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Original Article

Are Rice Millers an At-Risk Group for Lung Disease? – An Occupational Health Concern in Rural Sri Lanka

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Abstract

Rice milling is the largest agro-based industry in Sri Lanka, but workers rarely use protective gear. We tried to identify and quantify the effects of inhalation of rice husk dust on respiratory function of rice millers in Anuradhapura district, Sri Lanka. Rice millers (male:84, female:84) and controls (male:84, female:84) were matched for determinants of lung functions. Data were collected via questionnaires, physical examination and spirometry. Results showed that rice millers, irrespective of gender, had significantly lower FVC, FEV_1 and PEFR ($p<0.05$) and increased prevalences of respiratory symptoms when compared with controls. Among millers, 42% of males and 38% of females had features of chronic respiratory disease. Exposure to dust over a few hours caused significant reductions in FVC and FEV_1 in female millers. Observed deficiencies in lung functions were probably caused by occupational exposure to rice husk dust. Wearing face masks, worker education and adequate ventilation in mills are recommended.

Introduction

Rice (*Oryza sativa*) is the major staple food in the Sri Lankan diet (1) and also of more than one quarter of the world's population (2). Rice is also the single most important crop cultivated in Sri Lanka and at present occupies about 34% (780,000 hectares) of the total cultivated area (3). It is grown as a wetland crop in all the districts in the country in irrigated paddy fields (4).

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Rice milling is the process by which paddy is converted to rice. The rice grain comprises of an outermost hull/husk, an intermediate bran layer, and an innermost starchy endosperm/kernel. The main aim of rice milling is to remove the husk and the bran layers, and produce an edible rice kernel that is sufficiently milled and free of impurities. Though the main product of the rice milling industry is rice, it also produces a substantial amount of by-products such as husk, bran and broken rice. Therefore, a large amount of dust is generated during the milling activities (5).

Several studies carried out in the Asia Pacific region have addressed the unfavourable effects of exposure to rice husk dust. A cross sectional study carried out among Malaysian rice millers showed significantly higher prevalence of respiratory symptoms among rice millers than the controls. These symptoms included chest tightness (34.9%), morning phlegm (31.7%), shortness of breath (31.7%) and morning cough (19%) (5). Meanwhile, of a group of 150 Pakistani rice millers 18.7% had lung function changes attributable to obstructive lung disease, while 4% had features of restrictive lung disease (6). Furthermore, Indian rice millers were found to have significantly lower forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1) and peak expiratory flow rate (PEFR) when compared with controls (7). Similar findings were observed in another Indian study with 42.6% of the studied rice mill workers showing evidence of respiratory morbidity and 10.7% having decreased PEFR (8). In a study conducted among Malaysian rice millers, Lim *et al.* reported exposure to rice husk dust gave rise to acute and chronic irritant effects affecting eyes, skin and upper respiratory tract, allergic responses and also radiological changes in chest radiography (2). They collectively termed these changes the Rice millers' syndrome.

Rice milling in Sri Lanka is primarily a small to medium scale industry with very little formal control of working conditions by the government. Therefore, almost no protective measures are taken by these paddy mill workers against inhalation of rice husk dust. Furthermore, the average mill worker, with his low level of education, is ignorant of potential harmful effects of inhalation of various dust particles and is reluctant to adopt safety precautions. The present study was carried out with the aim of gaining conclusive data regarding the respiratory function of the Sri Lankan rice millers.

Methods

The subject group comprised of 84 male and 84 female rice millers randomly selected from 43 large, medium and small scale rice mills in Anuradhapura district, Sri Lanka, where 64.2% of the labour force is employed in the agricultural sector (9). Each selected rice miller was employed in rice mills for a total period of 2 years or more. They were exposed to the rice husk dust for 4 hours or more per day for at least 5 days a week. The control group was made up of 84 males and 84 females employed as security guards and cleaners in Rajarata University of Sri Lanka.

