STUDY OF PEAK EXPIRATORY FLOW RATE AMONG VEGETABLE FARMERS USING PESTICIDES IN BOYOLALI DISTRICT, CENTRAL JAVA, INDONESIA

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ABSTRACT

Pesticides exposure affects respiratory system. The study of peak expiratory flow rate (PEFR) as a parameter of lung function changes due to limited pesticide among farmers. This cross-sectional study aims to analyze factors affecting PEFR and formulate a model for predicting PEFR among 76 vegetable farmers using pesticides in Tlogolele Village, Boyolali Regency. Data were collected through questionnaire-based interview and clinical examination. PEFR test was conducted using a peak flow meter while cholinesterase level was investigated using Deutsche Gessellschaftfur Klinische Chemie method. The data were analyzed using unpaired T-test and Pearson test continued by multivariate regression models. The examination showed 75% of subjects had abnormal PEFR. Cholinesterase, body mass index, smoking habits, personal protective equipment usage, pesticide dosage, length of work per day, and last time of spraying did not show a significant correlation with PEFR. On the other hand, age, height, weight, frequency of spraying, and spraying duration showed a significant correlation with PEFR and a prediction equation for PEFR model was obtained as $R^2=0.268$ (p<0.001). The developed model will be useful for early detection of abnormal lung function.

Keywords: occupational health; peak expiratory flow rate; pesticide exposure.

INTRODUCTION

Pesticide exposure is still a health problem throughout the world especially in developing countries. In the past 10 years, there had not been any complete statistical data on morbidity and mortality due to pesticide poisoning globally (Calvert *et al*., 2010; WHO, 2008). The World Health Organization (WHO) estimates that there are around 5 million cases of accidental pesticide poisoning and 20,000 deaths per year due to pesticide poisoning. The incidence of acute pesticide poisoning in the workplace is 1.17 per 100,000 workers and insecticides are the most common cause (49%) of all pesticides. The incidence of pesticide poisoning is higher in agricultural sector compared to non-agricultural sector (Calvert *et al*., 2004; UN, 2017). The level of pesticide poisoning is influenced by various factors including internal and external factors. Internal factors include age, sex, and nutritional status. External factors are pesticide dosage, frequency of spraying, length of work per day, length of service, time of the last spraying, habitual use of personal protective equipment

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(PPE), spraying time, and environmental temperature (Djojosumarto P, 2008; Eddleston, 2015; Wudianto, 2007).

Exposure to pesticides in workplace occurs in all agricultural processes such as mixing, spraying, planting, harvesting, weighing, product packaging, and washing agricultural equipment. Spraying is the most important process in pest control (Sapbamrer & Nata, 2014). During the process of pesticide spraying, steam and aerosol droplets from the pesticide solution can enter the body through inhalation. Inhalation of pesticides can cause damage to the nose, throat, and lung tissue because of which lung function changes and the risk of respiratory symptoms and diseases increases (Sapbamrer *et al.*, 2019).

Several previous studies have reported an association between exposure to pesticides at work and respiratory disorders such as chronic obstructive pulmonary disease, asthma and chronic bronchitis (Alif *et al.*, 2017; Hoppin *et al.*, 2009; Lytras *et al.*, 2018). Occupational exposure can also induce or exacerbate asthma. Variability of asthma control is worse during periods at work than away from work (Quirce *et al.*, 2013; Suhadi *et al.*, 2018). Several other studies report that the prevalence of respiratory symptoms is associated with pesticides (Buralli *et al.*, 2018; Mathew *et al.*, 2015). Evidence of decreased lung function tests associated with pesticide exposure among agricultural workers has also been reported in several studies (Chakraborty *et al.*, 2009; Sapbamrer *et al.*, 2019). These studies support evidence that exposure to pesticides has an adverse effect on the respiratory system.

