Check for updates

RESEARCH ARTICLE

Association between pesticide exposure and obesity: A cross-sectional study of 20,295 farmers in Thailand [version 1; peer review: 1 approved with reservations, 1 not approved]

Kajohnsak Noppakun^{1,2}, Chudchawal Juntarawijit³

¹Department of Internal Medicine, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand

²Pharmacoepidemiology and Statistics Research Center (PESRC), Faculty of Pharmacy, Chiang Mai University, Chiang Mai, Thailand

³Faculty of Agriculture, Natural Resources and Environment, Naresuan University, Phitsanulok, 65000, Thailand

V1 First published: 04 Jun 2021, 10:445
<https://doi.org/10.12688/f1000research.53261.1>

Second version: 02 Feb 2022, 10:445
<https://doi.org/10.12688/f1000research.53261.2>

Latest published: 17 May 2022, 10:445
<https://doi.org/10.12688/f1000research.53261.3>

Abstract

Background: Obesity is a serious condition because it is associated with other chronic diseases which affect the quality of life. In addition to diet and exercise, recent research has found that pesticide exposure might be another important risk factor.

Methods: The objective of this large cross-sectional study was to determine the association between pesticide exposure and obesity among farmers in Nakhon Sawan and Phitsanulok province, Thailand. Data on pesticide use and obesity prevalence from 20,295 farmers aged 20 years and older was collected using an in-person interview questionnaire. The association was analysed using multivariable logistic regression, adjusted for its potential confounding factors.

Results: Obesity was found to be associated with pesticide use in the past. The risk of obesity was significantly predicted by types of pesticides, including insecticides (OR = 2.27, 95% CI 1.09-4.74), herbicides (OR = 4.72, 95% CI 1.16-19.29), fungicides (OR = 2.17, 95% CI 1.37-3.44), rodenticides (OR = 2.52, 95% CI 1.59-3.99), and molluscicides (OR = 3.37, 95% CI 2.13-5.31). Among 35 surveyed individual pesticides, 24 were significantly associated with higher obesity prevalence (OR = 1.75, 95% CI 1.00-3.06 to OR = 8.37, 95% CI 3.97-17.64), including herbicide butachlor, 17 insecticides (three carbamate insecticides, five organochlorine insecticides, and nine organophosphate insecticides), and six fungicides.

Conclusion: This study found obesity in farmers in Nakhon Sawan and Phitsanulok province, Thailand, to be associated with the long-term use of several types of pesticides. The issue should receive more public attention, and pesticide use should be strictly controlled.

Open Peer Review

Approval Status

	1	2	3
version 3 (revision) 17 May 2022			
version 2 (revision) 02 Feb 2022	 view		 view
version 1 04 Jun 2021	 view	 view	

1. **Yankai Xia**, Nanjing Medical University, Nanjing, China
2. **Yuki Ito**, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan
3. **Erik Jors**, University of Southern Denmark, Odense, Denmark

Any reports and responses or comments on the article can be found at the end of the article.

Keywords

Pesticide exposure, obesity, farmer health, insecticide exposure, herbicide exposure, fungicide exposure

Corresponding author: Chudchawal Juntarawijit (cjuntara@gmail.com)

Author roles: **Noppakun K:** Conceptualization, Formal Analysis, Investigation, Methodology, Writing – Original Draft Preparation, Writing – Review & Editing; **Juntarawijit C:** Conceptualization, Data Curation, Funding Acquisition, Investigation, Methodology, Project Administration, Resources, Supervision, Validation, Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: This project received grant support from the Thailand Science Research and Innovation (SRI)
The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Copyright: © 2021 Noppakun K and Juntarawijit C. This is an open access article distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: Noppakun K and Juntarawijit C. **Association between pesticide exposure and obesity: A cross-sectional study of 20,295 farmers in Thailand [version 1; peer review: 1 approved with reservations, 1 not approved]** F1000Research 2021, 10:445 <https://doi.org/10.12688/f1000research.53261.1>

First published: 04 Jun 2021, 10:445 <https://doi.org/10.12688/f1000research.53261.1>

Abbreviations

BMI: body mass index
 CM: carbamate pesticide
 CVD: cardiovascular diseases
 2,5-DCP: 2,5-dichlorophenol
 DDT: dichlorodiphenyltrichloroethane
 EDC: endocrine-disrupting chemicals
 ICD-10: International Classification of Diseases 10th
 OC: organochlorine pesticide
 OPs: organophosphate pesticide
 PCBs: polychlorinated biphenyl
 p,p'-DDE: dichlorodiphenyldichloroethylene
 VHV: village health volunteers

Background

Obesity is a global public health problem. In 2016, the World Health Organization (WHO) reported that there were approximately two billion people aged 18 years and older who were overweight, of which 650 million were obese, with this number expected to rise.¹ In Thailand, the latest national survey reported obesity prevalence among adults aged 18 years and older, to be 4.0% class I obesity (body mass index (BMI) 30.0-34.9 kg/m²), 0.8% class II obesity (BMI 35.0-39.9 kg/m²), and 0.1% class III obesity (BMI ≥40.0 kg/m²).² Obesity is not just an image problem, it can also affect health and well-being. Obesity has been linked with various health problems, including cardiovascular disease (CVD), type 2 diabetes mellitus (T2DM), cancer, and other health problems including liver and kidney disease, sleep apnea, and depression, which can eventually lead to mortality.³ Many factors can affect obesity, including age, genes, diet, a sedentary lifestyle, certain diseases, and medications, as well as other health conditions including sleeping habits, stress, and depression.⁴

Recent studies have found that pesticide exposure may be associated with metabolic disorders such as obesity.⁵ Mice studies have reported that chlorpyrifos, an organophosphate pesticide, has interfered with mucus-bacterial interactions in the gut, leading to increased lipopolysaccharide entry into the body resulting in excess fat storage.⁶ A study in Korea found women with *Methanobacteriales*, a bacteria in the gut that is linked to obesity, have higher body weight and waist circumference.⁷ This finding was consistent with a study in the United States of America (U.S.A) that with the use of the National Health and Nutrition Examination Survey (NHANES), found that obesity in adults was associated with the fumigant insecticide paradichlorobenzene,⁸ and 2,5-dichlorophenol (2,5-DCP) exposure.⁹ In a cohort study, dichlorodiphenyldichloroethylene (p,p'-DDE), and polychlorinated biphenyl (PCBs) were associated with higher BMI, high triglyceride levels, and insulin resistance.¹⁰ A recent study also linked a simultaneous exposure to bisphenol A (BPA), bisphenol S (BPS), and mono (carboxyoctyl) phthalate (MCOP), to an elevated risk of obesity.¹¹

As far as we know, to date, this issue has not been investigated in Thailand. This cross-sectional study aimed to determine the association between pesticide exposure and obesity among farmers in Nakhon Sawan and Phitsanulok province, Thailand. Identification of individual pesticides to predict the risk of obesity was the main interest. The results will be useful for verification of previous results and prevention of obesity.

Methods

Study design and setting

Data in this cross-sectional study was collected from farmers in Nakhon Sawan and Phitsanulok province, Thailand. Nakhon Sawan province is located about 250 km north of Bangkok, Thailand, with a population of 1,066,455 people and 401,432 households, from 15 districts (data for the year 2016). The majority of people are farmers, and the main crops are rice, sugarcane, and cassava. In 2017, the province had a gross domestic product (GDP) of 21,852 THB (716 USD).¹² In 2019, Phitsanulok province, located 377 km north of Bangkok, had a population of 865,368 people from nine districts and 342,787 households. Agriculture is the biggest sector of the economy, generating about 28% of GDP with an employment rate of 41.9%. The major crops in the province are rice, sugar cane, cassava, and vegetables¹³ (Thailand Information Centre, n.d.).

Study participants and sampling procedure

Study participants were farmers aged 20 years and older, who had worked as farmers for at least five years. Participants were selected using multistage sampling. Firstly, three districts from each province were randomly selected. In each district, three sub-districts were further randomly selected. In each sub-district, we selected 2,100-4,500 farmer families, accounting for about 30-100% of all farmer families in each sub-district. Using data from the local authority and personal contact, village health volunteers (VHV) identified farmer families, who were contacted for data collection. In each family, one adult who met the inclusion criteria was interviewed.

