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CHRONIC RESPIRATORY EFFECTS OF BIOMASS SMOKE EXPOSURE AMONG "RICE IN THE BAMBOO" PRODUCING WORKERS IN BANGSAEN, CHONBURI, THAILAND.

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ABSTRACT

Respiratory health assessment of workers occupationally exposed to smoke from biomass was conducted in Bangsaen, Chonburi province, Thailand. This area is well known for its "rice in the bamboo", a traditional delicacy of Thailand and other Asian countries. Sixty-three matched-pair workers and their respective controls participated in the study. Respiratory symptoms were assessed by ATS-DLD-78-C respiratory symptom questionnaire. Lung function tests were also conducted on all subjects. The study results revealed that the workers reported more frequent dyspnea, phlegm, and cough than the controls. Lung function results showed that mean FVC, FEV1, and FEF 25-75% and their corresponding predicted values were significantly lower among the workers. Regression analyses indicated that exposure to biomass smoke among the workers was significantly associated with any one of the respiratory symptoms (OR = 3.5, 95% CI = 1.26-9.64) and impaired lung function (OR = 9.46, 95% CI = 3.32-26.96), regardless of age, sex, and cigarette smoking history. The longer the workers worked in this occupation, the higher the risk of having impaired lung function (OR = 1.2, 95% CI = 1.05-1.4).

Keywords: Biomass smoke exposure, respiratory symptom, pulmonary function, occupational health.

INTRODUCTION

Biomass combustion generally produces smoke that causes air pollution. Evidence is growing that exposure to biomass smoke increases the risk of chronic respiratory disease and even lung cancer (Smith et al., 2000). It is estimated that smoke pollution, especially domestic exposure, is responsible for nearly 2 million excess deaths per year in developing countries, and about 4% of the global burden of disease (Bruce et al., 2000).

In Thailand, biomass fuels (wood, crop waste, and charcoal) for household and commercial uses accounted for 60% of the country's energy

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มหาวิทยาลัยบูรพา Burapha University

consumption (Energy Policy and Planning Office, Bangkok, 2008). "Rice in the bamboo" is the traditional delicacy of Thailand and very common among other Asian countries. It is made from glutinous rice, coconut milk, sugar, and beans stuffed in bamboo tubes and slowly cooked over an open fire of biomass (Figure 1). The workers start working before dawn for 3-8 hours a day, 5-7 days a week. They work all year round. The smoke emitted from this cooking process is both an occupational health hazard and an environmental nuisance. Nobody yet knows the health effects for the workers in these small, family-owned businesses. This study is aimed to determine the risk of chronic respiratory effects resulting from biomass smoke exposure among "rice in the bamboo" producing workers.

Figure 1. A worker is cooking "rice in the bamboo" over an open fire of wood and coconut husk in Bangsaen.

MATERIALS AND METHODS

Study site and subjects

The study was conducted in Sansuk municipality (Bangsaen), Chonburi province, Thailand. This area is renowned for its "rice in the bamboo" and produces around 10,000 tubes per day. There were seven factories that used biomass fuel in the cooking process. Others had changed to liquefied petroleum gas fuel oven. All workers in the factories that used biomass fuel were recruited for the study and assigned as the "exposed" group. In addition, individuals whose occupations did not involve in biomass smoke exposure, such as farmers, fishermen, janitors, and domestic workers were recruited from the municipal registration records, and assigned as the "unexposed" control group. Current cigarette smokers were excluded to prevent confounding effect due to cigarette smoking. All subjects provided written consent. The Ethical Review Board of Burapha University, Thailand approved protocol regarding human subjects.

Respiratory symptom and pulmonary function measurement

A respiratory symptom questionnaire was used to interview all subjects. The questionnaire was the Thai version of the American Thoracic Society (ATS-DLD-78-C) respiratory symptom questionnaire, with additional questions about past respiratory diseases (diagnosed by physicians as reported by the subjects), work history, and work practice (Ferris, 1978). Six chronic respiratory outcomes of self-reporting respiratory symptoms were derived from the questionnaire which included cough (cough more than 3 months), phlegm (phlegm more than 3 months), wheeze (wheeze more than 3 months), dyspnea (breathlessness when walk on the level), persistent cough and phlegm (cough and phlegm apart from cold for $\geq$ 4 days a week, for $\geq$ 3 months per year, for at least 1 year), and chronic bronchitis (phlegm production not from nasal $\geq$ 2 times a day, for $\geq$ 4 days a week, for $\geq$ 3 months per year, for at least 1 years). The researchers conducted the interview with the subjects during home visits.