Lung function can be assessed through several methods one of which is by peak expiratory flow rate (PEFR). PEFR measures the maximum expiratory speed that can be achieved by someone and is expressed in liters per minute (L/min) or liters per second (L/sec). PEFR mainly reflects the flow in large airways and depends on the conscious effort and muscle strength of the individual. PEFR values are obtained by spirometry test or using a simpler tool namely peak expiratory flow (PEF) meter. PEFR examination with PEF meter is easier, simpler, cheaper, and quantitative (Ismaila *et al.*, 2015; Mridha *et al.*, 2011; Thorat *et al.*, 2017). Differences in PEFR values among populations can be caused by geographical factors, types of environmental and occupational exposure, socioeconomic status, and ethnic differences that affect variations between individuals. Therefore, PEFR prediction model will be more appropriate if each region has its own values (Nayak *et al.*, 2016; Prasad *et al.*, 2006). Research on the correlation between pesticide exposure and PEFR is still very limited. To the best of our knowledge, there is only one study about the correlation between blood cholinesterase activity and PEFR in Indonesia in which the subject of that study was potato farmers with chronic exposure to organophosphate pesticides. The results indicate a significant positive correlation of a low degree of blood acetylcholinesterase activity with PEFR (Luthfanto *et al.*, 2014).

Boyolali Regency is one of regions in Central Java of which the economy relies on agricultural sector. For the last five years, 50 percent of Boyolali's population has worked in agricultural sector. Its best agricultural products include tobacco and vegetables. Selo District is a vegetable producing center in Boyolali (BPS Boyolali, 2018a). Tlogolele is one of villages in Selo District with main commodities of chilies, tomatoes and mustard greens.

Some areas of Tlogolele have agricultural activities throughout the year due to the availability of water in the area (BPS Boyolali, 2018). Based on research on pesticide poisoning in Selo District, data obtained from pesticide poisoning reached 73.9%. Factors related to pesticide poisoning are years of pesticide application, personal protective equipment (PPE), and frequency of spraying (Harriyani, 2016). Based on the explanation above, this study aims to determine PEFR, analyze the factors that affect PEFR and formulate a model of PEFR predictors towards vegetable farmers using pesticides in Tlogolele Village, Boyolali Regency.

METHODS

This study is an observational research applying cross-sectional design with the study permit No. 070/412/VI/39/2019 issued by *Kantor Kesatuan Bangsa dan Politik Kabupaten Boyolali* (The Office of Political and National Unity of Boyolali Regency). The study protocol was approved by the Ethics Commission of Medical Faculty, Sebelas Maret University with the Ethical Clearance No. 261/UN27.06/KEPK/EC/2019. This study was part of the study and development of implemented model for health service of work related illness in national health coverage era for holistic and integrated occupational health efforts.

Selection of Subjects

Samples were taken from farmers who used chemical pesticides in Tlogolele Village, Selo District, Boyolali Regency who met the inclusion and exclusion criteria. Inclusion criteria included staying for minimum one year in Selo District of Boyolali Regency, men aged between 20-65 years, carrying out pesticide spraying activities for at least one year, and willing to be the subject of research by signing informed consent. Exclusion criteria included a history and symptoms of lung and liver dysfunction, signs of malignancy, a history of alcoholic drinking habits, and the use of cholinesterase inhibitors. The sampling technique applied consecutive sampling.

Procedures

The independent variable of the study is blood cholinesterase activity investigated in Laboratory of Health and Medical Devices Testing (*Balai Laboratorium Kesehatan dan Pengujian Alat Kesehatani*) using *Deutsche Gessellschaftfur Klinische Chemie* (DGKC) method whereas the dependent variable is peak expiratory flow rate measured by *Philips Respironics PesonalBest®* peak flow meter. Additional variables were generated by questionnaire-based interview and clinical examination for demographic characteristics, history of pesticides application, and anthropometric variables. Data collection was completed at village hall of Tlogolele. The data collectors consisted of the interviewer and the note documenter who guided the respondents in answering the questionnaires. All data collectors were trained for their reliability in understanding the questions and the respondents' answers before the interview.