All local hospitals inside the selected subdistrict were contacted and public health staff and its membership VHV were invited to participate in the study. VHV who had mobile phone and internet access to the online questionnaires were recruited. These volunteers also had to attend a one-day training session to be informed about the project and to be trained on interviewing the participants, along with the correct use of online questionnaires. Most of the interviews took place in the participant's home, however sometimes in other places, e.g. local temple or hospital. Data was collected between October 2020 and February 2021. Data from all 20,295 participants were included in the data analysis.

The minimum sample size was calculated to be 18,772, based on the following assumptions: significance level = 95%; power of detection = 80%; ratio of unexposed/exposed = 1; percent of unexposed with outcome = 5%; odds ratio = 1.2.

Study questionnaire and data collection

Data was collected using an in-person interview questionnaire and an online version. The questionnaire had three major parts (provided as *Extended data*¹⁵). Part I, contained demographic information, including gender, age, marital status and education. Information on cigarette smoking and alcohol consumption were also collected.

In part II, there were questions regarding the long-term use of pesticides. This question was modified from the questionnaire used in our previous study.¹⁶ Data on both types and individual pesticides were collected. Pesticides were categorized into insecticides, herbicides, fungicides, rodenticides, and molluscicides. Insecticides were further subdivided into four classes: organochlorine, organophosphate, carbamate, and pyrethroid. For individual pesticides, we collected data on 35 pesticides that were commonly used in Thailand and have been reported in previous literatures to affect obesity.¹⁶ Study participants were asked whether they have ever used the pesticides, using a 'yes' or 'no' question. Pesticide use was defined as a mixture or spray pesticides for agriculture purposes. Household pest control was excluded in this study.

In part III, participants were asked whether they had been medically diagnosed with obesity by using a "yes" or "no" question. This information was later confirmed by the disease record ICD-10 of the local hospitals. The confirmed cases were included in the data analysis, while the missing data was excluded. In Thailand, the Ministry of Public Health follows the International Diabetes Federation's definition (2005), which defines obesity as a waist circumference of no more than 90 cm for men and 80 cm for women, plus two out of the following four criteria:¹⁷

1. Triglyceride level ≥ 150 mg/dL
2. HDL less than 40 mg/dL for men, or 50 mg/dL for women
3. Blood pressure $\geq 130/85$ mmHg, or taking medication for hypertension
4. Fasting blood glucose ≥ 100 mg/dL, or taking medication for hyperglycemia

Statistical analysis

Demographic data were analysed using descriptive statistics (frequency, percentage, mean, and standard deviation). An association between pesticides and obesity was determined using multivariable logistic regression, adjusted for gender (male, female), age (20-30, 31-40, 41-50, 51-60, 60+), smoking (non-smoker, ex-smoker, smoker) and alcohol consumption (non-drinker (or abstainer), ex-drinker, regular drinker), presented in odds ratio (OR), 95% confidence intervals.

P-values < 0.05 were statistically significant. All data analysis was performed using IBM SPSS Statistics (version 26) and OpenEpi online version 3.5.1.

Ethical considerations

The study was approved by the Ethical Committee of Naresuan University (COA No. 657/2019). Before the interviews, all the study participants gave informed consent to participate in the study, and they had the right to stop the interview at any time.

Results

Out of the 20,295 participants, most were women (45%), aged 40 years and older, with an average age of 55 (± 12 years). Current smokers were 11%, while 15% drank alcohol. Demographic data of the participants is shown in [Table 1](#) and the Underlying Data.¹⁸

Table 1. Characteristics of not obese, and obese participants.

Not Obese (N = 20217) N (%)	Obese (N = 78) N (%)	P value**
Gender		0.173
Male	9072 (99.7)	29 (0.3)
Female	11145 (99.6)	49 (0.4)
Age, yr		0.030*
20-30	722 (99.4)	4 (0.6)
31-40	1830 (99.4)	11 (0.6)
41-50	4238 (99.4)	24 (0.6)
51-60	6518 (99.6)	23 (0.4)
61+	6909 (99.8)	16 (0.2)
Mean $\pm$ SD = 55 $\pm$ 12		
Min-Max = 20-98		
Cigarette smoke		0.040*
Non- smoke	17043 (99.6)	64 (0.4)
Ex-smoker	918 (99.1)	8 (0.9)
Smoker	2256 (99.7)	6 (0.3)
Alcohol consumption		0.557
Non-drinker	15553 (99.6)	57 (0.4)
Ex-drinker	1461 (99.5)	8 (0.5)
Regular drinker	3203 (99.6)	13 (0.4)

*Statistically significant difference with p-value <0.05.

**Chi-square test

A total of 90 participants were diagnosed with obesity. Among these individuals, 12 were not confirmed by the ICD-10 record, thus only 78 were included in the data analysis. The prevalence of obesity among participants was 0.4% (Table 2). Besides obesity, many of the patients also had other diseases, e.g., hypertension, T2DM, dyslipidemia.

It was found that all types of pesticides, including insecticides, herbicides, fungicides, rodenticides, and molluscicides, were significantly associated with obesity prevalence (Table 3). The associations were also found in many of the surveyed individual pesticides (Table 4). Those pesticides were from various types of pesticide, including herbicides butachlor, 18 insecticides (three carbamate (CM) insecticide, five organochlorine pesticides (OC) insecticide, and nine organophosphate pesticides (OP) insecticide), and six fungicides.

Discussion

In this study, the prevalence of obesity was very low (0.4%). This might be due to the fact that the patients had underlying medical conditions, as stated in the ICD-10 records. This group of patients represent those with severe obesity or other health problems that needed medical attention. This was consistent with the data from a national survey in Thailand which found that the prevalence of obesity among adults aged 18 years and older to be 4.0% class I obesity (BMI 30.0-34.9 kg/m²), 0.8% class II obesity (BMI 35.0-39.9 kg/m²), and 0.1% class III obesity (BMI $\geq$ 40.0 kg/m²).² In further analysis, this study also found that many of the obesity cases have other health problems (hypertension (55%), T2DM (30%)) (Table 2).

This results of this study also found that many pesticides are strongly associated with the prevalence of obesity. The risk of obesity was significantly predicted by various types of pesticides, including insecticides (OR = 2.27, 95% CI 1.09-4.74), herbicides (OR = 4.72, 95% CI 1.16-19.29), fungicides (OR = 2.17, 95% CI 1.37-3.44), rodenticides (OR = 2.52, 95% CI 1.59-3.99), and molluscicides (OR = 3.37, 95% CI 2.13-5.31) (Table 3). Among 35 surveyed individual pesticides 24 were significantly associated with obesity (OR = 1.75, 95% CI 1.00-3.06 to OR = 8.37, 95% CI 3.97-17.64), including herbicide butachlor, 17 insecticides (three CMs- carbaryl, methomyl, carbosulfan, five organochlorine insecticides- endosulfan, dieldrin, aldrin, DDT, chlordane, and nine organophosphate insecticides- abamectin, chlorpyrifos, folidol

Table 2. Prevalence of obesity and the characteristics of obese patients.