The subject and control groups were matched for the known determinants of lung functions (10). The Mean±SD age of male millers was 44.8±11.1 years, whilst that of controls was 41.6±11.4 years. The Mean±SD age of female millers was 44.7±8.7 years, and it was 42.3±8.6 years among controls. There was no statistical difference in age ($p>0.05$) between the subjects and controls. The Mean±SD standing height of male millers was 165.4±6.4 cm and that of controls was 167.1±5.6 cm. It was 151.0±7.6 cm in female millers and 152.7±6.9 cm in controls. There was no significant difference ($p>0.05$) between the test and control subjects. Likewise, the Mean±SD body weights of the male millers' (59.7±9.8 kg) and controls (62.6±11.1 kg), and the female millers (53.0±10.8 kg) and controls (55.3±9.9 kg) did not show a statistically significant difference ($p>0.05$). The tobacco smoking status was compared using the pack year index calculated for each participant. All female participants had 0 pack year index. Male millers had a Mean±SD pack year index of 5.7±7.9 and the male controls 4.3±7.3. The difference was statistically insignificant ($p>0.05$). All subjects and controls belonged to the Sinhalese ethnic group.

Tools of data collection included an interviewer administered respiratory symptom and occupational history questionnaire, a medical examination carried out on each participant by the medically qualified principal investigator and spirometry. A modified and validated Sinhalese translation of the American Thoracic Society's standard respiratory disease questionnaire (11) was administered at interview. Spirometry was performed twice on each individual and the measurements were taken according to the guidelines published by the American Thoracic Society (12) using a Spirolab II (Medical International Research, Rome, Italy) portable spirometer. On the rice millers spirometry was performed once in the morning, before the start of day's work, and once in the afternoon, after the workers had been exposed to the rice husk dust for over 4 hours. Similarly in the controls too spirometry was performed once in the morning and once in the afternoon. The spirometer was calibrated using a fixed volume 3 liter calibration syringe (A-M systems, USA). This calibration was done following its use on 2 or 3 mills.

Respiratory symptoms and disorders considered in the analysis included 'usually having cough' and 'usually having phlegm' which were defined as 'cough or phlegm (in chest) of any severity and duration perceived and self-reported by the participant as 'usually having cough' or 'usually having phlegm'. 'Chronic cough' and 'chronic phlegm' were defined as 'cough or phlegm in chest on most days of the week (4 or more days) for 3 or more months per year'. The other important respiratory disorders considered were 'asthma' ('having had 2 or more episodes of wheezing with shortness of breath, at any time during lifetime'), 'chronic bronchitis' ('cough and phlegm during most days of the week (4 or more days), for 3 or more months per year, lasting at least 2 years') and 'chronic respiratory disease' ('presence of at least one of the following symptoms: cough or phlegm during most days of the week (4 or more days) for 3 or more months per year, recurrent wheezing (most days and nights), or 2 or more episodes of wheezing with shortness of breath') (13).

The data analysis was carried out using SPSS™ version 17.0 (Statistical Product and Service Solutions, Chicago) software. Ethical clearance for this study conducted from 2009 to 2013 was obtained from the Research, Ethics and Higher Degrees Committee of the Faculty of Medicine & Allied Sciences, Rajarata University of Sri Lanka. Written informed consent was taken from all study participants prior to their participation.

Results

Table I shows the prevalence of respiratory symptoms, signs and disorders among millers and their controls.

The prevalence of usual cough, usual phlegm, chronic phlegm, wheeze without cold and wheeze on most days or nights were significantly higher among both male and female millers than the controls ($p<0.05$). Although both male and female millers had a higher prevalence of chronic cough, wheeze with shortness of breath and asthma as compared to their respective controls, the difference was significant only among males ($p<0.05$). While an increase in prevalence of chronic bronchitis was also observed among both male and female millers, the values were not statistically different from their respective controls ($p>0.05$). However, both the male and female millers had a significantly higher prevalence of chronic respiratory disease features than the controls ($p<0.05$).

TABLE I : Prevalence of respiratory symptoms and disorders among rice millers and controls.

Variable	*Gender*	*Millers % (n)*	*Controls % (n)*	*p value*
Usually having cough	Male**	26% (22)	5% (4)	<0.01*
	Female**	27% (23)	10% (8)	<0.01*
Having chronic cough	Male**	20% (17)	2% (2)	<0.01*
	Female**	17% (14)	7% (6)	0.057
Usually having phlegm	Male**	32% (27)	12% (10)	<0.01*
	Female**	29% (24)	13% (11)	0.014*
Having chronic phlegm	Male**	24% (20)	7% (6)	<0.01*
	Female**	19% (16)	5% (4)	<0.01*
Having chronic bronchitis	Male**	11% (9)	4% (3)	0.072
	Female***	8% (7)	2% (2)	0.168
Having wheeze without cold	Male**	19% (16)	5% (4)	<0.01*
	Female**	23% (19)	11% (9)	0.038*
Having wheeze on most days or nights	Male**	20% (17)	0% (0)	<0.01*
	Female**	18% (15)	4% (3)	<0.01*
Having wheeze with shortness of breath (SOB)	Male**	17% (14)	4% (3)	<0.01*
	Female**	17% (14)	8% (7)	0.102
Having asthma	Male**	12% (10)	4% (3)	0.043*
	Female**	13% (11)	7% (6)	0.201
Having chronic respiratory disease	Male**	42% (35)	11% (9)	<0.01*
	Female**	38% (32)	13% (11)	<0.01*