Data Analysis

Categorical data including smoking habits, personal protective equipment usage, and pesticide dosage were analyzed using unpaired T-test. Meanwhile, the ratio data of cholinesterase, age, height, weight, body mass index, frequency of spraying, the length of work per day, spraying duration, and last time of spraying were analyzed for their distributions followed by Pearson or Spearman test depending on the normal distribution of the data. Multivariate regression models were performed on the data. All the statistical analyses were performed using IBM SPSS software version 22 (IBM Corp., Chicago, USA). p-values <0.05 were considered significant.

RESULTS AND DISCUSSION

The research subjects consisted of 76 farmers who used chemical pesticides. Demographic and physical characteristics, history of pesticide application, PEFR, and blood cholinesterase are shown in Table 1. The mean age of the study sample was 41.86 ± 10.18. Most of these farmers were graduated from elementary school for as many as 59 (77.6%). The highest income was less than Indonesian rupiah (IDR) 1,000,000 which were occupied by 50 subjects (65.8%). Normal nutritional status was 50 (65.8%) with the mean of body mass index (BMI) of 22.09±2.38 kg/m². Smoking habits were performed by 60 subjects (78.9%). The mean height of the study sample was 159.03±7.02 m while the mean body weight was 56.06±8.42 kg.

Data on pesticide application in this study included the use of personal protective equipment (PPE), pesticide dosage, frequency of spraying, length of work, duration of spraying, and last time of spraying (Table 1).

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The results showed that there were only 14 subjects (18.4%) used complete PPE. As many as 43 subjects (56.6%) had used the dosage of pesticides according to the rules namely 1.5-2 cc/liters of solvent. The highest frequency of spraying was 2 times/week performed by 37 subjects (48.7%). The longest working duration was 2 hours/day performed by 25 subjects (32.9%). The longest spraying duration was 11-20 years by 34 subjects (44.7%). The closest last time of spraying was 1-7 days for as many as 44 subjects (57.9%).

The results of the examination in this study are 71 subjects (93.4%) with normal cholinesterase levels and 5 subjects (6.6%) with abnormal cholinesterase levels. The results of this study are in line with a study showing normal cholinesterase which is higher than abnormal cholinesterase (Sandra *et al*., 2019). An examination of cholinesterase activity is an assessment of organophosphate poisoning in workers. Decreasing blood cholinesterase activity is reduced due to the inhibition of cholinesterase enzyme activity by organophosphates. However, cholinesterase activity may not always be able to describe the level of chronic organophosphate poisoning especially at low dose exposure because there is a recovery period of cholinesterase activity after exposure. This recovery period ranges from 35-100 days after exposure (Eddleston, 2015; Ye *et al*., 2013).

Based on PEFR normal values guidelines by Indonesian Pneumobile Project Team in 1992 (Alsagaff *et al*., 1992), the PEFR examination in this study showed an abnormal result in 57 subjects (75%). The mean PEFR value of the sample was 407.96 ± 96.04. These results are in line with studies that show higher abnormal lung function than normal lung function in farmers with exposure to pesticides (Luthfanto *et al*., 2014; Sandra *et al*., 2019). This study is also consistent with other studies which figure out a significant decrease in PEFR among farmers compared to the control (Priyadharshini *et al*., 2017). Decreased PEFR values can be a sensitive indicator in predicting the amount of airway obstruction. Pesticide aerosol drops that are sprayed in the air can get in through inhalation which causes irritation and narrowing of the airway (Sapbamrer *et al*., 2019). The results of these studies provide evidence on the adverse effects of exposure to pesticides on the respiratory system.

Bivariate test results (Table 2) in this study showed a significant relationship between age (r=-0,458; p=0,000), height (r=0.434; p=0,000), weight (r=-0,322; p=0.005), spraying frequency (r=-0.279; p=0.015), and spraying duration (r=-0.336; p=0.002) with PEFR. Whereas variables of blood cholinesterase, BMI, smoking habits, PPE usage, pesticide dosage, length of work, and last time of spraying did not show a significant relationship with PEFR. Negative correlation on age variable with PEFR is in line with studies conducted both in the general population and certain occupational exposures (Bhardwaj *et al*., 2014; Price *et al*., 2013). PEFR values decrease with increasing age due to degenerative changes in musculoskeletal system of the thoraco-abdominal compartment which cause a decrease in the strength of respiratory muscles. In addition, the airways also experience increasing resistance due to functional changes with age (Bhardwaj *et al*., 2014; Mukherjee *et al*., 2018).