	Number (%)
Total numbers of obese	90
Obese confirmed with ICD-10	78
Not confirmed	12
Prevalence of obesity (78*100/20,295)	0.4%
Gender	
Male	29 (37.2)
Female	49 (62.8)
Age, years	
20-30	4 (5.1)
31-40	11 (14.1)
41-50	24 (30.8)
51-60	23 (29.5)
60+	16 (20.5)
Mean $\pm$ SD = 51 $\pm$ 12	
Min-Max = 27-72	
Having other related diseases	
Hypertension	43 (55.1)
Diabetes mellitus	23 (29.5)
Dyslipidemia	11 (14.1)
Heart disease	2 (2.6)
Sleep disorder	2 (2.6)
Stroke	1 (1.3)

(parathion), methamidophos, monocrotophos, mevinphos, dicrotophos, dichlorvos, profenofos), and six fungicides-metalaxyl, propineb, carbendazim, thiophanate, benomyl, bordeaux mixture (Table 4). Turnbaugh et al,¹⁹ found pesticides affect the gut microbiome that controls the energy harvest, which may lead to obesity. This finding was supported by a recent study that found long-term exposure to chlorpyrifos affects gut microbiota homeostasis and induces inflammation, resulting in excess fat accumulation in the body.⁶ Additionally, a Korean study reported on the Methanobacteriales in the gut being associated with increased waist circumference, and bodyweight.⁷

Some pesticides are endocrine-disrupting chemicals (EDC). These are exogenous chemicals that interfere with the action of hormones, and/or obesogens, that inappropriately regulate lipid metabolism and adipogenesis to promote obesity.²⁰ At present, there are 105 pesticides listed as EDC, insecticides (46%) e.g. OCs DDT, 2,4-D, aldrin, endosulfan, chlorpyrifos, herbicide (21%) e.g. alachlor, diuron, glyphosate, and fungicides (31%) e.g., benomyl, carbendazim. A study found EDCs affect weight gain by altering lipid metabolism, fat cell size and number, and hormones involved in appetite, food preference, and energy metabolism.²¹

Epidemiological studies on the association between pesticide exposure and obesity are rare. U.S.A National Health and Nutrition Examination Survey (NHANES) from 2005-2008, indicated that obesity of the general population was associated with environmental exposure to some pesticides, e.g. 2,4-dichlorophenol (2,4-DCP), and 2,5-dichlorophenol (2,5-DCP).⁸ Among non-diabetic individuals, a study found that exposure to OC pesticides, especially p,p'-DDE, increased the risk of higher BMI, triglycerides, and decreased HDL cholesterol.¹⁰ Another study using NHANES survey from 2003-2006, also found exposure to environmental pesticides increased obesity in children aged 6-19 years.²² In this study, a dose-dependency was observed between the quartile of exposure to 2,5-DCP and the prevalence of obesity. These results were supported by a follow-up study which found 2,5-DCP exposure to be significantly associated with obesity (OR = 1.09, 95% CI 1.1-1.19) among children and adolescents aged 6-18 years.⁹ A follow-up cohort study has

Table 3. Association (OR) between different types of pesticide and obesity.

	Not obese (N = 20217) N (%)	Obese (N = 78) N (%)	OR (crude)	OR (adjusted)*
Any pesticide				
No	1092 (99.3)	8 (0.7)	1.0	1.0
Yes	19113 (99.6)	70 (0.4)	0.50 (0.24-1.04)	0.49 (0.23-1.02)
Insecticide				
No	4246 (99.8)	8 (0.2)	1.0	1.0
Yes	15959 (99.6)	70 (0.4)	2.33 (1.12-4.84)**	2.27 (1.09-4.74)
Herbicide				
No	2292 (99.9)	2 (0.1)	1.0	1.0
Yes	17913 (99.6)	76 (0.4)	4.86 (1.19-19.81)	4.72 (1.16-19.29)
Fungicide				
No	12071 (99.7)	31 (0.3)	1.0	1.0
Yes	8124 (99.4)	47 (0.6)	2.25 (1.43-3.54)	2.17 (1.37-3.44)
Rodenticide				
No	15800 (99.7)	46 (0.3)	1.0	1.0
Yes	4405 (99.3)	32 (0.7)	2.50 (1.59-3.92)	2.52 (1.59-3.99)
Molluscicide				
No	15357 (99.8)	38 (0.2)	1.0	1.0
Yes	4848 (99.2)	40 (0.8)	3.33 (2.14-5.20)	3.37 (2.13-5.31)

*Adjusted variables: Gender (male, female), age (20-30, 31-40, 41-50, 51-60, 60+), smoking (never, ex-smoker, current smoker), alcohol consumption (never, used to drink, currently drink).

**Significant OR were indicated in bold numbers.

Table 4. Association (OR) between individual pesticide and obesity.

Pesticide	Not obese (N = 20217) N (%)	Obese (N = 78) N (%)	OR crude	OR adjusted
Herbicide				
Glyphosate				
No	5715 (99.7)	17 (0.3)	1.0	1.0
Yes	14490 (99.6)	61 (0.4)	1.42 (0.83-2.43)	1.41 (0.82-2.42)
Paraquat				
No	10617 (99.7)	37 (0.3)	1.0	1.0
Yes	9588 (99.6)	41 (0.4)	1.23 (0.79-1.92)	1.20 (0.77-1.87)
D24				
No	10527 (99.7)	35 (0.3)	1.0	1.0
Yes	9678 (99.6)	43 (0.4)	1.34 (0.86-2.10)	1.32 (0.85-2.07)
Butachlor				
No	16025 (99.7)	43 (0.3)	1.0	1.0
Yes	4180 (99.2)	35 (0.8)	3.12 (2.00-4.88)**	3.05 (1.94-4.79)
Alachlor				
No	18660 (99.6)	68 (0.4)	1.0	1.0
Yes	1545 (99.4)	10 (0.6)	1.78 (0.91-3.46)	1.69 (0.87-3.30)

Table 4. *Continued*

Pesticide	Not obese (N = 20217) N (%)	Obese (N = 78) N (%)	OR crude	OR adjusted
Diuron				
No	19798 (99.6)	74 (0.4)	1.0	1.0
Yes	407 (99.0)	4 (1.0)	2.63 (0.96-7.23)	2.48 (0.90-6.85)
Organophosphate insecticide				
Abamectin				
No	9570 (99.7)	25 (0.3)	1.0	1.0
Yes	10635 (99.5)	53 (0.5)	1.91 (1.19-3.07)	1.87 (1.16-3.02)
Chlorpyrifos				
No	15459 (99.7)	40 (0.3)	1.0	1.0
Yes	4746 (99.2)	38 (0.8)	3.09 (1.98-4.83)	2.98 (1.90-4.68)
Folidol (parathion)				
No	17665 (99.7)	62 (0.3)	1.0	1.0
Yes	2540 (99.4)	16 (0.6)	1.80 (1.03-3.11)	1.75 (1.00-3.06)
Methamidophos				
No	19430 (99.6)	71 (0.4)	1.0	1.0
Yes	775 (99.1)	7 (0.9)	2.47 (1.13-5.39)	2.37 (1.08-5.19)
Monocrotophos				
No	19743 (99.6)	72 (0.4)	1.0	1.0
Yes	462 (98.7)	6 (1.3)	3.56 (1.54-8.23)	3.58 (1.55-8.39)
Mevinphos				
No	19965 (99.6)	74 (0.4)	1.0	1.0
Yes	240 (98.4)	4 (1.6)	4.50 (1.63-12.40)	4.35 (1.57-12.06)
Dicrotophos				
No	19747 (99.6)	72 (0.4)	1.0	1.0
Yes	459 (98.7)	6 (1.3)	3.59 (1.55-8.51)	3.51 (1.51-8.15)
Dichlorvos				
No	19987 (99.6)	75 (0.4)	1.0	1.0
Yes	218 (98.6)	3 (1.4)	3.67 (1.15-11.72)	3.74 (1.17-11.98)
EPN				
No	19620 (99.6)	75 (0.4)	1.0	1.0
Yes	585 (99.5)	3 (0.5)	1.34 (0.42-4.27)	1.32 (0.41-4.22)
Imidacloprid				
No	19524 (99.6)	73 (0.4)	1.0	1.0
Yes	681 (99.3)	5 (0.7)	1.96 (0.79-4.88)	1.90 (0.76-4.72)
Profenofos				
No	19719 (99.6)	72 (0.4)	1.0	1.0
Yes	486 (98.8)	6 (1.2)	3.38 (1.46-7.81)	3.15 (1.35-7.31)
Carbamate insecticide				
Carbaryl				
No	18948 (99.7)	64 (0.3)	1.0	1.0
Yes	1257 (98.9)	14 (1.1)	3.30 (1.84-5.90)	3.32 (1.85-5.96)