*p<0.05
**Chi square test
***Fisher's exact test

Comparisons of mean lung functions are shown in Table II. While the mean FVC (Forced vital capacity), FEV_1 (Forced expiratory volume in the first second) and PEFR (Peak expiratory flow rate) were found to be lower among millers than the respective controls with a statistical significance, irrespective of the gender, $FEF_{25-75\%}$ (Average mid-expiratory flow rate), which represents the small airway function, was significantly lower among female millers only. The FEV_1/FVC ratio (Tiffeneau-Pinelli index) was significantly higher among the male millers than the controls. Table III compares the mean lung function values of the millers before and after exposure to the rice husk dust within a day.

TABLE II : Comparison of the mean lung function values of rice millers and controls.

Lung function variable	*Gender*	*Time of the day test was done*	*Millers' Mean±SD*	*Controls' Mean±SD*	*p value*
FVC (Liters)**	Male	Morning	2.82±0.65	3.14±0.54	<0.01*
		Afternoon	2.82±0.60	3.15±0.58	<0.01*
	Female	Morning	1.96±0.48	2.12±0.41	0.026*
		Afternoon	1.87±0.43	2.15±0.39	<0.01*
FEV_1 (Liters)**	Male	Morning	2.54±0.56	2.76±0.48	<0.01*
		Afternoon	2.53±0.54	2.72±0.45	0.015*
	Female	Morning	1.76±0.38	1.93±0.38	<0.01*
		Afternoon	1.71±0.39	1.93±0.36	<0.01*
FEV_1/FVC ratio (%)***	Male	Morning	90.70±7.80	87.84±9.54	0.018*
		Afternoon	89.89±7.57	86.70±7.68	0.009*
	Female	Morning	90.36±7.61	91.42±9.92	0.061
		Afternoon	91.71±8.66	90.86±9.82	0.879
PEFR (Liters/sec)**	Male	Morning	8.15±2.41	8.9±1.84	0.023*
		Afternoon	8.17±2.17	9.13±1.86	<0.01*
	Female	Morning	5.53±1.50	6.43±1.77	<0.01*
		Afternoon	5.62±1.52	6.38±1.59	<0.01*
$FEF_{25-75\%}$ (Liters)**	Male	Morning	3.38±1.10	3.37±0.88	0.974
		Afternoon	3.34±1.08	3.31±1.24	0.861
	Female	Morning	2.36±0.73	2.79±1.04	<0.01*
		Afternoon	2.42±0.74	2.78±1.34	0.032*

*p<0.05
**Independent sample t test
***Mann Whitney U test

TABLE III : Mean lung function values of millers before exposure (morning) and after exposure (afternoon) to rice husk dust and that of controls.

Lung function variable	*Gender*	*Category*	*Morning/Before exposure to dust Mean±SD*	*Afternoon/After exposure to dust Mean±SD*	*p value***
FVC (Liters)	Male	Millers	2.82±0.65	2.82±0.60	0.997
		Controls	3.14±0.54	3.15±0.58	0.726
	Female	Millers	1.96±0.48	1.87±0.43	0.04*
		Controls	2.12±0.41	2.15±0.39	0.401
FEV_1 (Liters)	Male	Millers	2.54±0.56	2.53±0.54	0.664
		Controls	2.76±0.48	2.72±0.45	0.090
	Female	Millers	1.76±0.38	1.71±0.39	0.046*
		Controls	1.93±0.38	1.93±0.36	0.912
FEV_1/FVC ratio (%)	Male	Millers	90.70±7.80	89.89±7.57	0.212
		Controls	87.84±9.54	86.70±7.68	0.157
	Female	Millers	90.36±7.61	91.71±8.66	0.113
		Controls	91.42±9.92	90.86±9.82	0.588
PEFR (Liters/sec)	Male	Millers	8.15±2.41	8.17±2.17	0.915
		Controls	8.91±1.84	9.13±1.86	0.138
	Female	Millers	5.53±1.50	5.62±1.52	0.545
		Controls	6.43±1.77	6.38±1.59	0.701
$FEF_{25-75\%}$ (Liters)	Male	Millers	3.38±1.10	3.34±1.08	0.656
		Controls	3.37±0.88	3.31±1.24	0.541
	Female	Millers	2.36±0.73	2.42±0.74	0.445
		Controls	2.79±1.04	2.78±1.34	0.956