Height shows a positive correlation with PEFR. This is in line with research conducted on both male and female populations (Garg *et al*., 2015). Taller people have greater chest volume. Also, airway growth and respiratory muscle effort increase with greater body height (Mukherjee *et al*., 2018). Analysis on weight variable with PEFR is in line with studies that show a positive correlation between body weight and PEFR (Bedi & Dang, 2016; Kaur *et al*., 2013). This finding is due to respiratory tract and greater muscular expiratory effort as we gain weight (Mukherjee *et al*., 2018).

The spraying duration in this study shows a negative correlation with PEFR. These results are in line with a research by Fareed *et al*. (2013) which shows a negative correlation between duration of exposure and PEFR (r=-0.41; p<0.01). The duration of exposure in this study is also associated with respiratory symptoms. Research conducted by

Chakraborty *et al.* (2009) also shows results that are consistent with the results of this study. In this study, spraying frequency shows a negative correlation with PEFR. To the best of our knowledge, no previous studies have analyzed the correlation between the frequency of spraying and PEFR.

Table 1. Demographic and Physical Characteristics, History of Pesticide Application, PEFR, and Blood Cholinesterase among Male Sprayers (n = 76)

Variable	n (%)	Mean±SD or Median (Min-Max)
Age		41.86±10.18
Education		
No school	2 (2.6)	
Graduated from elementary school	59 (77.6)	
Graduated from middle school	8 (10.5)	
Graduated from high school	7 (9.2)	
Income		
<IDR 1,000,000	50 (65.8)	
IDR 1,000,000-2,500,000	24 (31.6)	
IDR 2,500,000-5,000,000	2 (2.6)	
Smoking habit		
Yes	60 (78.9)	
No	16 (21.1)	
Nutritional Status / Body Mass Index		
Less	4 (5.3)	
Normal	50 (65.8)	22.09±2.38
More	22 (28.9)	
Height (cm)		159.03±7.02
Weight (kg)		56.06±8.42
Use of PPE		
Complete	14 (18.4)	
Incomplete	62 (81.6)	
Pesticide Dosage		
By the rules	43 (56.6)	
Not according to rules	33 (43.4)	
Spraying Frequency (times/week)		2 (1-4)
Length of Work (hours/day)		2 (1-6)
Spraying Duration (year)		20 (1-40)
Last Time of Spraying (day)		7 (1-196)
Peak Expiratory Flow Rate (L/min)		
Normal	19 (25)	407.96±96.04
Abnormal	57 (75)	
Blood Cholinesterase (U/L)		
Normal	71 (93.4)	5754.00 (2534-9761)
Abnormal	5 (6.6)	

Note: Mean±SD = mean±standard deviation; Median (Min-Max) = median (minimum-maximum); IDR = Indonesian rupiah; PPE = personal protective equipment

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Previous studies analyzed the correlation between frequency of spraying and other lung function parameters such as forced expiratory volume in one second/forced vital capacity (FEV_1/FVC), and forced expiratory flow at 25-75% of the pulmonary volume ($FEF_{25-75\%}$). The results of this study indicate a negative correlation between the frequency of spraying and FEV_1/FVC (r=-0.85; p<0.001) and $FEF_{25-75\%}$ (r=-0.62; p<0.001) (Buralli *et al*., 2018). Research using the cumulative exposure index in describing variable of spraying frequency and duration of exposure also shows the results that the cumulative exposure index is a predictor of $FEF_{25-75\%}$ with a value of R^2 50% (r=-0.254; p=0.039) (Hernández *et al*., 2008). The level of pesticide poisoning depends on pesticide toxicity, pesticide formulation, pesticide particle size, PPE usage, duration, frequency, and intensity of exposure. Inhalation of pesticides can cause damage to the nose, throat, and lung tissue which can cause malfunction and increase the risk of respiratory symptoms and diseases (Damalas and Koutroubas, 2016; Mamane *et al*., 2015).