Table 4. *Continued*

Pesticide	Not obese (N = 20217) N (%)	Obese (N = 78) N (%)	OR crude	OR adjusted
Methomyl				
No	18879 (99.6)	68 (0.4)	1.0	1.0
Yes	1326 (99.3)	10 (0.7)	2.09 (1.08-4.08)	1.99 (1.02-3.91)
Carbosulfan				
No	17714 (99.7)	56 (0.3)	1.0	1.0
Yes	2491 (99.1)	22 (0.9)	2.79 (1.70-4.58)	2.67 (1.62-4.40)
Carbofuran				
No	18088 (99.6)	64 (0.4)	1.0	1.0
Yes	2117 (99.3)	14 (0.7)	1.87 (1.05-3.34)	1.75 (0.97-3.17)
Pyrethroid insecticide				
Permethrin				
No	17769 (99.6)	67 (0.4)	1.0	1.0
Yes	2436 (99.6)	11 (0.4)	1.20 (0.63-2.27)	1.14 (0.60-2.17)
Organochlorine insecticide				
Endosulfan				
No	17127 (99.7)	53 (0.3)	1.0	1.0
Yes	3078 (99.2)	25 (0.8)	2.63 (1.63-4.23)	2.56 (1.58-4.18)
Dieldrin				
No	20026 (99.6)	75 (0.4)	1.0	1.0
Yes	179 (98.4)	3 (1.6)	8.92 (2.57-26.75)	8.18 (2.52-26.59)
Aldrin				
No	20108 (99.6)	75 (0.4)	1.0	1.0
Yes	97 (97.0)	3 (3.0)	8.29 (2.57-26.75)	8.18 (2.52-26.59)
DDT				
No	19285 (99.6)	69 (0.4)	1.0	1.0
Yes	920 (99.0)	9 (1.0)	2.73 (1.36-5.49)	2.74 (1.36-5.53)
Chlordane				
No	19929 (99.6)	70 (0.4)	1.0	1.0
Yes	276 (97.2)	8 (2.8)	8.25 (3.93-17.31)	8.37 (3.97-17.64)
Heptachlor				
No	17046 (99.6)	62 (0.4)	1.0	1.0
Yes	3159 (99.5)	16 (0.5)	1.39 (0.80-2.42)	1.36 (0.79-2.37)
Fungicide				
Metalaxyl				
No	18638 (99.7)	63 (0.3)	1.0	1.0
Yes	1567 (99.1)	15 (0.9)	2.83 (1.61-4.99)	2.68 (1.51-4.74)
Mancozeb				
No	18843 (99.6)	70 (0.4)	1.0	1.0
Yes	1362 (99.4)	8 (0.6)	1.58 (0.76-3.29)	1.47 (0.70-3.08)
Maneb				
No	19280 (99.6)	71 (0.4)	1.0	1.0
Yes	925 (99.2)	7 (0.8)	2.06 (0.94-4.48)	2.02 (0.92-4.41)

Table 4. *Continued*

Pesticide	Not obese (N = 20217) N (%)	Obese (N = 78) N (%)	OR crude	OR adjusted
Propineb				
No	19261 (99.6)	68 (0.4)	1.0	1.0
Yes	944 (99.0)	10 (1.0)	3.00 (1.54-5.85)	2.89 (1.48-5.64)
carbendazim				
No	17904 (99.7)	57 (0.3)	1.0	1.0
Yes	2301 (99.1)	21 (0.9)	2.87 (1.74-4.74)	2.71 (1.64-4.50)
	<0.001*			
Thiophanate				
No	19831 (99.6)	73 (0.4)	1.0	1.0
Yes	374 (98.7)	5 (1.3)	3.63 (1.46-9.04)	3.52 (1.41-8.78)
Benomyl				
No	19965 (99.6)	74 (0.4)	1.0	1.0
Yes	240 (98.4)	4 (1.6)	4.50 (1.63-12.40)	4.58 (1.65-12.68)
Bordeaux mixture				
No	20096 (99.6)	76 (0.4)	1.0	1.0
Yes	109 (98.2)	2 (1.8)	4.85 (1.18-20.00)	5.35 (1.29-22.16)

*Adjusted variables: Gender (male, female), age (20-30, 31-40, 41-50, 51-60, 60+), smoking (never, ex-smoker, current smoker), alcohol consumption (never, used to drink, currently drink).

**Significant OR were indicated in bold numbers.

found that middle-aged obese women were associated with mothers that used DDT, while pregnant with these women. (OR = 1.26, 95% CI 6-49 to OR = 1.31, 95% CI 6-62).²³

Though a large sample size was used, the number of obese participants was still small. This limited the power of detection and control of confounding factors. Data on other risk factors, such as diet, exercise, or genetics were not collected. These confounding factors might have a different impact on the results. Another concern was that the obesity cases from ICD-10 records may not have been valid or represent the prevalence of the disease in the study. Currently, data on the validity of ICD-10 diagnosis coding for overweight/obesity in Thailand is not available. However, studies in Europe e.g., Sweden and Denmark, reported that the data is accurate and suitable to be used in epidemiological research.²⁴

The strength of this study was in its large sample size, and the ability to identify several groups and individual pesticides that were associated with obesity. This finding supported the literature and the hypothesis that pesticide exposure can increase obesity risk.

Conclusion

In Nakhon Sawan and Phitsanulok province of Thailand, obesity in farmers was associated with the long-term use of several types of pesticides, including insecticides, herbicides, fungicides, rodenticides, and molluscicides. The study additionally found 24 individual pesticides that increased the risk of obesity. This finding was consistent with the literature and studies done in other countries. The information should be publicized, and pesticide use should be controlled. Further studies should be done to confirm the results, and to determine a safe limit of pesticide exposure for obesity risk.

Data availability

Underlying data

Figshare: Dataset for study on pesticide exposure and obesity, among farmers in Nakhon Sawan and Phitsanulok province, Thailand.

<https://doi.org/10.6084/m9.figshare.14524983.v1>.¹⁸

This project contains the following underlying data:

- Dataset Pesticide and obesity (SAV and CSV). (All underlying data gathered in this study)
- Data Dictionary (DOCX).

Extended data

Figshare: Dataset for study on pesticide exposure and obesity, among farmers in Nakhon Sawan and Phitsanulok province, Thailand.

<https://doi.org/10.6084/m9.figshare.14524980.v1>.¹⁵

This project contains the following extended data:

- Questionnaire-pesticide and obesity-English (DOCX). (Study questionnaire in English)
- Questionnaire-pesticide and obesity-Thai (DOCX). (Study questionnaire in Thai)

Data are available under the terms of the [Creative Commons Zero “No rights reserved” data waiver](#) (CC0 1.0 Public domain dedication).

Acknowledgments

The author is grateful to all the study participants who took the time to participate in this study and provided valuable information. Thank you very much to local hospital staff from Nakhon Sawan, and Phitsanulok province, and the village health volunteers for collecting data. Thank you also to Mr. Kevin Mark Roehl of Naresuan University’s Writing Clinic (DIALD) for editing assistance.