*p<0.05
**Paired t test

Discussion

The present study suggests that the cardiorespiratory health of rice millers in Anuradhapura district, Sri Lanka, irrespective of gender, is adversely affected. In this study conducted over a period of three years, nearly fifty percent of 168 rice millers examined showed clinical features of respiratory disease.

All the respiratory symptoms and disorders tested were found to be higher among rice millers than among the controls. Among the millers, irrespective of gender, the prevalence of usually having cough, usually having phlegm, chronic phlegm, wheeze without cold, wheeze on most days or nights (persistent wheeze), and chronic respiratory disease was significantly higher ($p<0.05$) than in the controls. In addition, the prevalence of chronic cough, wheeze with shortness of breath (SOB), and asthma were significantly higher among male millers than the controls.

Studies from economically developed countries (14)(15) have also reported comparable observations. McCurdy *et al.* reported the prevalence of chronic cough, persistent wheeze, asthma and chronic bronchitis among Californian male rice farmers to be 7.1%, 8.8%, 7.1% and 6.3% respectively (15). These values, however, were much lower than the values recorded in the present study, which are 20%, 20%, 12% and 11% respectively. Deacon and Paddle observed the prevalences of cough, wheeze and chest tightness to be between 8–13% among grain food manufacturing workers in the United Kingdom (14), which were also lower than the values observed in the current study. The main reason for these differences may be the higher level of attention paid to occupational safety in developed countries than in developing countries. The use of protective gear such as face masks may have reduced the severity to dust exposure among the Californian and English grain workers, leading to the lower respiratory symptom prevalence among them. The better grain processing techniques and storage facilities available in developed countries and the lesser contamination of the grain by microorganisms may also have contributed to the outcome.

Although the prevalence of chronic bronchitis was observed to be higher among millers than the controls in the current study, this difference was not statistically significant. One reason for this maybe that the majority of male participants in the current study were tobacco smokers. While all the female participants were non smokers, 58 (69%) of male millers and 67 (79.8%) of male controls were either current or ex-smokers, with the mean tobacco smoking pack year index showing no significant difference between the two groups. Smoking has been identified as the greatest risk factor for chronic bronchitis, which is a type of COPD (Chronic obstructive pulmonary disease), and it has been shown that over 40% of the smokers develop chronic bronchitis in their lifetime. It has also been shown that smoking is the cause for 8 to 9 out of 10 cases of COPD (16). Tobacco smoke contains more than 7000 chemicals, most of which are toxic to cilia, the tiny hair-like processes lining the airways (16). The toxins in the inhaled smoke would slow down the ciliary action, paralyze them, and finally destroy them, thereby hindering their sweeping action of mucus. This would cause the mucus to build up in the airways, giving rise to long standing cough and phlegm in the chest, both of which are cardinal features of chronic bronchitis (16). Therefore, it may be assumed that the effect of tobacco smoke overrides the effect of grain dust in causing chronic bronchitis. Previous studies (17) have shown that the effects of tobacco smoking and grain dust can be additive. This probably could be the reason why a significant difference was not seen between male millers and controls in the prevalence of chronic bronchitis in the current study.

It was of interest to note that the difference in the prevalence of chronic respiratory disease among both male (42%) and female (38%) millers and their respective controls (Table I) was highly significant ($p<0.01$). The magnitude of the harm rice husk dust could cause to human lungs is exemplified by the fact that nearly 50% of the rice millers in this study had features of chronic respiratory disease. The observed values are in accordance with an Indian study, in which 42.7% of rice millers were shown to have respiratory morbidity (8).