Pulmonary function tests were conducted on each subject by a researcher trained at Harborview Medical Center, University of Washington, USA, using the American Thoracic Society guideline (ATS, 1995). A portable spirometer, Pony Fx (COSMED Inc., Italy) was used with subject in the seated position, using nose clips. The device was calibrated daily. Standing height and weight were measured using standardized equipment. Spirometry measures included forced expiratory volume in 1 second (FEV1), forced vital capacity (FVC), FEV1/FVC ratio, force expiratory flow rate between 25-75% of vital

capacity (FEF 25-75%), and peak expiratory flow (PEF). At least three acceptable and two reproducible forced expiratory maneuvers were required for analysis. FEV1 and FVC were expressed in liters and also as a percentage of the predicted value by the Thai spirometric equations (Dejsomritrutai, 2000), obtained by multiple linear regression models adjusted for age, sex, and height.

Data analysis

Simple descriptive analyses of sample characteristics and respiratory data were conducted. Differences in sample characteristics and respiratory symptoms between the exposed and unexposed group were compared by using Pearson's chi-square test, and t-test. The Mann-Whitney U test was used to compare exposure-year for both groups. Multiple logistic regression models were developed for association between subjects' characteristics and respiratory effects. Independent variables in the models were grouped by exposure (0=unexposed, 1= exposed), sex (0=female, 1=male), age, and duration of exposure (years in current job x hours of work in a day x days worked in a week x 52, and divided by 365). Odds ratios were derived from the models to describe the strength of association between independent variables and respiratory effects. The data were analyzed by using SPSS software version 13.0 (SPSS Inc., Chicago, IL, USA, 2001).

RESULTS

Population characteristics

The study was conducted during January to June 2008. One hundred and twenty six subjects were recruited in the study (63 exposed and 63 unexposed). Table 1 shows the subjects' characteristics. Both exposed and unexposed groups had more female than male. Significant differences were detected for age, hours worked per day, and years at school. The exposed group was slightly older ($p = 0.48$), worked longer in a day ($p< 0.001$), but spent fewer years at school than the unexposed group ($p< 0.001$). In terms of cigarette smoking history, majority of the subjects never smoked (91%). Ex-smokers were about 9% of the subjects in each group ($p = 0.67$). In summary, the exposed group and the unexposed group were relatively similar in most demographic characteristics, such as gender, socio-economic status, and smoking history.

Table 1. The characteristics of subjects used in the study.

	Exposed (n=63)	Unexposed (n=63)	*p*-value
Gender: n (%)			
Male	14 (22.2%)	16 (25.4%)	0.676
Female	49 (77.7%)	47 (74.6%)	0.676
Height (cm.): mean (SD)	156.57 (14.25)	157.44 (7.80)	0.671
Age (yrs): mean (SD)	52.39 (13.56)	47.71 (12.73)	0.048*
Years at school: mean (SD)	5.2 (2.8)	8.2 (4.8)	<0.001*
Years in current job: mean (SD)	18.25 (12.23)	14.35 (13.53)	0.104
Hours worked per day: mean (SD)	4.82 (2.72)	9.0 (2.27)	<0.001*
Days worked per week: mean (SD)	5.8 (2.1)	6.4 (0.8)	0.435
Cigarette smoking history: n (%)			
Ex-smoker	3 (4.8)	8 (12.7)	0.115
Never smoke	60 (95.2)	55 (87.3)	0.467

*Significant level: *p*-value < 0.05

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Respiratory effects

The participation rate for pulmonary function tests was 100%. Among those who could produce at least two pulmonary maneuvers, 79% met the ATS reproducible criteria (the values must be within 5% of each other) for FVC and 75% for FEV1. However, all 126 subjects' pulmonary function data were included in the analyses.

As shown in Table 2, mean FVC, FEV1, and FEF 25-75% were significantly lower among the exposed subjects. Predicted values for FVC, FEV1, and FEF 25-75% were also lower. However, there was no significant difference for predicted value for FEV1/FVC between the two groups.