References

1. World Health Organization: **Obesity and Overweight**. WHO. [Publisher Full Text](#)
2. Jitnarin N, Kosulwat V, Rojroongwasinkul N, *et al.*: **Prevalence of overweight and obesity in Thai population: Results of the National Thai Food Consumption Survey**. *Eat Weight Disord*. 2011; **16**(4): e242. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
3. Pi-Sunyer X: **The medical risks of obesity**. *Postgrad Med*. 2009; **121**(6): 21–33. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
4. Endalifer ML, Diress G: **Epidemiology, Predisposing Factors, Biomarkers, and Prevention Mechanism of Obesity: A Systematic Review**. *J Obes*. 2020; **2020**. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
5. Czajka M, Matysiak-Kucharek M, Jodłowska-Jedrych B, *et al.*: **Organophosphorus pesticides can influence the development of obesity and type 2 diabetes with concomitant metabolic changes**. *Environ Res*. 2019; **178**: 108685. [PubMed Abstract](#) | [Publisher Full Text](#)
6. Liang Y, Zhan J, Liu D, *et al.*: **Organophosphorus pesticide chlorpyrifos intake promotes obesity and insulin resistance through impacting gut and gut microbiota**. *Microbiome*. 2019; **7**(1): 19. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
7. Lee HS, Lee JC, Lee IK, *et al.*: **Associations among organochlorine pesticides, methanobacteriales, and obesity in Korean women**. *Luque RM, ed. PLoS One*. 2011; **6**(11): e27773. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
8. Wei Y, Zhu J, Nguyen A: **Urinary concentrations of dichlorophenol pesticides and obesity among adult participants in the U.S. National Health and Nutrition Examination Survey (NHANES) 2005–2008**. *Int J Hyg Environ Health*. 2014; **217**(2–3): 294–299. [PubMed Abstract](#) | [Publisher Full Text](#)
9. Parastar S, Ebrahimpour K, Hashemi M, *et al.*: **Association of urinary concentrations of four chlorophenol pesticides with cardiometabolic risk factors and obesity in children and adolescents**. *Environ Sci Pollut Res*. 2018; **25**(5): 4516–4523. [PubMed Abstract](#) | [Publisher Full Text](#)
10. Lee DH, Steffes MW, Sjödin A, *et al.*: **Low dose organochlorine pesticides and polychlorinated biphenyls predict obesity, dyslipidemia, and insulin resistance among people free of diabetes**. *Pan X, ed. PLoS One*. 2011; **6**(1): e15977. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
11. Zhang Y, Dong T, Hu W, *et al.*: **Association between exposure to a mixture of phenols, pesticides, and phthalates and obesity: Comparison of three statistical models**. *Environ Int*. 2019; **123**: 325–336. [PubMed Abstract](#) | [Publisher Full Text](#)
12. Nakhon Sawan Provincial Office: **Nakhon Sawan Province**. 2021. [Reference Source](#)
13. Phitsanulok Provincial Agriculture and Cooperatives Office: **Basic Agricultural Data, Phitsanulok (In Thai)**. 2021. [Reference Source](#)
14. Thailand Information Center: **Phitsanulok province**. Accessed February 22, 2021. [Reference Source](#)
15. Juntarawijit C: **Questionnaire-pesticide and rhinitis-Thailand**. *Figshare. Dataset*. 2021. [Publisher Full Text](#)
16. Juntarawijit C, Juntarawijit Y: **Association between diabetes and pesticides: A case-control study among Thai farmers**. *Environ Health Prev Med*. 2018; **23**(1). [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
17. Khamchata L, Dumrongpakapom P, Theeranut A: **Metabolic Syndrome: Dangerous signs required management**. *Srinagarind Med J*. 2018; **33**(4): 386–395.

18. Juntarawijit C: **Pesticide and obesity.** *Figshare. Dataset. Published.* 2021;
[Publisher Full Text](#)
19. Turnbaugh PJ, Ley RE, Mahowald MA, *et al.*: **An obesity-associated gut microbiome with increased capacity for energy harvest.** *Nature.* 2006; **444**(7122): 1027–1031.
[PubMed Abstract](#) | [Publisher Full Text](#)
20. Hatch EE, Nelson JW, Stahlhut RW, *et al.*: **Association of endocrine disruptors and obesity: Perspectives from epidemiological studies.** *Int J Androl.* Blackwell Publishing Ltd; 2010; **33**: 324–332.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
21. Gupta R, Kumar P, Fahmi N, *et al.*: **Endocrine disruption and obesity: A current review on environmental obesogens.** *Curr Res Green Sustain Chem.* 2020; **3**: 100009.
[Publisher Full Text](#)
22. Twum C, Wei Y: **The association between urinary concentrations of dichlorophenol pesticides and obesity in children.** *Rev Environ Health.* 2011; **26**(3): 215–219.
[PubMed Abstract](#) | [Publisher Full Text](#)
23. La Merrill MA, Krigbaum NY, Cirillo PM, *et al.*: **Association between maternal exposure to the pesticide dichlorodiphenyltrichloroethane (DDT) and risk of obesity in middle age.** *Int J Obes.* 2020; **44**(8): 1723–1732.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
24. Gribsholt SB, Pedersen L, Richelsen B, *et al.*: **Validity of ICD-10 diagnoses of overweight and obesity in danish hospitals.** *Clin Epidemiol.* 2019; **11**: 845–854.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)

Open Peer Review

Current Peer Review Status: ? ✖

Version 1

Reviewer Report 15 October 2021

<https://doi.org/10.5256/f1000research.56626.r95935>

© 2021 Ito Y. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Yuki Ito

Department of Occupational and Environmental Health, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan

The authors have investigated the relationships of pesticides used by farmers and obesity following the Thailand Ministry of Public Health definitions. They found a positive association between pesticide use and obesity. However, there are major points to be concerned as mentioned below. Also, the paper may benefit from an English language edit.

Abstract:

- Background in the Abstract should be specified by demonstrating the relationships between pesticides exposure and obesity.
- The authors should write the objective in the background section, not in the method section.

Background:

- The background should address the rationale of the study.
- In the last line of the first paragraph of the background section, the authors have stated lots of factors associated with obesity. Unfortunately, they cited only one article. More corresponding references should be added in this section.
- In the second paragraph, the authors described the association of PCBs, bisphenols, and one phthalate with obesity. Instead of these descriptions, the authors should cite other epidemiological studies examining the relationship between pesticide exposure and obesity.
- Authors stated that “identifications of individual pesticides to predict the risk of obesity was the main interest”. However, they did not assess the risk of pesticide exposure. They only investigated the observational relationships between the groups of pesticide use and obesity. The last line has no basis to write in this section.

Methods:

- The authors should remove the duplicate statement such as, “the major crops in the province are rice, sugar cane, casava and vegetables” from the study settings and design section.
- Please clarify the last two lines of “study participants and sampling procedure”. Define the term exposed and unexposed.
- A major concern is the definition of obesity. The authors investigated the relationship between pesticide use and obesity following the definition of the Thailand Ministry of Public Health. However, the definition of obesity is not clear. Based on the author’s statement, it seems like the definition of a metabolic syndrome but not obesity (see the article by Engin, 2017¹). The authors should clarify it. They can consider BMI, WC, and/or other anthropometric indices of overweight and obesity if data is available.

Results:

- Out of 20,295, only 78 study participants were obese. The overall prevalence of obesity was very low, although the authors did not calculate prevalence both in males and females.
- Tables 1 and 2 were not prepared carefully. These two tables should merge and put data in each column and row carefully.
- If possible, please provide all the demographic data (collected by questionnaires), including socio-economic status, education, ethnicity, etc.
- For investigating the OR, they have adjusted the results only by gender, age, smoking, and alcohol consumption. They have no data about diet, physical activity, socioeconomic status or income that may affect the results.

Discussion:

- This section should be written based on results deeply and sharply. They should explain their findings, e.g. why and how by comparing other studies.
- Additionally, this study is only based on questionnaire data and did not monitor the individual exposure levels of pesticides. This is another major limitation of this study.

Conclusion:

- The conclusion should be short and specific based on the results.
- The authors should not use “increased the risk of obesity”.

References

1. Engin A: The Definition and Prevalence of Obesity and Metabolic Syndrome. *Adv Exp Med Biol.* 2017; **960**: 1-17 [PubMed Abstract](#) | [Publisher Full Text](#)

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

No

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Exposure assessment of pesticides and their association with health effects.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 24 Nov 2021

Chudchawal Juntarawijit, Naresuan University, Phitsanulok, Thailand

Comment

The authors have investigated the relationships of pesticides used by farmers and obesity following the Thailand Ministry of Public Health definitions. They found a positive association between pesticide use and obesity. However, there are major points to be concerned as mentioned below. Also, the paper may benefit from an English language edit.

Response

Thank you, we really appreciate your time and effort to review the manuscript.

