The Effects of Respirable Dust Exposure on Pulmonary Function among Aircraft Repair Workers

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Abstract

Despite extensive research on the effects of occupational dust exposure on pulmonary illness, few studies have addressed risks among airport workers. In this cross-sectional study, the effects of occupational exposure to respirable dust on pulmonary function were investigated among aircraft repair workers at the Bangkok International Airport. Among 156 participants, pulmonary function tests were assessed, and occupational exposure was assigned by job title. Of these, 114 participants provided usable data on the pulmonary function test. Multiple regression was used to evaluate the association of pulmonary function with exposure group, while adjusting for age, sex, and education. We observed significant and inverse associations of exposure group with FEV, FEV1, and MMEF among smokers, whereas insignificant associations were found for nonsmokers. Additionally, insignificant association of exposure group with PEF was found for both smokers and nonsmokers. The findings suggest that occupational dust induced by repairing an aircraft has potential heath hazards, and should be controlled.

Keywords: pulmonary function, respirable dust, airport worker

1. Introduction

It has been well documented that ambient particulate air pollution is inversely associated with pulmonary function in children and adults [1-5]. Concern about this association has been raised in occupational fields because occupational dust is a significant problem occurring in various workplaces. Importantly, it is more likely to contain hazardous substances used in manufacturing than that in ambient air. This underscores a need to investigate its effects on pulmonary illness among the exposed workers.

Airports are one type of workplaces suffering from occupational dusts. A potential source of the dust may result from the incomplete fuel combustion of an aircraft engine. This evidence is likely to occur whenthe efficiency of the engine is reduced during taxiing, causing higher emission of unburned hydrocarbons [6]. Another potential source may be resulted from the repair procedures. For example, grinding engine parts may induce dust into work environment, and the materials used in the repair procedures may be in dust form which could be dispersed into the air. The presence of potential sources of dust in the airport suggests that airport workers may be at risk of pulmonary illness if preventive measures are not effective.

There has been limited literature addressing the effects of occupational dust on pulmonary function among airport workers. A few of which were the recent studies of Tunnicliffe and colleagues [6], examining the effects of avation fuel and jet stream exhausts. The other study was the study of Killburn [7], examining the effects of metal dust. Despite the difference in the exposures of interest, similar findings were found in the two studies, i.e., significant differences in respiratory symptoms but insignificant differences in pulmonary function between different exposure groups. The results indicated that a specific pulmonary illness may be affected by various occupational exposures, and that investigation of this relationship is necessary in order to understand the natural history of pulmonary illness.

From a walk-through survey, it was observed that the aircraft repair workers at the Bangkok International Airport might be exposed to the occupational dust induced by repairing processes. The dust in this setting may contain known hazardous substances, such as fiberglass dust resulted from grinding, silica dust resulted from sand blasting, and cotton dust resulted from repairing passenger seats. The adverse effects of these substances have been extensively investigated in previous studies. These studies mainly focused on their effects on a specific respiratory system disease. For example, a range of studies has examined the effects of fiber glass on lung cancer [8-15]. However, little is known about the effects of the airborne dust containing these substances on pulmonary function. To address this issue, we investigated the association of pulmonary function with exposure to respirable dusts among aircraft repair workers at the Bangkok International Airport.

2. Materials and Methods

2.1 Design and study population

A cross-sectional study was conducted to investigate the adverse effects of respirable dusts on lung function of the airplane repair workers at the Bangkok International Airport. Data were collected on site using lung function tests and questionnaires. One hundred and fifty-six from 193 eligible workers participated in the study. Of these, 114 subjects provided usable data the on the lung function test and questionnaire, and these were used in the analysis.

2.2 Pulmonary function

The pulmonary function test was performed with an electronic spirometer (Spiro Sense Spirometry System, Burdick, Inc., U.S.A.), in October 2000. The device was calibrated before each test, using flow-volume syringe. Each subject was asked to perform at least three acceptable blows, based on the Snowbird guidelines [16], to ensure that maximal effort and cooperation were obtained and that the tests provided an accurate reflection of the subject's pulmonary function. The best of the three acceptable measurements was recorded and used in the analysis. The pulmonary function variables addressed in the analysis included: i) maximal forced vital capacity (FVC), ii) forced expiratory volume in 1 second (FEV1), iii) peak expiratory flow rate (PEF), and iv) maximal mid-expiratory flow rate (MMEF).

