

PREDICTORS OF LUNG IMPAIRMENT AMONG RURAL DWELLERS IN SOUTHERN THAILAND

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Abstract

Objective: This study aimed to identify the predictors of lung impairment among people in rural communities of southern Thailand. **Method:** A cross-sectional descriptive research design was employed and 434 persons who had been living for at least 15 years in four communities in two provinces in the southern part of Thailand were recruited. A questionnaire was completed by the participants; a physical examination and pulmonary function test with a flow-sensing spirometer was then administered. Chi square and one-way ANOVA were used in univariate analysis, while multivariate multinomial logistic regression was used to examine the predictors of lung impairment. **Results:** Tobacco leaf curing predicted obstructive, restrictive and combined obstructive and restrictive lung impairment (OR = 14.333, 95% CI = 5.118-40.142; OR 9.354, 95% CI 4.308-20.314; OR 1.19E10, 95% CI 3.77E10-3.74E10); restrictive lung disease was predicted by age, BMI >30, and BMI = 25.0-29.99 (OR 1.024, 95% CI 1.003-1.046; OR 3.713, 95% CI 1.655-8.331; OR 2.997, 95% CI 1.536-5.847); and combined obstructive and restrictive lung impairment was predicted by brick kilns (OR 6.72E8, 95% CI 1.20E8-3.51E9). **Conclusions:** Standard guidelines for running tobacco leaf curing, brick kilns and regulating local manufacturing need to be addressed to protect people from chronic lung diseases. Moreover, regulation should be imposed on the control of polluting plants located far away from the residents of the community. Polluting plants (small cottage factories) should be located far away from the residential areas of communities and regulations or laws need to be approved to ensure air pollution control.

Keywords: Lung impairment, rural area, air pollution

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Introduction

Air pollution is a common cause of lung function impairment in people who live in small cottage factory areas in Thailand. In the absence of central regulation, limited standard factory operations have led to no common rules for regulating local factory operations (Factory Act, 1992). Consequently, both dust and smoke air pollution has become a burden for the communities where these factories are located. Associated with pollution, lung impairment is gradually becoming a chronic health problem and is the most important risk factor associated with lung function abnormalities. Most research in Thailand has involved high risks for lung function impairment in factory workers (Thepaksorn *et al.*, 2013; Thepaksorn, 2017) because of under-controlled pollution by federal laws and regulation. In Thailand, small cottage factories have rapidly grown in number and are freely established in many villages in rural areas (Thepaksorn *et al.*, 2017). Although these cottage factories directly emit both dust and smoke air pollution into the atmosphere, there are few routine investigations aimed at controlling pollution. As a result, villagers are at high risk for lung function impairment which is caused by restrictive, obstructive or mixed types of lung impairment (Mofatt *et al.*, 1995).

This impairment leads to increases in both morbidity and mortality rates due to respiratory disease (Zhang *et al.*, 2011). However, limited research has been conducted to examine the lung function of people living in air-polluted areas, even though people who live in these areas account for a higher percentage of chronic respiratory diseases such as chronic obstructive pulmonary disease (COPD), asthma, and chronic bronchitis with limited prevention strategies for morbidity of the respiratory system.

Lung function impairment is a consequence of dust and smoke in air pollution. Dust is emitted from small cottage factories and a consequence occurring as a result of separating and sorting tobacco leaves by hand (total dust concentration = 14.4 mg/m^3 ; inhalable dust

concentration = 2.4 mg/m^3) (Zuskin *et al.*, 2004). It has been revealed that exposure to dust leads to abnormal lung function (Zhang *et al.*, 2005). Stone blasting emits a variety of particle sizes of granite, silica, sandstone and marble. Exposed persons are at high risk for respiratory problems and free silica dust from stone crushing causes restrictive lung function impairment (Chattopadhyay *et al.*, 2006), while working in the stone quarry industry more than 15 years can cause workers to have silicosis (Singh *et al.*, 2007). There is a two-fold increased mortality risk from silicosis, lung cancer and non-malignant respiratory disease among exposed persons as compared to the general population (Ulm *et al.*, 2004). Stone crushing workers who have been exposed to stone dust have a higher prevalence of restrictive lung function (Chattopadhyay *et al.*, 2006). Quartz stone workers with combined restrictive and obstructive lung function impairments have a mean duration of exposure at 1.36 ± 2.68 years of work experience (Singh *et al.*, 2007). Smoke from combustion process consists of carbon monoxide, sulfur dioxide nitrogen dioxide also emitted from the small cottage factories. Carbon monoxide, nitrogen oxide and sulfur dioxide have impact on the lung's endothelial cells, which further leads to deterioration of lung cells and causes lung function impairment (Skinder *et al.*, 2014). Nitrogen dioxide causes lower FEV1 in adults (Forbes *et al.*, 2009). Sulfur dioxide is associated with bronchial hyper-responsiveness to methacholine, airflow limitation and deteriorating lung function (Abramson *et al.*, 2010). Exposed persons have more chronic respiratory problems such as chronic cough, phlegm and chest tightness than non-exposed persons and FEV1 is lower than the same rate among unexposed persons (Eugenija *et al.*, 1998).