We admitted that this study may be far from perfect. By using a descriptive cross-sectional study, this study has several limitations. As compared to an analytical cross-sectional study, a better study design with a control group is often found in medical studies. With the descriptive design, this study had some limitations and could not be compared with the analytical one. This study lacks data on some confounding variables and relies only on the questionnaire method for pesticide exposure data. However, the results supported the usefulness of ICD-10 data for studying obesity. We hope that the result could be useful as a small piece of information to the relatively rare literature on the association of pesticides and obesity.

The English language was edited by Mr. Kevin.

Abstract:
Comment

Background in the Abstract should be specified by demonstrating the relationships between pesticides exposure and obesity.

Response

Currently, there was not enough evidence demonstrating the relationship between pesticides exposure and obesity. With 250 words as the maximum word count limited by F1000Research, the issue, therefore, was only briefly described here.

Comment

The authors should write the objective in the background section, not in the method section.

Response

We agree and the objective has been revised and moved to the background section, as follows:

Background: ...The objective of this study was to determine the association between pesticide exposure and obesity among farmers in Nakhon Sawan and Phitsanulok province, Thailand.

Methods: This study was a population-based cross-sectional study.

Background:**Comment**

The background should address the rationale of the study.

Response

The main reason why this study is needed was that obesity is an important public health problem and exposure to pesticides might be one of its causes. However, currently, there was only limited evidence. This study was among a few studies trying to investigate the association between obesity and pesticide exposure using a large cross-sectional study design.

Comment

In the last line of the first paragraph of the background section, the authors have stated lots of factors associated with obesity. Unfortunately, they cited only one article. More corresponding references should be added in this section.

Response

The reference was a systematic review that mentioned various factors associated with obesity.

Comment

In the second paragraph, the authors described the association of PCBs, bisphenols, and one phthalate with obesity. Instead of these descriptions, the authors should cite other epidemiological studies examining the relationship between pesticide exposure and obesity.

Response

In this section, we try to present information on pesticides and obesity. To our knowledge, all of the epidemiological studies on pesticides and obesity were already included. In the last statement, we just want to mention that not only pesticides but also some other compounds, e.g., PCBs, bisphenols, and one phthalate might also cause obesity.

To make it clear, the statement has been revised.

Comment

Authors stated that “identifications of individual pesticides to predict the risk of obesity was the main interest”. However, they did not assess the risk of pesticide exposure. They only investigated the observational relationships between the groups of pesticide use and obesity. The last line has no basis to write in this section.

Response

To be more precise, the statement “*identifications of individual pesticides to predict the risk of obesity was the main interest*” has been revised as follows:

“The main interest was to associate obesity to pesticides, either by group or individual chemical.”

Methods:**Comment**

The authors should remove the duplicate statement such as, “the major crops in the province are rice, sugar cane, cassava and vegetables” from the study settings and design section.

Response

Actually, that statement was not duplicated but they described major crops of the two different provinces, Nakhon Sawan and Phitsanulok.

Comment

Please clarify the last two lines of “study participants and sampling procedure”. Define the term exposed and unexposed.

Response

Exposed refers to the exposure group or those who used pesticides. Unexposed refers to the unexposed group or those who do not use pesticides.

This information has been added to the paper.

Comment

A major concern is the definition of obesity. The authors investigated the relationship between pesticide use and obesity following the definition of the Thailand Ministry of Public Health. However, the definition of obesity is not clear. Based on the author’s statement, it seems like the definition of a metabolic syndrome but not obesity (see the article by Engin, 2017¹). The authors should clarify it. They can consider BMI, WC, and/or other anthropometric indices of overweight and obesity if data is available.

Response

We thank you the reviewer for making a very important point and agreeing to revise our manuscript as we picked up the case with obesity using a diagnosis in ICD-10. We have deleted the statement *"In Thailand, the Ministry of Public Health follows the International Diabetes Federation's definition (2005), which defines obesity as a waist circumference of no more than 90 cm for men and 80 cm for women, plus two out of the following four criteria:..."* and replaced with the following, *"In Thailand, the Ministry of Public Health follows The World Health Organization obesity criteria for Asia Pacific Region in which body mass index over 25.0 kg/m² was identified as obesity."*

Results:**Comment**

Out of 20,295, only 78 study participants were obese. The overall prevalence of obesity was very low, although the authors did not calculate prevalence both in males and females.

Response

Prevalence of obesity was very low since the study use data from ICD-10 records, instead of survey data on BMI or waist circumstance. The issue was already discussed in the manuscript.

Comment

Tables 1 and 2 were not prepared carefully. These two tables should merge and put data in each column and row carefully.

Response

The two tables have been merged. An error in the table head has been corrected.

Comment

If possible, please provide all the demographic data (collected by questionnaires), including socioeconomic status, education, ethnicity, etc.

Response

In this survey, we collected data from respondents who are farmers living in a rural area of six districts but found obesity cases in five districts (Table 1).

For socioeconomic data, only the district location of participants, and their education, and monthly income were collected. However, these factors were not included in the model because of several reasons. For district location, most of the participants were farmers from rural areas, thus there was no reason to believe district location to associate with obesity. Moreover, the district was closely related to pesticide use and will cause multicollinearity problems, if included in the model (Bhandari, 2020). For income, there was no relationship with obesity in middle-income countries, e.g. Thailand (Ameye and Swinnen, 2019). For education, previous research found a higher risk of obesity to be inversely associated with education (Anyanwu, 2010). However, in this study more obesity was found among those with higher education (Table 1). In addition, when these two variables were included in the model, not much effects on OR were found. For example, for molluscicide the OR was

changed from 2.28 (1.48-3.64) to 2.37 (1.48-3.79) when added education and to 2.39 (1.49-3.83) when added income (Table 2-1). For baseline diseases, most of them should be considered as the so-called 'downstream outcome' closely related to obesity and thus, should not be included in the model (DVL, 2020).

More demographic information has been added to Table 1.

For ethnicity, in Thailand, we did not have ethnic groups.

Comment

For investigating the OR, they have adjusted the results only by gender, age, smoking, and alcohol consumption. They have no data about diet, physical activity, socioeconomic status or income that may affect the results.

Response

Yes, we agree that that information on diet and physical activity would be useful and should be used for the adjustment. It is a study limitation and the issue was already discussed in the study limitation. The problem should not seriously affect study results since all of the participants were farmers from rural areas.

For data on socioeconomic, actually, we also collected data on district location, education, and monthly income. However, these factors were not included in the model because of several reasons. For district location, most of the participants were farmers from rural areas, thus there was no reason to believe district location to associate with obesity. However, the district was closely related to pesticide use and caused a multicollinearity problem, therefore, it was not included in the model (Bhandari, 2020). For education and income, previous research found a higher risk of obesity to inversely associate with education (Anyanwu, 2010). For income, there was no relationship with obesity in middle-income countries, e.g. Thailand (Ameye and Swinnen, 2019). When the model included these two variables, the OR was not much changed. For example, for Molluscicide the OR was changed from 2.28 (1.48-3.64) to 2.37 (1.48-3.79) when added education and to 2.39 (1.49-3.83) when added income (Table 2-1). For baseline diseases, most of them should be considered as the so called 'downstream outcome' closely related to obesity but not confounding and thus, should not be included in the model as well (DVL, 2020).

Discussion:**Comment**

This section should be written based on results deeply and sharply. They should explain their findings, e.g. why and how by comparing other studies.

Response

Thank you for the suggestion. We agree and try to comply with your suggestion as much as we can.

Comment

Additionally, this study is only based on questionnaire data and did not monitor the individual exposure levels of pesticides. This is another major limitation of this study.

Response

For a large study of long-term effects of pesticides, a questionnaire might be the only option. Since pesticide dose is a good marker for short-term pesticide exposure. However, it was costly and may not be suitable for a large survey study. The questionnaire method is probably the best alternative to collect data on long-term pesticide exposure. The method is commonly used in epidemiological studies e.g., Agricultural Health Study in the United State. For studies using a large group of participants, the method has been proved to be useful without any serious bias (Coble *et al.*, 2011) (Hoppin *et al.*, 2002).

The limitation was further discussed as suggested.

Conclusion:**Comment**

The conclusion should be short and specific based on the results.