2.3 Interview

All subjects were interviewed for their information on demography, socioeconomic, occupational history, smoking habit, and medical history, using questionnaire. The interview was carried out before performing pulmonary function test, by trained interviewers.

2.4 Exposure classification

In this analysis, the subjects were classified into three exposure groups by the industrial hygienist of the airport. The classification was done on the basis of their job titles that reflected their likelihood of exposure to dusts in the workplace. The low exposure group consisted of printing staff, mechanical cleaning staff, and bench repair staff. The medium exposure group included break and wheel removing and assembling staff, sewing staff, sorting staff, and chemical cleaning staff. The high exposure group consisted of grinding staff. According to this classification, there were 20 subjects in the low exposure group, 43 in the medium group, and 51 in the high exposure group.

To verify the exposure classification, respirable dust sampling was carried out in a subgroup of 39 subjects in November 2000, using personal samplers (SKC Air Sampling Pumps, SKC Inc., U.S.A.). The subjects volunteered to wear the device over the work shift, on a day after their lung function tests and interviews. They were trained to operate the device by an industrial hygienist of the research team. They turned it on, wore it for a full shift, turned it off at the end of the work shift, and returned it to the industrial hygienist on the same day. The concentration of respirable dust exposure of the individuals was calculated using the gravimetric method.

2.5 Statistical analysis

Multiple regression analysis was used to evaluate the effects of occupational exposure to respirable dust on FVC, FEV1, PEF, and MMEF, while adjusting for age, sex, race, education, income, duration of employment at the airport, and environmental tobacco smoking. Asthma was not considered to be a potential confounder in this analysis because no self-report asthma. Due to the small sample size (20 subjects) in the low exposure group, the subjects in the low exposure group were grouped with those in the medium exposure group. For simplicity, this combined group was named as the low exposure group, and used as a reference category in the regression model. Significant predictors ($p<0.1$) for each of pulmonary function variables were detained in the final model, which included age, sex, and education. To examine the variation of the exposure-pulmonary function relationship among smokers and nonsmokers, separate models were estimated for the two groups.

3. Results

Table 1 shows the means of respirable dust concentrations in each group. They did not exceed the current standard of threshold limit values (3 mg/m^3) [17]. Moreover, the mean levels in each group were in agreement with the classification of exposure groups initially made by the industrial hygienist, validating the exposure classification. There was a relatively small difference in the mean levels of low and medium exposure groups, supporting the combination of the two groups which was subsequently compared with high exposure group in the regression analysis.

Table 1: Personal exposure to respirable dust and standard deviation among the subsamples, stratified by exposure groups, November 2000.

Exposure group (n)	Mean of respirable dusts exposure (mg/m^3)	Standard deviation (mg/m^3)
Low (9)	0.1148	0.0456
Medium (15)	0.1336	0.0772
High (15)	0.5175	0.3674

Characteristics of the subjects by exposure group were summarized in table 2. Comparisons across exposure groups showed similarity for age, race, educational level, environmental tobacco smoking, duration of employment at the airport,

income, and self report on asthma, but not for sex ($p < 0.05$). Proportions of male workers in low and high exposure groups were higher than the medium exposure group.

Means and standard deviations of FVC, FEV_1, PEF, and MMEF in the three exposure groups are presented in table 3. In low and medium exposure groups, the means were slightly lower than those in the high exposure group. When stratified by smoking status, similar results were observed for nonsmokers. Conversely, they were slightly lower in the high exposure group than in low and medium exposure groups, among smokers (table 4).

Table 2: Characteristics of subjects stratified by exposure groups.

varaibles	Low (n=20)	(%)	Medium (n=43)	(%)	High (n=51)	(%)
male *	16	(80)	27	(62.8)	49	(96.1)
age ≤ 35 yr.	7	(35)	17	(39.5)	21	(42.2)
race (Thai)	21	100	42	97.7	45	88.2
education less than bachelor degree	12	60	27	64	28	54
ever Smoke	9	45	15	34.9	26	51.0
environmental tobacco smoking	13	65	28	65.1	32	62.8
duration of emplyment >4yr	20	100	41	95.4	48	94.1
income <25000 baht/month	11	55	22	51.2	27	52.9

*p <0.05

Table 3: Means and standard deviations of pulmonary function of subjects stratified by exposure groups.