Lung function impairment is caused by not only environmental factors, but also by obesity. A number of studies have revealed body mass index (BMI) to be associated with lung function abnormalities (Liu *et al.*, 2016). There is evidence to support the idea that BMI

indicating obesity is associated with lower lung function in men and women (Hsieh *et al.*, 2016). Respiratory dysfunction in obese individuals may cause by alterations of the ratios between the lungs, chest wall and diaphragm, thereby causing respiratory mechanical damage and abnormalities in gas exchange (Magnani and Cataneo, 2007). Age is also a predicting factor for lung impairment, and the risk of impaired lung function increases slightly with age (Quanjer *et al.*, 2012).

The purpose of this study was to identify the predictors of lung impairment among people living in southern community in Thailand. The selection of lung impairment-inducing factors was guided by global and international literature. The risk factors include environmental factors and personal factors as presented in Figure 1.

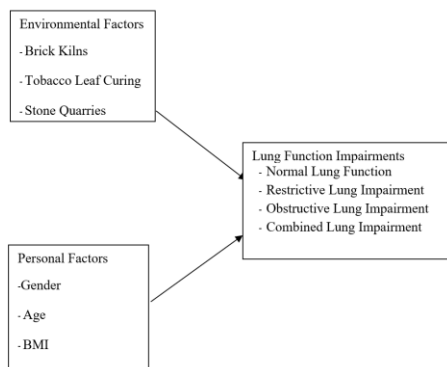


Figure 1. Predictors of Lung Impairment

Materials and Methods

A cross-sectional descriptive research design was employed and 434 community dwellers were recruited. The inclusion criteria required that participants be aged more than 18 years with residence in the community for more than 15 years.

Study Areas

Two provinces, “A and B”, were selected from 14 provinces in the south of Thailand by simple random sampling. Each province has

four districts with communities exposed to air pollution from brick kilns, tobacco leaf curing and stone quarries or factories. Each province selected by purposive sampling has a district with communities exposed to all three types of air pollution and one community unexposed to air pollution (Figure 2).

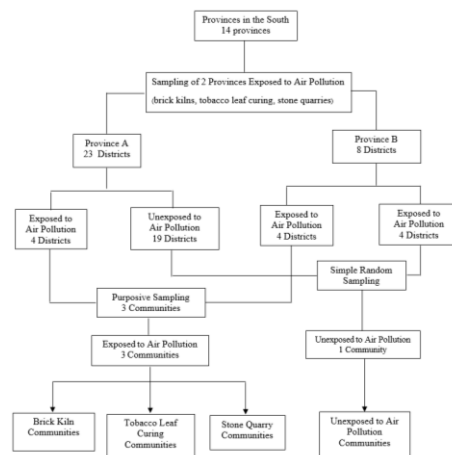


Figure 2. Study Areas

Participants

A total of four communities were recruited, including a brick kiln community, a tobacco leaf curing community from Province A; stone quarries community and none exposed air pollution community from Province B. The participants had been living in the areas for more than 15-20 years before the survey. Four hundred and thirty-four samples (25%) of 1736 people were selected from four communities by simple random sampling. The lists of samples' names in each community were obtained from community leaders and community health volunteers. Four communities participated in the study. The brick kiln community is near thirty small brick manufacturing kilns. Air pollution emission detection devices were not used in any kilns in the community. Pollution emissions were released directly from the rooftops of the kilns and into the surrounding rural areas. Wood burning was a main source of domestic energy. During brick firing, various air pollutants are

emitted into the surrounding environment such as coal particles, dust and flue gases with particulate matter. This community has a population of approximately 428 people and 107 people (25%) were recruited as participants. In the tobacco leaf curing community, the villagers were employed in small cottage factories for tobacco leaf curing. Thirty kiln factories are located in the village and the tobacco leaves are cured once per week. Wood burning is used to cure the tobacco leaves which sulfur chemicals added to the wood to color the tobacco leave. There were 420 people in the community and 105 (25%) were recruited as participants. Five stone quarries and 440 people are in the community with a variety of occupations such as automobile repair workers, palm oil and rubber farm workers who used herbicides. The villagers were at high risk for exposure to dust from industrial stone quarries and 110 were recruited as participants. The unexposed community was sampled from low risk exposure to air pollution communities. Community dwellers were employed by palm oil and rubber tree farms using herbicides; 448 lived in the community and 112 of the residents were recruited as participants.