Response

Thank you for the suggestion. We agree and try to comply with your suggestion as much as we can.

Comment

The authors should not use "increased the risk of obesity".

Response

The statement has been changed to "*The study additionally found exposure to 24 individual pesticides was significantly associated with obesity.*"

References

Anyanwu, G. E., Ekezie, J., Danborno, B., & Ugochukwu, A. I. (2010). Impact of education on obesity and blood pressure in developing countries: A study on the Ibos of Nigeria. *North American Journal of Medical Sciences*, 2(7), 320–324.
<https://doi.org/10.4297/najms.2010.2320>

Bhandari A. (2020). What is multicollinearity? Here's everything you need to know. Analytics Vidhya. Available: [Multicollinearity | Detecting Multicollinearity with VIF](https://www.analyticsvidhya.com/blog/2020/07/multicollinearity-detecting-multicollinearity-with-vif/) (analyticsvidhya.com)

Coble *et al.*, (2011). An updated algorithm for estimation of pesticide exposure intensity in the agricultural health study, *Int. J. Environ. Res. Public Health*; 8(12), 4608–4622. doi: 10.3390/ijerph8124608.

Hannah Ameye and Johan Swinnen, (2019). Obesity, income and gender: The changing global relationship, *Global Food Security*, 23, 267–281.
<https://doi.org/10.1016/j.gfs.2019.09.003>.

Hoppin, F. Yucel, M. Dosemeci, and D. P. Sandler, (2002). Accuracy of self-reported pesticide use duration information from licensed pesticide applicators in the Agricultural Health

Study, J. Expo. Anal. Environ. Epidemiol.; 12(5), 313–318. doi: 10.1038/sj.jea.7500232.

Table 2-1 Odds ratio when more variables were added to the model.

Pesticide: Molluscicide

OR (in the table 2) 3.36 (2.13-5.31)

OR (when add baseline disease) 3.30 (2.08-5.22)

OR (add district location) 2.28 (1.43-3.64)

OR (add education) 2.37 (1.48-3.79)

OR (add income) 2.39 (1.49-3.83)

Competing Interests: No competing interests were disclosed.

Reviewer Report 01 October 2021

<https://doi.org/10.5256/f1000research.56626.r94404>

© 2021 Xia Y. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Yankai Xia

State Key Laboratory of Reproductive Medicine, Center for Global Health, School of Public Health, Nanjing Medical University, Nanjing, China

This study used questionnaire-based pesticide exposure data of 20,295 farmers to determine the association between pesticide use and obesity in Thailand. With the large-scale cross-sectional epidemiological data, the study determined that regional obesity in farmers could be associated with pesticide use. The study displayed novelty and value in public health on Thailand regional health. However, I thought there were several questions in this manuscript. Therefore, I thought major revision was necessary. The detailed review points were listed below.

1. In the abstract, the authors declared that they collected the long-term pesticide exposure data. However, I thought the term 'long-term' should be considered carefully as the questionnaire did not collect the frequencies of pesticides use (only yes or no). Also, the nature of the cross-sectional study (without follow-up) could poorly support the conclusion.
2. In the farmer population, pesticide-attributed obesity may be associated with the living conditions or geographical location of these individuals. Therefore, I thought it would be helpful if the authors provided the related data of these individuals.
3. Methods: Since there is a great difference between genders on obesity diagnosis, I recommended the authors perform stratified analysis to determine the gender-specific associations.
4. Results: The authors checked the relations between pesticide exposure and obesity. Is there

any interaction between the different pesticides?

5. Results: The authors should clarify the demographic characteristics in detail.
6. Results: It will be helpful to display the C-index of each model to validate the reliability.
7. Discussion: I noticed that the OR for pesticides is from 1.75 to 8.37, while the OR over 3 may be overestimated and lead to unnecessary panic for public health. I thought the authors should discuss their results more carefully.
8. Discussion: I thought the authors should declare the nature of the cross-sectional study and tell the readers that the study was limited in explaining the causality.
9. Discussion: The strengthen part only replicates the conclusion.
10. One of the most limited parts of this study was the lack of dose or level data of pesticides use, which may cause serious bias. The authors should make a discussion about this.
11. The authors should explain the reliability and validity of their questionnaire as there may be information bias that exists with the questionnaire method.
12. I recommended the authors list the data on body measure index or waist circumferences in Table 1.
13. Waist circumferences and baseline diseases should be adjusted as covariates.
14. According to the previous literature, there is a great difference between populations in different age groups. Therefore, I thought age-specific associations between pesticides use and obesity should be considered.
15. As the authors declared, the limited data on dietary patterns, physical activities, and genetic variants may lead to potential bias. However, I thought the authors should be concerned about whether their adjusted models could explain the variance.
16. Could the authors list the blood pressure, glucose, triglyceride, and HDL value in the tables? Also, I think adjusting them in the model should be considered.
17. The effects of pesticides exposure may have co-exposure patterns, the authors should notice that.

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Exposure to pesticides and health effects

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 24 Nov 2021

Chudchawal Juntarawijit, Naresuan University, Phitsanulok, Thailand

Comment

This study used questionnaire-based pesticide exposure data of 20,295 farmers to determine the association between pesticide use and obesity in Thailand. With the large-scale cross-sectional epidemiological data, the study determined that regional obesity in farmers could be associated with pesticide use. The study displayed novelty and value in public health on Thailand regional health. However, I thought there were several questions in this manuscript. Therefore, I thought major revision was necessary. The detailed review points were listed below.

Response

Thank you very much for your time and effort to review this manuscript and for providing valuable suggestions.

Comment

1. In the abstract, the authors declared that they collected the long-term pesticide exposure data. However, I thought the term 'long-term' should be considered carefully as the questionnaire did not collect the frequencies of pesticides use (only yes or no). Also, the nature of the cross-sectional study (without follow-up) could poorly support the conclusion.

Response

The term '*long-term use*' has been replaced with '*historical use*'.

In this study, actually, we also collected data on the frequency and duration of pesticides use and calculated cumulative days of exposure. Unfortunately, there was only a small number of cases with obesity, therefore the association between quartile days of exposure

and obesity could not be performed.

Comment

2. In the farmer population, pesticide-attributed obesity may be associated with the living conditions or geographical location of these individuals. Therefore, I thought it would be helpful if the authors provided the related data of these individuals.

Response

In this survey, we collected data from respondents who are farmers living in a rural area of six districts but found obesity cases in five districts (Table 1).

For socioeconomic data, only the district location of participants, and their education, and monthly income were collected. However, these factors were not included in the model because of several reasons. For district location, most of the participants were farmers from rural areas. Moreover, the district was closely related to pesticide use and will cause multicollinearity problems, if included in the model (Bhandari, 2020). For income, there was no relationship with obesity in middle-income countries, e.g. Thailand (Ameye and Swinnen, 2019). For education, previous research found a higher risk of obesity to be inversely associated with education (Anyanwu, 2010). However, in this study more obesity was found among those with higher education (Table 1). In addition, when these two variables were included in the model, not many effects on OR were found. For example, for molluscicide, the OR was changed from 2.28 (1.48-3.64) to 2.37 (1.48-3.79) when added education and to 2.39 (1.49-3.83) when added income (Table 2-1). For baseline diseases, most of them should be considered as the so-called 'downstream outcome' closely related to obesity and thus, should not be included in the model (DVL, 2020).

More demographic information has been added to Table 1.

Comment

3. Methods: Since there is a great difference between genders on obesity diagnosis, I recommended the authors perform stratified analysis to determine the gender-specific associations.

Response

Thank you for bringing up a good point. Though, there is a great difference between genders on obesity diagnosis, the prevalence of obesity between gender was not different ($p=0.173$) (Table 1). In addition, we already added gender as a covariate in the analysis of the adjusted odds ratio as shown in Table 2 and Table 3. Moreover, the number of subjects with obesity diagnosed was too small to do stratification.

Comment

4. Results: The authors checked the relations between pesticide exposure and obesity. Is there any interaction between the different pesticides?