Pulmonary function	Low (n=20) mean	sd	Medium (n=43) mean	sd	High (n=51) mean	sd
FVC	3.43	0.67	3.54	0.85	3.74	0.68
FEV1	3.03	0.52	3.08	0.76	3.26	0.65
PEF	7.92	1.90	8.04	2.26	8.82	1.83
MMEF	4.05	0.60	3.92	1.19	4.14	1.38

Table 4: Means and standard deviations of pulmonary function of smokers and nonsmokers stratified by exposure groups.

Pulmonary function	Low (n=9) Mean	sd	Medium (n=15) mean	sd	High (n=26) mean	sd
Smoker:						
FVC:	3.75	0.47	3.93	0.73	3.60	0.48
FEV1:	3.29	0.31	3.41	0.67	3.10	0.43
PEF:	7.89	1.75	8.86	1.87	8.60	1.65
MMEF:	4.20	0.40	4.35	1.17	3.83	0.97
Nonsmoker:						
FVC:	3.17	0.72	3.32	0.85	3.90	0.81
FEV1:	2.83	0.57	2.90	0.75	3.42	0.80
PEF:	7.95	2.10	7.61	2.36	9.06	2.01
MMEF:	3.93	0.73	3.70	1.16	4.46	1.66

Table 5 shows the results from multiple regression analysis for the association between respirable dusts exposure and pulmonary function of the workers, after adjusting for age, sex, and education. High exposure group was insignificantly associated with approximately 0.1 liter decreases in FVC and FEV1, and PEF, and approximately 0.2 liter/sec in MMEF. When stratified by smoking status, , the association became statistically significant for FVC, FEV1, and MMEF but not for PEF. It was also observed that the pulmonary deficits increased from 0.1 liter to 0.3 liter for FVC and FEV1, and from 0.2 liter/sec to 0.6 liter/sec for MMEF, among smokers. In contrast, the high exposure group was insignificantly associated with increases in FVC, FEV1, and MMEF, and with decreases in PEF, among nonsmokers.

4. Discussion

It was found that occupational exposure to respirable dusts was significantly associated with decreases in FVC, FEV1, and MMEF among smokers, while adjusting for age, sex, and education. In contrast, the insignificance and opposite direction of the associations were observed among nonsmokers. The results indicated that there were joint effects of occupational exposure to respirable dusts with smoking on pulmonary function of the workers. This evidence is biologically plausible. The extent to which the respirable dusts induce adverse effects on pulmonary function depends on their ability to penetrate and deposit in the lung. Smoking has been reported to cause airway inflammatory response and hypertrophy and hyperplasia of mucus glands [18], increase airway reactivity [19], and decrease clearance response [20-21]. These changes may impair the defense mechanisms of the airway on clearing the inhaled dusts, and/or the airway response to the deposited material.

Similar results were observed in the study of Xu and Wang [22]. The authors reported the synergistic effects of air pollution and smoking on pulmonary function of adults living in residential and industrial areas in Beijing. Conversely, Tunnicliffe and colleagues [6] did not find any significant differences in pulmonary function of airport workers exposed

Table 5: Adjusted regression coefficients (standard error in parenthesis) for high exposure to respirable dusts in relation to lung function of workers.†

Pulmonary function	All subjects (n=114)	Smokers (n=50)	Nonsmokers (n=64)
FVC (liter)	-0.1328 (0.1174)	-0.3103 (0.1508)*	0.0312 (0.1814)
FEV1 (liter)	-0.1390 (0.1063)	-0.3193 (0.1271)*	0.0253 (0.1692)
PEF (liter/sec)	-0.0971 (0.3288)	0.0408 (0.4857)	-0.2775 (0.4590)
MMEF (liter/sec)	-0.2231 (0.2218)	-0.5617 (0.2569)*	0.0959 (0.3578)

† Adjusted for age, sex, and education.
* p <0.0

to aviation fuel or jet stream, among never-smokers, current smokers, and ex-smokers. The authors stated that the healthy worker effect may explain the findings because the workers participating in the study were relatively young. This problem should be minimized in our analysis because approximately 60% of the participants in our analysis were older than 35 years.