Table 2. Results of the analysis obtained from data derived by means of a spirometer.

	Exposed (n=63)		Unexposed (n=63)		
	Mean	SD	Mean	SD	*p*-value
Absolute value					
FVC (L)	2.13	0.77	2.45	0.62	0.012*
FEV1 (L)	1.81	0.63	2.13	0.55	0.003*
FEV1/FVC (%)	85.42	10.21	87.0	7.42	0.344
FEF 25-75 (L)	2.25	1.32	2.70	0.81	0.023*
PEF (L)	4.52	2.0	4.82	1.54	0.344
Predicted value					
FVC (%)	75.95	17.69	85.68	14.6	0.001*
FEV1 (%)	79.56	17.58	90.68	15.09	<0.001*
FEV1/FVC (%)	101.24	11.18	102.36	8.56	0.534
FEF 25-75 (%)	81.6	31.93	98.89	29.16	0.002*
PEF (%)	65.37	27.66	67.62	27.85	0.657

*Significant level: *p*-value < 0.05

Table 3. Number and prevalence (%) of respiratory disease, symptoms and impaired lung function between exposed and unexposed subjects.

	Exposed (n=63)	Unexposed (n=63)	*p*-value
Respiratory diseases [a]	6 (9.5%)	3 (4.8%)	0.491
Respiratory symptoms [b]			
Cough	8(12.7%)	2(3.2%)	0.048*
Phlegm	15(23.8%)	3(4.8%)	0.002*
Dyspnea	16(25.4%)	5(7.9%)	0.009*
Wheeze	9(14.3%)	5(7.9%)	0.257
Chronic bronchitis	3 (4.8%)	1(1.6%)	0.309[c]
Persistent cough and phlegm	5 (7.9%)	2 (3.2%)	0.220[c]
Any one of the symptoms	29 (46.0%)	9 (14.3%)	<0.001*
Impaired lung functions [d]	41 (65.1%)	17 (27.0%)	<0.001*

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[a] Disease diagnosed by physician as reported by subjects

[b] Symptom results from the questionnaire

[c] Fisher exact chi-square, 1 sided

[d] Results from data collected by means of a spirometer based on predicted values

* Significant level: p-value < 0.05

Table 3 illustrates number and prevalence (%) of respiratory disease, symptoms and impaired lung function. Past respiratory illnesses were higher among the exposed subjects than the controls but not significant. These illnesses included bronchitis, asthma, and tuberculosis. The prevalence of dyspnea, phlegm, and cough were higher in the exposed group (p<0.009, p<0.002, and p = 0.048, respectively). There was no significant difference for wheeze, chronic bronchitis, and persistent cough and phlegm among the two groups. The prevalence of any one of the respiratory symptoms was significantly higher among the exposed subjects (p <0.001).

Impaired lung function was assigned for subjects based on predicted values: restrictive defect (FVC <80% predicted), obstructive defect (FEV1 < 80% predicted), and small airway disease (FEF 25-75% < 65% predicted). The prevalence of impaired lung function was significantly higher among the exposed group (p <0.001).

Table 4. Multiple logistic regression analyses for the associations between subject characteristics and respiratory effects.

Subject characteristics [a]	Respiratory symptoms OR [b] (95% CI)	Impaired lung function OR [b] (95% CI)
Group	3.49 (1.26-9.64)	9.46 (3.32-26.96)
Gender	1.21 (0.40-3.68)	0.41 (0.97-1.05)
Age	1.02 (0.98-1.06)	1.01 (0.97-1.05)
Hour-years	0.83 (0.70-0.98)	1.21 (1.05-1.40)
Cigarette smoking history	3.31 (0.49-22.34)	1.14 (0.22-5.78)

[a] Group (exposed=1, unexposed=0), Gender (male=1, female=0), Hour-years (year), Cigarette smoking history (ex-smoker=1, never smoke=0)

[b] Odds ratio

The results from regression analyses (Table 4) revealed that exposure to biomass smoke was significantly associated with any one of the respiratory symptoms (OR = 3.5, 95% CI = 1.26-9.64) and impaired lung function (OR = 9.46, 95% CI = 3.32-26.96). Male had higher risk of respiratory symptoms (OR = 1.21, 95% CI = 0.40-3.68), whereas female had an increased risk of impaired lung function (OR = 0.41, 95% CI = 0.97-1.05). Age slightly increased the risk of respiratory symptoms (OR = 1.02, 95% CI = 0.98-1.06), and impaired lung function (OR = 1.01, 95% CI = 0.97-1.05). In addition, the difference in one year of work increased the risk of impaired lung function (OR = 1.21, 95% CI = 1.05-1.40).

