10]; Available from: URL: http://www.phraehospital.go.th/~occmed/PowerPoint/chlolineesterate.doc

26) Singhaseni P. Pesticides. In: Bovornkitti S, Loftus JP, Srisamran K, editors. Environmental Medicine. Bangkok: Ruean Kaew; 1999. p. 505–31 (in Thai).

27) Quinlan M, Mayhew C, Bohle P. The global expansion of precarious employment, work disorganization, and consequences for occupational health: Placing the debate in a comparative historical context. Int J Health Serv 2001; 31: 507–36.

28) Sujirarat D, Viwatwongkasem C. Factors influencing the level of serum insecticide retention in agricultural workers. Thai J Epidemiol 1995; 4: 68–75 (in Thai).

29) Janz NK, Becker MH. The Health Belief Model: A decade later. Health Educ Q 1984; 11: 1–47.

30) Arcury TA, Quandt SA, Russell GB. Pesticide safety among farmworkers: Perceived risk and perceived control as factors reflecting environmental justice. Environ Health Perspect 2002; 110 (Suppl 2): 233–40.

31) McCauley LA, Sticker D, Bryan C, et al. Pesticide knowledge and risk perception among adolescent Latino farm workers. J Agric Saf Health 2002; 8: 397–409.