The effects of occupational dust can vary depending on what constitutes the exposure. In this analysis, constituents associated with the deficits in pulmonary function cannot be specified because the composition of the exposure was unknown. The composition was largely dependent on the environment set in the workplace and the materials used in the repair procedures; and it can vary from job title to job title. In this study, workers whose job titles were bonding or grinding, were more likely to be exposed to fiberglass dust than those who were in other job titles. This is because fiberglass has been widely used in various parts of an airplane due to its high efficiency in insulation [23]. This suggested that the intensity of fiberglass dust in bonding and grinding job titles should be higher than that in other job titles. In other words, the high exposure group is likely to be exposed to be respirable dust containing fiberglass much more than low exposure group. However, it cannot be concluded that fiberglass played a significant role in the observed findings since the effects of other unmeasured compounds in the dusts cannot be discounted.

There were potential problems that may influence the observed findings. One of which may come from selection bias. The workers with pulmonary problems may have more concern about their health status than those without such problem. Thus, they may have participated in the study in a higher proportion than those without the problem, leading to self selection bias. According to the relatively high response rate of 60 % (114 out of 193 workers), this problem should be reduced.

Another potential problem was misclassification of exposure groups. This concern is minor because the results from validation study were in agreement with the exposure classification. Moreover, in the validation study, the small difference in the means of personal exposure in low and medium exposure groups indicated that exposure distribution in the combined group should be relatively homogeneous, suggesting that exposure misclassification was unlikely. Additionally, more than 90 % of the subjects were employed in their current job longer than 4 years, indicating that job mobility rarely occurred among the participants. This should minimize the possible misclassification of the exposure group.

Smoking and asthma have been considered to be the important potential confounders in the analysis of pulmonary air pollution association, because they have been found to be associated with FEV1 and FVC [24]. However, in this analysis, it was found that smoking was an effect modifier rather than a confounder. Confounding bias from asthma was unlikely in this analysis because nobody reported on asthma, and this can be regarded as a strength of this analysis. In addition, the findings were unlikely to be biased by healthy worker effect because the comparisons were made against active workers, not an external reference population.

5. Conclusions

In summary, it has been demonstrated that occupational exposure to respirable dusts was significantly associated with deficits in FVC, FEV1, and MMEF among aircraft repair workers who were smokers, after adjusting for age, sex, and education, whereas insignificant associations were observed for nonsmokers. Future research may be needed to examine what constituents are responsible for the observed findings. On the other hand, the results indicated that preventive measures and protective devices are needed for the aircraft repair workers even though the concentration of occupational dust does not exceed the allowable standard.

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7. References

[1] Dockery, D. W., Ware, J. H., Ferris, B. G., Speizer, F. E., and Cook, N. R., Change in Pulmonar Function in Children Associated with Air Pollution Episodes, J Air Pollution, Control, Association, Vol. 32; pp. 937-942, 1982.

[2] Chestnut, L., Schwartz, J., Savitz, D. Burchfiel, C., Pulmonary Function and Ambient Particulate Matter: Epidemiological Evidence from NHANES I, Arch Environ Health, Vol. 46; pp. 135-144, 1991.

[3] Pope, C., and Kanner, R., Acute Effects of PM10 Pollution on Pulmonary Function of Smokers with Mild to Moderate Chronic Obstructive Pulmonary Disease, Am Rev Respir Dis, Vol. 147; 1336-1340, 1993.

[4] Raizenne, M., Neas, L. M., Damokosh, A.,I., Dockery, D. W., Spengler, J. D., Koutrakis, P., Ware, J. H., and Speizer, F. E., Health Effects of Acid Aerosols on North America Children: Pulmonary Function, Environ Health Perspect, Vol. 104; pp. 506-514, 1996.

[5] Gauderman, W. J., McConnell, R., Gilliland, F., London, S., Thomas, D., Avol, E., Vora H., Berhane, K., Rappaport, E. B., Lurmann, F., Margolis, and H. G., Peters, J., Association between Air Pollution and Lung Function Growth in Southern California Children, Am J of Respir Crit Care Med., Vol. 162; pp. 1384-1390, 2000.