Lung functions, FVC, FEV_1 and PEFR, in both male and female millers were significantly reduced in comparison to the controls (Table II). Female millers, in addition, had significantly lower $FEF_{25-75\%}$. These differences were apparent both before and after exposure to rice husk dust. When air pollutants are breathed into the lungs, the harmful particles which bypass the lung defense mechanisms such as hairs in nostrils, mucus membrane lining the nasal passage and pharynx and ciliary action, may get trapped in the alveoli, causing a localized inflammatory response (18). Enzymes such as elastase are released during this inflammatory response, causing alveolar septal disintegration. The inflammatory response also causes impairment of lung defense mechanisms and disruption of lung tissue repair mechanisms. This may lead to significant deformities in lung architecture, including loss of lung elastic recoil, leading to functional consequences (18). A similar chronic inflammatory response in the lungs can be expected due to long term exposure to rice husk dust. This may play a role in chronic reductions in lung functions in those exposed to rice husk dust.

In the current study it was observed that the mean FEV_1/FVC ratios of all four groups, i.e. male and female millers and their respective controls, were within normal values (> 80%) (Table II). However, male millers were found to have a significantly higher mean FEV_1/FVC ratio than male controls, while there was no significant difference between the female millers and their controls. The high or normal FEV_1/FVC ratio of the millers, combined with their significantly reduced mean FVC and FEV_1 values, suggests chronic restrictive lung disease changes. In addition, the mean PEFR of both male and female millers were also significantly lower than that of controls. Decreased PEFR values may indicate larger airway obstruction (19). Thus, the studied group of rice millers, irrespective of gender, seems to possess features of mixed obstructive and restrictive chronic lung disease.

However, the restrictive lung disease changes observed in male millers were more prominent than that of female millers, owing to their significantly higher FEV_1/FVC ratio when compared with controls (Table II). The main reason for this gender difference may be the fact that the majority of male millers and controls were smokers. While the mean tobacco smoking pack year indexes were similar between male millers and controls, the additive effects of tobacco smoke and grain dust in the millers (17)(20) may have brought about the significant changes of FEV_1/FVC ratio between them. Smokers are known to develop prominent restrictive changes in lungs with the tobacco smoke destroying lung elastic tissue and preventing full expansion of lungs, thus leading to emphysema. They may also develop chronic obstructive airway changes as tobacco smoke causes inflammation driven pathologies in the lungs, giving rise to progressive airflow limitation. Thus it could be assumed that this additive effect of smoking and rice husk dust could be the reason for the restrictive and obstructive lung disease changes seen among male rice millers in the current study. Although no significant difference in mean FEV_1/FVC ratio was seen between the female rice millers and controls, the millers had a significantly lower mean PEFR value. These findings, combined with their significantly lower mean FVC, FEV_1 and $FEF_{25-75\%}$ values, suggest mixed restrictive and obstructive lung disease changes among female millers as well. Tobacco smoke is also known to affect small airways and cause obstructive changes (21). $FEF_{25-75\%}$ is a measure of small airway obstruction (19). Therefore, owing to the almost similar degrees of tobacco smoke induced small airway damage in male millers and controls, both groups seem to have similar mean $FEF_{25-75\%}$ values. The harmful effects of tobacco smoke overriding grain dusts have been noted when Cotton *et al.* observed the harmful effects of tobacco smoke to be more pronounced than that of grain dusts with regard to causing chronic reductions in lung functions and increasing respiratory symptoms (17).

The exposure to rice husk dust even only for a few hours seemed to affect female millers and their mean post-exposure FVC and FEV_1 values were found to be significantly lower, when compared with pre-exposure values. In the male millers used in the current study, however, the lung functions did not show a remarkable change, and this could be due to the effects of smoking among males (Table III).

In conclusion, this study has shown that rice millers employed in Anuradhapura district, Sri Lanka, irrespective of gender, have significantly reduced lung functions and increased prevalences of respiratory symptoms and disorders, when compared with controls. These adversities are probably caused by the occupational exposure to rice husk dust. Exposure to the rice husk dust over a few hours caused significant reductions in FVC and FEV_1, but was seen only in female millers. Both male and female millers had features of mixed restrictive and obstructive lung disease.

Measures employed by the mill workers during work to avoid direct contact with dust, such as wearing of face masks, are recommended. Also, measures need to be taken to standardize, implement and maintain adequate ventilation in mills (i.e. fixing of dust extraction fans) and also to educate Sri Lankan rice millers regarding this preventable harm they are unknowingly exposing themselves to. Introduction of a rice mills hygiene protocol should prove to be beneficial.

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