Pulmonary Function Assessment of Woodworkers Exposed to Mixed Tropical Hardwood Dust in Kumasi

Isaac Ekow Ennin
University of Health and Allied Sciences
Margaret Agyei Frempong
Kwame Nkrumah University of Science and Technology
Francis. A. Yeboah
Kwame Nkrumah University of Science and Technology
Raymond Saa-Eru Maalman (smaalman@gmail.com)
University of Health and Allied Sciences

Research Article

Keywords: lung function, respiratory symptoms, mixed tropical hardwood dust and woodworkers

Posted Date: March 11th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1404710/v1

Abstract

Background

Several studies have shown that exposed woodworkers present frequent respiratory symptoms and reduced lung volumes and airflow values including FVC, FEV_1, FEV_1/FVC and PEFR than controls from the general population. However, other studies have reported no significant negative health effects of wood dust on the respiratory system, no relationship between wood dust and respiratory symptoms, insignificant changes in lung function and normal FEV_1 and FVC values in woodworkers compared to non-exposed controls. The effect of wood dust on the pulmonary function depends on the wood species, phytochemicals present in the wood and the concentration level of ambient air wood dust exposed to the woodworkers. The ambient air dust concentration level at the wood workshops may depend on the humidity and ventilation at the workshops. The workshops at the Sokoban Wood Village are well ventilated. This study aimed at assessing the pulmonary function of woodworkers exposed to mixed tropical hardwood in Kumasi.

Method

The study was carried out among woodworkers, teachers and security men located in Kumasi. A cross-sectional, cluster and convenient sampling of 175 adult male workers were selected (86 woodworkers and 89 non-woodworkers) to participate in the study. Pulmonary function assessment was carried out using a modified version of the British Medical Research Council's (MRC) questionnaire on respiratory symptoms and the spirometer (Alpha Vitalograph) for lung function testing. The relative humidity and the level of wood dust exposure to woodworkers were measured using the personal exposure meter (PATS+: Berkeley Air Monitoring Group).

Results

The mean % relative humidity in the workshop was 67.6 and ambient air wood dust concentration ranged between (0.003–1.02) mg/m^3. The frequency of respiratory symptoms at the workplace was prevalent among the woodworkers ranging between (8–76%) ($p < 0.05$). However, the lung volumes and airflow values were not significantly reduced in the woodworkers ($p > 0.05$).

Conclusion

The study reveals that woodworkers exposed to mixed tropical hardwood dust shows a less frequent respiratory symptoms with an insignificant reduction in the lung volumes and airflow values at the workplace due to low ambient air wood dust concentration.

Introduction

High levels of wood dust exposure to woodworkers have been suggested to cause occupational pulmonary disorders [1]. Woodworkers exposed to wood dust levels ranging from 0.2–7.4mg/m^3 have been reported to suffer from various respiratory symptoms [2]. Bohadana et al. [3] reported bronchial hyper-reactivity in woodworkers exposed to oak and beech dust levels between 2.96 – 12.74 mg/m^3. A study at the Accra Timber Market reported significantly reduced lung volumes and airflow values in workers exposed to tropical hardwood dust levels ranging between 0.19–0.71 mg/m^3 [4]. In another study, Tobin et al.[5], reported the high prevalence of respiratory symptoms particularly cough and phlegm among tropical hardwood workers with a mean exposure level of 1.39 mg/m^3. Earlier epidemiological studies have shown that exposure to both softwood and hardwood dust is associated with several non-malignant health effects such as allergic rhinitis, chronic bronchitis, and allergic asthma [6]. In addition, respiratory symptoms such as sneezing, coughing, phlegm and chest pain have been reported in some woodworkers [2, 5, 7–9]. Respiratory disorders such as obstructive, restrictive, and combined lung function defects and associated respiratory symptoms in exposed woodworkers attributed primarily to airway inflammation [10–13]. Airway inflammation via immune response stimulated by the chemical and mechanical irritants and sensitizing effects of extractive chemicals from wood dust has been reported in woodworkers [10, 11].

Respiratory disorders have been displayed in spirometry as reduced lung function [14, 15]. Many studies have shown in exposed woodworkers reduced lung function parameters including VC, FVC, FEV_1, FEV_1/FVC and PEFR than controls from the general population (16–19]. Jacobsen et al.[20] observed a reduced baseline lung function (FEV_1, FVC or FEV_1/FVC) in woodworkers in several papers they reviewed on woodworkers.