Instruments

The instruments for collecting data were as follows; The questionnaire which was composed of the following two parts: demographic data on: gender, age, family history of asthma and allergies, and smoking history and health status data on height, weight and lung capacity; and the instruments for physical examinations included: a spirometer; a wall-mounted stadiometer; and a standard balance beam scale.

A spirometer used to measure lung capacity by a research assistant (nurse practitioner) who measured the lung function by using spirometry was trained by a specialist respiratory physician and met the acceptability and reproducibility criteria of American Thoracic Society/European Respiratory Society (AST/ERS (Coates, 2013) and ensuring adequate inter-rater reliability ($r = 1.00$). The instrument was calibrated every four hours throughout

the study by using a standard syringe. The following three types of lung function impairment were examined: restrictive, obstructive and combined lung function impairment. The lung function parameters to indicate the type of impairment were forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and FEV1/FVC ratio (Thoracic Society of Thailand under Royal Patronage. Guideline for pulmonary function test 2010, 2018), which were interpreted as follows: 1) restrictive lung impairment was indicated when FVC was less than or equal to 80 percent, low FEV1, and FEV1/FVC normal or increased; 2) obstructive lung impairment was indicated when FVC was less than 70 percent and FEV1/FVC was less than 70 percent; and 3) combined restrictive and obstructive was indicated when FVC was normal and FEV1/FVC increased.

A wall-mounted stadiometer was used to measure height. A standard balance beam scale was used to measure body weight; the scale was calibrated to the nearest 0.1 kg.

Body mass index was calculated as the weight in kilograms divided by the square of the height in meters (kg/m^2) and classified into four groups by using the World Health Organization criteria as follows: underweight ($<18.5 \text{ kg}/\text{m}^2$), normal (18.5 to $<25 \text{ kg}/\text{m}^2$), overweight (25 to $<30 \text{ kg}/\text{m}^2$), and obese ($\leq 30 \text{ kg}/\text{m}^2$) (WHO, 2014).

Procedures

Once approved by the Research Ethics Committee on Research in Human Subjects, Mahidol University, the recruited participants completed informed consent forms, a questionnaire and a physical examination. The primary researcher informed about the purpose of the study, asked the potential participants about their willingness to participate, what being in the study would involve, anonymity and confidentiality issues, and the right to withdraw from the study, at any time. Next, the participants completed informed consent forms. The participants' names and data files were kept in a cabinet accessible only by the

Table 1. Univariate chi-square and one-way ANOVA testing of lung impairment among the air pollution exposure group (N=434)

Variables			Normal Lung	Lung Impairment			Total	Univariate Test		
				Obstructive	Restrictive	Combined				
			Continuous variables					F-test	df	p
Age	Mean		45.88	46.22	51.34	47.72	47.04	3.163	3, 430	< .05
	SD		14.675	12.231	14.598	13.332	14.463			
			Category Variables					Chi square	df	p
Gender	Female	n	178	33	69	13	293	12.444	3	< .01
		%	41.0%	7.6%	15.9%	3.0%	67.5%			
	Male	n	106	16	14	5	141			
		%	24.4%	3.7%	3.2%	1.2%	32.5%			
Exposure	Tobacco Leaf Curing	n	27	23	45	10	105	108.868	9	< .01
		%	9.5%	46.9%	54.2%	55.6%	24.2%			
	Brick kiln	n	91	6	8	2	107			
		%	32.0%	12.2%	9.6%	11.1%	24.7%			
	Stone Quarries	n	76	14	14	6	110			
		%	26.8%	28.6%	16.9%	33.3%	25.3%			
	Non-Exposure	n	90	6	16	0	112			
		%	31.7%	12.2%	19.3%	0.0%	25.8%			
BMI	<18.50	n	15	1	2	1	19	23.956	9	< .01
		%	5.3%	2.0%	2.4%	5.6%	4.4%			
	18.50-24.99	n	170	26	29	12	237			
		%	59.9%	53.1%	34.9%	66.7%	54.6%			
	25.00-29.99	n	66	14	35	2	117			
		%	23.2%	28.6%	42.2%	11.1%	27.0%			
	>=30.00	n	33	8	17	3	61			
		%	11.6%	16.3%	20.5%	16.7%	14.1%			
N Total		n	284	49	83	18	434			
		%	65.4%	11.3%	19.1%	4.1%	100.0%			

primary researcher. During the data collection, none of the participants experienced abnormal symptoms and no one resigned from the study.