[6] Tunnicliffe, W. S., O'Hickey, S. P., Fletcher, T. J., Miles, J. F., Burge, P. S., and Ayres, J.G., Pulmonary Function and Respiratory Symptoms in a Population of Airport Workers, Occup Environ Med., Vol. 56; pp. 118-123, 1999.

[7] Kilburn, K.H., Neurobehavioral and Respiratory Findings in Jet Engine Repair Workers: A Comparison of Exposed and Unexposed Volunteers, Environmental Research Section A., Vol. 80; pp. 244-252, 1999.

[8] Lee, I. M., Hennekens, C. H., Trichopoulos, D., and Buring, J. E., Man-made Vitreous Fibers and Risk of Respiratory System Cancer: a Review of the Epidemiologic Evidence, J Occup Environ Med., Vol. 37; pp. 725-738, 1995.

[9] Rosenthal, F. S., Exposure Assessment for Airborne Man-Made Mineral Fibres: The Role of Fibre Dimensions, Ann. Occup. Hyg., Vol. 37; pp. 395-417, 1993.

[10]Infante-Rivard C., Armstrong, B., Petitclerc, M., Cloutier, L., and Thrtiault, G, Lung Cancer Mortality and Silicosis in Quebec, 1938-85, The Lancet., Vol. 23; pp._1504-1506, 1989.

[11] Finkelstein, M. M., Silica, Silicosis, and Lung Cancer, J Occup Environ Med. Vol. 43; pp. 98-201, 2001.

[12] Steenland, K. and Sanderson, W., Lung Cancer Among Industrial Sand Workers Exposed to Crystalline Silica, Am J Epidemiol., Vol. 153; pp. 695-703, 2001.

[13] Smith, A. H., Lopipero, P. A., and Barroga, V. R., Meta-Analysis of Studies of Lung Cancer among Silicotics, Epidemiology, Vol. 6; pp. 617-623, 1995.

[14] Rylander, R., Diseases Associated with Exposure to Plant Dusts: Focus on Cotton Dust, Tubercle and Lung Disease, Vol. 73; pp. 21-26, 1992.

[15] McL, N. R., and Pickering, C. A., Byssinosis: A Review, Thorax, Vol. 51; pp. 632-637, 1996.

[16] ATS Statement., Snowbird Workshop on Standardization of Spirometry, Am Rev Respir Dis, Vol. 119; pp. 831-838, 1979.

[17] ACGIH., TLVs and BELs: Threshold Limit Values for Chemical Substances and Physical Agents Biological Exposure Indices., ACGIH, Ohio, 1997.

[18] U.S. Department of Health and Human Services (DHHS)., The Health Consequences of smoking: Chronic Obstructive Lung Disease. Washington, DC: U.S. Government Printing Office, DHHS (PHS) 84-50205., 1984.

[19] Bates, D. V., Respiratory Function in Disease., 3rd ed., W. B. Saunders., Philadelphia, PA, 1989.

[20] Ericsson, C. H., Svartengran, K. and Svartengran, M. et al., Repeatability of Airway Deposition and Tracheobronchial Clearance Rate over Three Days in Chronic bronchitis, Europ Respir J., Vol. 8; pp. 1886-1893, 1995.

[21] Verra, F., Escudier, E., and Lebargy, F., et al, Ciliary Abnormalities in Bronchial Epithelium of Smokers, Ex-Smokers, and Nonsmckers, Am J Respir Crit Care Med, Vol. 151; pp. 630-634, 1995.

[22] Xu, X. and Wang, L., Synergistic Effects of Air Pollution and Personal Smoking on Adult Pulmonary Function, Arch Environ Health, Vol. 53; pp. 44-53, 1998.

[23] Nomenclature Committee of the Thermal Insulation Manufacturers Association, Man-Made Vitreous Fibers: Nomenclature, Chemistry and Physical Properties, TIMA., Stamford, CT., 1991.

[24] Griffith, K. A., Sherrill, D. L., Siegel, E. M., Manolio, T. A., Bonekat, H. W. and Enright, P.L., Predictors of Loss of Lung Function in the Elderly, The Cardiovascular Health Study, Am J Respir Crit Care Med, Vol. 163; pp. 61-68, 2001.