After conducting a bivariate analysis, all variables (use of PPE, pesticide dosage, spraying duration, height, cholinesterase, age, body weight, and spraying frequency) met the criteria for entry into the multivariate analysis (Table 3). With multivariate analysis of linear regression backward method, the PEFR equation is obtained as = 465.537 + (-3.627xage) + (2.389xweight) + (-24.31x frequency of spraying) with an R^2 = 26.8%. Equations consisting of age, body weight, and spraying frequency contributed 26.8% to the dependent variable (PEFR) while the remaining 73.2% was influenced by other variables. In Indonesia, a model to predict PEFR values was carried out by the Indonesian Pneumobile Project Team in 1992. However, the PEFR values in this study were obtained from the general population. The PEFR equation in this study consists of age and height factors (Alsagaff *et al*., 1992).

Table 2. Correlation between blood cholinesterase, demographic and physical characteristics with history of pesticide application and PEFR

Variable	Peak Expiratory Flows (L/min)			
	Mean±SD	Mean difference (95%CI)	p value	r
Cholinesterase (U/L)	-	-	0.145	0.169
Age (years)	-	-	0.000*	-0.458
Height (cm)	-	-	0.000*	0.434
Weight (kg)	-	-	0.005*	0.322
BMI (kg/m²)	-	-	0.391	0.1
Smoking habit				
Yes	405.67±94.85	-10.90 (-65.04-43.25)	0.69	-
No	416.56±103.13			
Use of PPE				
Complete	441.79±78.58	41.46 (-14.73-97.66)	0.146	-
Incomplete	400.32±98.50			
Pesticide dosage				
By the rules	423.95±94.07	36.83 (-6.93-80.59)	0.098	-
Not according to rules	387.12±95.99			
Spraying frequency (times/week)	-	-	0.015*	-0.279
Length of work (hours/day)	-	-	0.831	0.025
Spraying duration	-	-	0.002*	-0.356
Last time of spraying (days)	-	-	0.400	-0.098

Note: Mean±SD = mean±standard deviation; 95%CI = 95% confidence interval; BMI = body mass index; PPE = personal protective equipment; *p<0.05

Table 3. Model for predicting PEFR of male sprayers (n = 76)

Variable	Unstandardized Coefficients		Standardized Coefficients	p value
	B	Standard Error	Beta	
Constant	465.537	87.323		0.000
Age	-3.627	0.960	-0.385	0.000
Weight	2.389	1.170	0.209	0.045
Spraying frequency	-24.310	13.895	-0.179	0.084

Note: R^2 = 26.8%

Research on cement factory workers in Nigeria shows the results of the PEFR prediction model with the PEFR equation/year of exposure = −69.985 + 3.425xage + 2.922xheight − 2.473xweight + 10.9xyear of exposure (R^2 84.3% ; p<0.001) (Ismaila *et al*., 2015). To the best of our knowledge, there is no PEFR prediction model for farmers with pesticide exposure. The PEFR prediction model is useful in initial screening for respiratory system disorders in farmers using pesticides.

PEFR is an indicator of airway obstruction that is sensitive and accurate. PEFR examination with PEF meters is easier, simpler, cheaper, and quantitative as well as noninvasive (Mridha *et al*., 2011; Thorat *et al*., 2017). PEFR prediction models for farmers using pesticides are useful in initial screening for respiratory system disorders. The results of this study strengthen the evidence of the correlation between pesticide exposure and respiratory system disorders. However, this study has several limitations. First, this research was only conducted in one region/village with a limited sample size. Second, this study was only conducted towards male farmers so that it limits the generalization of research results to the other gender. Third, other laboratory support parameters that might influence the level of cholinesterase were not examined in this study (e.g. hemoglobin, liver function tests, and malignancy markers.

CONCLUSION

The equation model to determine PEFR based on age, weight, and frequency of spraying was obtained with enough coefficients determination. This developed model will be useful in determining the PEFR of vegetable farmers as an effort to access possible medical

attention. Multicentre studies with multigender and larger sample sizes are recommended to obtain PEFR predictor models.

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