Descriptive statistics were used to characterize the sample, including demographic information and information related to health and physical examinations. Chi-square analysis and one-way ANOVA were used to test univariate analysis and multivariate multinomial logistic regression analysis was used to test the factors correlated with the three types of lung impairment, namely, obstructive, restrictive and combine lung impairment compared to normal lung function variables. Statistical significance was set at $p < 0.05$.

Results and Discussion

The participants ranged from 18 to 84 years old with a mean age of 47.07 years (SD = 14.46). Table 1 shows the results of the univariate analysis used chi-square analysis for the following three category variables: gender (chi-square = 12.44, df = 3, $p < 0.01$); types of exposure (chi-square = 108.87, df = 9, $p < 0.01$); and BMI (chi-square = 23.96, df = 9, $p < 0.01$). One-way ANOVA testing was used for the continuous variable, age ($F = 3.16$, df = 3, 430,

$p < 0.01$). The results revealed that all variables were correlated with the type of lung impairment at $p < 0.01$. Therefore, all significant variables were added to the multivariate analysis.

Table 2 shows the results on the predictors of lung impairment by using multinomial multivariate logistic regression analysis. The Nagelkerke R^2 was 0.335 or 33.5 percent of the variance in lung impairment, which was predicted by variables (chi square = 146.817, df = 24, $p < 0.01$). The odds ratio (EXP(B)) value and Wald criterion significantly demonstrated that the incidence of obstructive lung impairment increased when exposed to tobacco leaf curing (OR = 14.333, 95% CI = 5.118-40.142, $p < 0.01$). Similarly, the incidence of restrictive lung impairment increased with exposure to tobacco leaf curing (OR = 9.354, 95% CI = 4.308-20.314, $p < 0.01$), higher BMI of both more than 30 and between 25-29.99 (OR = 3.713 and 2.997, 95% CI = 1.655-8.331 and 1.536-5.847, respectively, $p < 0.01$) compared to normal BMI and when raised with higher age (OR = 1.024, 95% CI = 1.003-1.046, $p < 0.05$). Moreover, the incidence of combined lung impairment was raised when exposed to tobacco leaf curing and brick kilns (OR = 1.19×1010 and 6.72×108, 95% CI =

Table 2. Multinomial multivariate logistic analysis of lung impairment among the air pollution exposure group (N=434)