DISCUSION

"Rice in the bamboo" producing workers reported increased respiratory symptoms compared with the control. Significant differences were detected in terms of dyspnea, phlegm, and cough. This finding was similar to a recent study conducted

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in Mexico (Regalado et al., 2006) and other population-based studies in developing countries (Bahera and Jindal, 1991; Dutt et al., 1996) in that respiratory symptoms were reported more frequent among subjects exposed to biomass smoke.

Pulmonary function tests demonstrated restriction and a mixed defect. Highly significant decreases in FVC, FEV1, and FEF 25-75% were detected among the workers in this study. This finding was similar to other studies conducted in biomass smoke exposed populations (Dutt et al., 1996; Shrestha and Shrestha, 2005; Saha et al., 2005; Regalado et al., 2006). Mean predicted value for FEV1 was also significant. This finding indicated airflow obstruction (predicted FEV1< 80%) and was similar to the results found by others (Dutt et al., 1996; Regalado et al., 2006). In summary, the results of lung function tests indicated that restriction or a mixed defect were significant initial physiologic changes.

The mechanisms underlying increased respiratory symptoms and impaired lung function among subjects exposed to biomass smoke are still uncertain (Tzanakis et al., 2001). Whether they are due to particulate matter, irritant gases, or volatile organic compounds are remained to be uncovered. It has been reported that aldehydes and acids reduce the ciliary activity of the respiratory tract, and interfere with the ability of the airway epithelium to remove particles (Dost, 1991). This may explain that there are the increase of cough and phlegm among the exposed workers. High concentration of irritant gasses has been reported to cause pulmonary symptom similar to asthma, a condition referred to as reactive airway dysfunction syndrome (Brooks et al., 1985). The result of this study also showed that there were a few subjects suffering from this ailment. Unfortunately, assessment of respiratory hyper responsiveness was not a part of the protocol in this study.

Despite a wealth of knowledge that biomass and wood smoke affects respiratory health in human, the world's consumption of biomass fuel is increasing (RWEDP, 1997). In rural areas of lesser-developed countries, biomass is still used in low efficiency stoves, in poorly ventilated kitchens, and in open fire for cooking and heating (Smith, 2002). It is unlikely that this can be changed in the near future.

Thailand is moving towards an industrializing country. As a result, there are a number of conflict of interest issues arising from industrial growth (The Nation, 2009). In the case of small food producing industry, such as "rice in the bamboo", the factories are mostly located in the residential area (Figure 2). Smoke emitted from the production process causes an occupational health problem as shown by the study results. It is also obvious that the smoke, which pollutes the air; is an environmental nuisance. The authors suggest that, it is necessary to encourage the use of cleaner energy such as gas ovens. The municipality should re-enforce public health law. Information regarding health effects of exposure to biomass smoke should be emphasized.

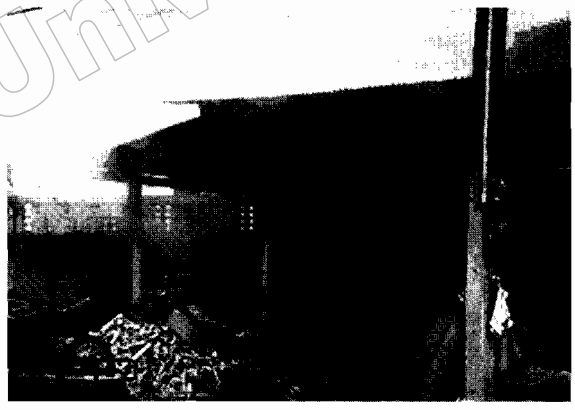

Figure 2. Air pollution derived from "rice in the bamboo" cottage factory in Bangsaen.

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