Response

That is a good point. Yes, we also believed that there might be some interaction between

the different pesticides. However, due to limitations on small cases, the problem could not be further investigated. The issue has been added to the discussion section.

Comment

5. Results: The authors should clarify the demographic characteristics in detail.

Response

The results and Table 1 have been revised.

Comment

6. Results: It will be helpful to display the C-index of each model to validate the reliability.

Response

According to Austin and Steyerberg (2012), there are three primary reasons to develop a logistic regression model. The first one is to determine the independent predictors of a binary outcome. The second one is to define the association between a predictive variable and the outcome after adjusting for confounding factors. The third reason is to predict the probability of the occurrence of a binary outcome given a specific vector of covariates. The third reason often occurs in biomedical research, where researchers are interested in predicting the prognosis of individual patients. And the C-statistic is an indicator of assessing the prediction of the logistic regression model. However, the main objective was to find the association between obesity and pesticide exposure.

Comment

7. Discussion: I noticed that the OR for pesticides is from 1.75 to 8.37, while the OR over 3 may be overestimated and lead to unnecessary panic for public health. I thought the authors should discuss their results more carefully.

Response

Yes, we agree with you and the statement '*Some results were with high OR and wide confidence intervals, and thus should be interpreted with caution.*' has been added to the study limitation section.

Comment

8. Discussion: I thought the authors should declare the nature of the cross-sectional study and tell the readers that the study was limited in explaining the causality.

Response

Thank you for your suggestion. The following statements have been added to the study limitation:

'There were several limitations to the study that need to be mentioned. By using a cross-sectional design, the study was limited in explaining the causality since both disease and exposure data were examined at the same time.'

Comment

9. Discussion: The strengthen part only replicates the conclusion.

Response

The statement has been deleted.

Comment

10. One of the most limited parts of this study was the lack of dose or level data of pesticides use, which may cause serious bias. The authors should make a discussion about this.

Response

Pesticide dose is a good marker for short-term pesticide exposure. However, it was costly and may not be suitable for a large survey study. The questionnaire method is probably the best alternative to collect data on long-term pesticide exposure. The method is commonly used in epidemiological studies e.g., Agricultural Health Study in the United State. For studies using a large group of participants, the method has been proved to be useful without any serious bias (Coble et al., 2011) (Hoppin et al., 2002). The limitation on the issue was further discussed as suggested.

Comment

11. The authors should explain the reliability and validity of their questionnaire as there may be information bias that exists with the questionnaire method.

Response

The limitation of questionnaire use was further discussed. As mentioned before, the questionnaire method might be the only option for the study of long-term exposure to pesticides among a large population. Since the technique was used in both case and control groups, information bias if occur might be non-differential.

Comment

12. I recommended the authors list the data on body measure index or waist circumstancs in Table 1.

Response

In this study, data on BMI and WC were not collected as most previous studies did. The study was designed to be a descriptive cross-sectional study to explore the prevalence of medical-diagnosed obesity using ICD-10 records and to identify its associated risk factors. The usefulness and limitation of the ICD-10 data were already discussed in the manuscript.

Comment

13. Waist circumferences and baseline diseases should be adjusted as covariates.

Response

As mentioned before, we did not have waist circumference data since the study used a medical diagnosis of obesity (ICD-10), which is also based on BMI and waist circumferences data.

For baseline diseases, they should be considered as a so-called 'downstream outcome' variable. According to Dan VanLunen (2020), this type of variable should not be used as a covariate.

Comment

14. According to the previous literature, there is a great difference between populations in different age groups. Therefore, I thought age-specific associations between pesticides use and obesity should be considered.

Response

We agree that age-specific association could improve study quality. This study uses a different study design from those in the literature. In this study, we use a descriptive cross-sectional design, whereas, most of the literature uses analytical cross-sectional with a control group. The analytical study might be better in control of confounding variables but not suitable for a large-scale study.

In this study, the age-specific association was also not possible because the number of cases with obesity was small.

Comment

15. As the authors declared, the limited data on dietary patterns, physical activities, and genetic variants may lead to potential bias. However, I thought the authors should be concerned about whether their adjusted models could explain the variance.

Response

Yes, we agree. More information has been added to the study limitation as follows:

'Data on other risk factors, such as diet, exercise, or genetics were not collected. These confounding factors might have a different impact on the results. However, the problem may not have much effect on the study results since the case and control groups were from the same community and had the same occupation.'

Comment

16. Could the authors list the blood pressure, glucose, triglyceride, and HDL value in the tables? Also, I think adjusting them in the model should be considered.

Response

As mentioned before, the study was designed as a simple descriptive cross-sectional survey to try to find a prevalence of obesity using ICD-10 data.

Among the two types of a cross-sectional study, descriptive and analytical, each one has its own strength and limitations. The descriptive studies, which could be conducted in a large-scale study, are often used for prevalence studies. For the analytical study, a study with a control group, often found in a medical study, and has better control for confounding.

Comment

17. The effects of pesticides exposure may have co-exposure patterns, the authors should notice that.

Response

Thank you for raising this good point. Yes, co-exposure was an interesting issue. However, with the study design and the small number of cases, this study could not evaluate the problem. The issue has been added in the discussion as a study limitation.

References

Anyanwu, G. E., Ekezie, J., Danborno, B., & Ugochukwu, A. I. (2010). Impact of education on obesity and blood pressure in developing countries: A study on the Ibos of Nigeria. *North American journal of medical sciences*, 2(7), 320–324.

<https://doi.org/10.4297/najms.2010.2320>

Austin, P.C., and Steyerberg, E.W. (2012). Interpreting the concordance statistic of a logistic regression model: relation to the variance and odds ratio of a continuous explanatory variable. *BMC Med Res Methodol* 12 (82). <https://doi.org/10.1186/1471-2288-12-82>

Bhandari A. (2020). What is multicollinearity? Here's everything you need to know. Analytics Vidhya. Available: [Multicollinearity | Detecting Multicollinearity with VIF \(analyticsvidhya.com\)](https://www.analyticsvidhya.com/blog/2020/07/multicollinearity-detecting-multicollinearity-with-vif/)

Coble et al., (2011). An updated algorithm for estimation of pesticide exposure intensity in the agricultural health study, *Int. J. Environ. Res. Public Health*; 8(12), 4608–4622. doi: 10.3390/ijerph8124608.

Dan VanLunen (DVL). (2020). Get a Grip! When to Add Covariates in a Linear Regression. A Guide to Accurately and Precisely Measuring Effects! Available: <https://towardsdatascience.com/get-a-grip-when-to-add-covariates-in-a-linear-regression-f6a5a47930e5>

Hannah Ameye and Johan Swinnen, (2019). Obesity, income and gender: The changing global relationship, *Global Food Security*, 23, 267–281. <https://doi.org/10.1016/j.gfs.2019.09.003>.

Hoppin, F. Yucel, M. Dosemeci, and D. P. Sandler, (2002). Accuracy of self-reported pesticide use duration information from licensed pesticide applicators in the Agricultural Health Study, *J. Expo. Anal. Environ. Epidemiol.*; 12(5), 313–318. doi: 10.1038/sj.jea.7500232.

Competing Interests: No competing interests were disclosed.

Author Response 24 Nov 2021

Chudchawal Juntarawijit, Naresuan University, Phitsanulok, Thailand

Table 2-2 OR after adding more variables to the model.

Pesticide: Molluscicide

OR (as shown in Table2) 3.36 (2.13-5.31)

OR (after add baseline diseases) 3.30 (2.08-5.22)

OR (add district location) 2.28 (1.43-3.64)

OR (add education) 2.37 (1.48-3.79)

OR (add income) 2.39 (1.49-3.83)

Competing Interests: No competing interests were disclosed.

The benefits of publishing with F1000Research:

- Your article is published within days, with no editorial bias
- You can publish traditional articles, null/negative results, case reports, data notes and more
- The peer review process is transparent and collaborative
- Your article is indexed in PubMed after passing peer review
- Dedicated customer support at every stage

For pre-submission enquiries, contact research@f1000.com

F1000Research