Lung Impairment	Variables	B	Std. Error	Wald	df	Sig.	Exp(B)	95% CI for Exp(B)	
								Lower	Upper
Obstructive	Intercept	-2.856	0.692	17.018	1	<.01			
	Age	-0.001	0.012	0.003	1	ns	0.999	0.976	1.023
	Exposure								
	<i>Tobacco Leaf Curing</i>	<u>2.663</u>	<u>0.525</u>	<u>25.678</u>	<u>1</u>	<u><.01</u>	<u>14.333</u>	<u>5.118</u>	<u>40.142</u>
	Brick Kilns	0.065	0.612	0.011	1	ns	1.067	0.322	3.542
	Stone Quarries	1.012	0.521	3.768	1	ns	2.751	0.990	7.640
	Non-Exposure (Ref)	0			0				
	BMI								
	>30	0.712	0.487	2.143	1	ns	2.039	0.786	5.292
	25.00-29.99	0.534	0.395	1.830	1	ns	1.706	0.787	3.697
	<18.50-24.99	-0.627	1.104	0.322	1	ns	0.534	0.061	4.650
	18.50-24.99 (Ref)	0			0				
	Gender								
	Female	-0.137	0.367	0.139	1	ns	0.872	0.425	1.791
	Male (ref)	0			0				
Restrict	Intercept	-3.799	0.632	36.089	1	<.01			
	Age	<u>0.024</u>	<u>0.011</u>	<u>5.198</u>	<u>1</u>	<u><.05</u>	<u>1.024</u>	<u>1.003</u>	<u>1.046</u>
	Exposure								
	<i>Tobacco Leaf Curing</i>	<u>2.236</u>	<u>0.396</u>	<u>31.935</u>	<u>1</u>	<u><.01</u>	<u>9.354</u>	<u>4.308</u>	<u>20.314</u>
	Brick Kilns	-0.797	0.487	2.679	1	ns	0.451	0.173	1.170
	Stone Quarries	0.031	0.419	0.006	1	ns	1.032	0.454	2.344
	Non-Exposure (Ref)	0			0				
	BMI								
	>30	<u>1.312</u>	<u>0.412</u>	<u>10.123</u>	<u>1</u>	<u><.01</u>	<u>3.713</u>	<u>1.655</u>	<u>8.331</u>
	25.00-29.99	<u>1.097</u>	<u>0.341</u>	<u>10.356</u>	<u>1</u>	<u><.01</u>	<u>2.997</u>	<u>1.536</u>	<u>5.847</u>
	<18.50-24.99	-0.195	0.854	0.052	1	ns	0.823	0.154	4.393
	18.50-24.99 (Ref)	0			0				
	Gender								
	Female	0.485	0.355	1.871	1	ns	1.624	0.811	3.255
	Male (ref)	0			0				
Combine	Intercept	-22.286	1.038	461.278	1	<.01			
	Age	0.005	0.019	0.065	1	ns	1.005	0.968	1.043
Combine (Cont.)	Exposure								
	<i>Tobacco Leaf Curing</i>	<u>20.896</u>	<u>0.586</u>	<u>1273.666</u>	<u>1</u>	<u><.01</u>	<u>1.19E+10</u>	<u>3.77E+09</u>	<u>3.75E+10</u>
	<i>Brick Kilns</i>	<u>18.023</u>	<u>0.844</u>	<u>456.230</u>	<u>1</u>	<u><.01</u>	<u>6.72E+08</u>	<u>1.20E+08</u>	<u>3.51E+09</u>
	Stone Quarries	19.360	0.000		1		2.56E+09	2.56E+09	2.56E+09
	Non-Exposure (Ref)	0			0				
	BMI								
	>30	0.411	0.722	0.324	1	ns	1.508	0.366	6.208
	25.00-29.99	-0.642	0.806	0.634	1	ns	0.526	0.109	2.554
	<18.50-24.99	0.301	1.167	0.067	1	ns	1.352	0.137	13.315
	18.50-24.99 (Ref)	0			0				
	Gender								
	Female	0.285	0.591	0.233	1	ns	1.330	0.418	4.236
	Male (ref)	0			0				

Chi-square = 146.817, df = 24, p < .01 Nagelkerke R² = .335

Reference of dependent variable: Normal lung

3.77×10⁹-3.75×10¹⁰ and 1.20×10⁸-3.51×10⁹, respectively, p<0.01). Gender, however, was a significant variable in the univariate analysis, even though it did not significantly predict lung impairment when multinomial multivariate logistic regression analysis was applied.

Discussion

The participants in the communities had been exposed to air pollution from tobacco leaf curing, bricks kilns and stone quarries for more than 15 years. The community dwellers did not use any respiratory protective equipment,

which increased lung impairment, especially during the curing process when sulfur chemicals are added to boiling water to increase the yellow color of tobacco leaves.

The tobacco leaf curing factories were significantly associated with obstructive, restrictive and combined lung impairments. Sulfur gas was the leading cause of lower respiratory diseases such as COPD (84%), bronchiectasis (44.1%) and lung fibrosis (7.7%) (Balali-Mood *et al.*, 2011). However, a previous study about patients with disabilities exposed to sulfur mustard poisoning revealed more obstructive impairment than restrictive impairment (Balali-Mood *et al.*, 2011).

The kilns for tobacco leaf curing are freely established in the centers of the villages where the village populations are highly dense. Furthermore, one kiln is located near a house where tobacco leaves are cured once a week. Therefore, the highest levels of smoke and flue gases are emitted from a chimney at the rooftop. Timber fuels are a major source of energy for curing tobacco leaves and timber fuel is consumed at an average of 14 kg per kilogram of cured tobacco leaf (Siddiqui, 2001). In general, flue gases such as CO, CO₂, NO and hydrocarbons, are emitted from timber fuel burning (Fernandes *et al.*, 2011). Zhang and colleagues (2005) reported the prevalence of chronic respiratory or nasal symptoms and lung function abnormalities in tobacco workers to be significantly higher than in control workers, especially among male tobacco workers who had symptoms of chronic coughing (32.86%), chronic phlegm (28.57%), dyspnea (24.29%), chest tightness (20%), snuffles (25.71%) and sniffles (30%). These authors also found that female tobacco workers were at significantly higher risk for diseases leading to impaired lung function. However, female and male tobacco workers reported significantly decreased FEV₁, FEF₅₀, and FEF₇₅ compared to the predicted values (Zuskin *et al.*, 2004).

According to the findings, brick manufacturing kilns were significantly associated with combined (obstructive and restrictive) lung function impairment. These findings are similar to previous studies finding brick workers to demonstrate significantly lower FVC and FEV₁ than the predicted values and suggesting a restrictive pattern (Zuskin *et al.*, 2004). This finding is consistent with a study by Das (2014) which found that brick field workers indicated a significant reduction in FVC and FEV₁ Das (2014). However, stone quarries were not found to be related to lung impairment. This result might be due to the fact that stone quarries are located in coconut, palm oil, and rubber tree plantations with vast areas ranging from 100 to 200 m in radius and surrounding stone quarries to spread particulate matter. Generally, a large surface area of leaves has a waxy coating of

accumulated particulate matter from stone quarries (Prajapati *et al.*, 2007). Moreover, the rainy season in southern Thailand lasts for a long period of time with heavy year-round rainfall. Therefore, rainwater reduces the dust accumulation on tree leaf surfaces (Prajapati *et al.*, 2007).

An interesting finding in this study is that obesity and overweight were significantly associated with restrictive lung function impairment (Thyagarajan *et al.*, 2008). Increased BMI has been found to be associated with lower lung function (Banks *et al.*, 2011). These findings are similar to a previous study by Rossi and colleagues (Rossi *et al.*, 2011) who found increased weight to be associated with decreases in both FEV₁ and FVC. This mechanism may partly determine the reductions in chest wall compliance, lung elastic recoil and peripheral airway size that negatively affect FEV₁ and FVC. Additionally, age was found to be significantly associated with lung function. This finding is similar to a previous study (Quanjer *et al.*, 2012) finding age to be a predicting factor for lung impairment and a risk for impaired lung function. Moreover, previous findings have also confirmed a 5-year decline in lung function with a 38 mL/y and 32 mL/y decrease in FEV₁ and FVC, respectively (Rossi *et al.*, 2011).

Restrictive lung impairment was found to be associated with the physical and population characteristic factors of the participants. Firstly, there was evidence that obesity and overweight conditions were significantly associated with restrictive lung function impairment (Thyagarajan *et al.*, 2008). Increased BMI has also been found to be associated with lower lung function (Banks *et al.*, 2011). These findings are similar to a previous study by Rossi and colleagues (Rossi *et al.*, 2011) who found increased weight to be associated with decreases in both FEV₁ and FVC. Obesity (Yeh *et al.*, 2011) and abdominal obesity are conversely related to lung function impairment (Leone *et al.*, 2009). Increased body mass may partly induce reductions in chest wall compliance, lung elastic recoil and peripheral airway size with negative effects on FEV₁ and FVC. Secondly, age was found to be

significantly associated with lung function. This finding was similar to the findings of a previous study (Quanjer *et al.*, 2012) finding age to be a predicting factor for lung impairment, and a risk for impaired lung function. Furthermore, previous findings have also confirmed a 5-year decline in lung function with a 38 mL/y and 32 mL/y decrease in FEV1 and FVC, respectively (Rossi *et al.*, 2011).

Limitation and Recommendation

According to ethical concerning and limited time to collect data, The sample were recruited by convenience and volunteer sampling. Those people may be the group of people who concerning own health, and may be not the best represent to population. A longitudinal randomized control study to explore the effects of pollution emitted from small cottage factories on community residents and workers' lung function would also be beneficial.

Conclusions

In conclusion, these research findings suggest that community health care providers should provide health information and raise awareness about air pollution risks in communities with tobacco leaf curing, brick kilns and stone quarries. People working in these industries need respiratory protective devices available for use. A routine health examination should include pulmonary function testing according to the American College of Occupational and Environmental Medicine guidelines for factory workers on a regular basis. The findings from this study could show whether or not improved emission controls are needed. Health impacts should be referenced to specific polluted community contexts in order to develop evidence-based recommendations that inform decision-making in order to protect and improve community health and well-being. To minimize negative health impacts, proposed policies, programs or projects in rural communities should be promoted.

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