However, several studies have reported no significant negative health effects of wood dust on the respiratory system. In their study, Fransman, et al [22] did not find any relationship between wood dust and respiratory symptoms such as rhinitis. Other studies have also reported of normal FEV_1 and FVC values in woodworkers and no significant changes in lung function of woodworkers compared to non-exposed control [21, 23–26]. Similarly, Tobin et al. [5] reported normal FEV_1 /FVC in woodworkers exposed to tropical hardwood dust. In addition, Baran et al. [8] in their study reported no negative effect of wood dust on the lung function of the woodworkers investigated. Nde et al. [9] in their study among woodworkers exposed to tropical hardwood dust reported no significant difference between the prevalence of abnormalities in lung function of carpenters and the matched non-exposed. In the present study, the pulmonary function of woodworkers exposed to tropical hardwood dust was assessed by determining the ambient air wood dust and the humidity of the workplace, and the status of lung function.

Methods

A cross-sectional survey was used to investigate the pulmonary assessment of tropical woodworkers. The study population comprised of exposed woodworkers selected from Sokoban Wood Village, a wood processing hub in Kumasi Metropolis and non-exposed workers from the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi. Volunteered participants who satisfy the eligibility criteria were studied.

A wood workshop in the Sokoban wood village occupies an area of about 18-36 m^2 with high rise concrete pillars and roofing to improve ventilation and create shelter respectively. About 6 to 8 shops are adjoined to each other in a chain. The workshops do not have walls enclosing them from floor to roof. The wood shavings and wood dust are conveyed intermittently out of the workshop to keep the working environment clean.

Determination of ambient air wood dust

The concentration of ambient air wood dust was measured for eight hours of work. Two machine operators were sampled using personal exposure meters (PATS manufacture: Berkeley Air Monitoring Group) which was strapped on the arms of the participants. The meter was removed after 8 hours and sent to the Environmental Protection Agency (EPA) office in Accra for assessment of the dust exposure levels. The measurements were assisted by technical personnel from the EPA.

Determination of Respiratory symptoms at the workplace

All the participants answered questionnaires on medical history, occupational history, smoking status and respiratory symptoms at the workplace and during vacation by a face-to-face interview in a language of their understanding where necessary. Questions on respiratory symptoms were adapted from the British Medical Research Council's (MRC) questionnaire on respiratory symptoms (1960)

Lung Function Testing

The test was performed using the electronic spirometer Vitalograph Alpha (Vitalograph LTD, Buckingham, England) according to the standards of the American Thoracic Society. The test measured vital capacity (VC), forced vital capacity, (FVC), forced expiratory volume in one second (FEV_1), forced expiratory volume ratio (FEV_1/FVC) and peak expiratory flow rate (PEFR). The test was first explained and demonstrated to participants. Participants performed the test in a standing position with heads up.

All the measurements were taken between the hours of (9:00 am-12:00 noon) to minimize diurnal variation [25]. The precise technique in executing various lung function tests for the study was based on the operational manual of the instrument. The instrument was calibrated daily and operated within the ambient temperature range of 26-28°C.

Data Analysis

The field data were entered directly into Microsoft Excel 2010 statistical package and analysed using STATA version 14. The level of statistical significance was set at a p-value <0.05 and statistical analysis was conducted using the student t-test to compare the lung function indices, between the woodworkers and non-exposed workers. The Fisher exact test was used to determine the frequency of respiratory symptoms at the workplace among woodworkers and non-exposed workers.

Ethical issue

Approval for this research was granted by the Committee on Human Research, Publication and Ethics (CHRPE) of the School of Medical Sciences of Kwame Nkrumah University of Science and Technology (KNUST) and Komfo Anokye Teaching Hospital (KATH) Kumasi, Ghana (Ref: CHRPE/AP/304/15). In addition, permission was obtained from the Sokoban Wood Workers Association as well as the KNUST Primary and Junior High School and the KNUST Security Service for their staff participation. Also informed written consent was obtained from each participant before being enrolled in the study. The nature, purposes and procedures of the study were explained to the association leaders and the participants before seeking their approval.

Results

Demographic Indices of the Study Participants

The study recruited 175 comprising 86 woodworkers and 89 non-exposed workers. Table 1 shows a t-test comparison of the demographic data of the woodworkers and the non-exposed workers. The mean age and height of the woodworkers were significantly different from the non-exposed workers. The woodworkers were much young and taller than the non-exposed workers. However, there was no significant difference in the mean weight of the two groups.

Table 1 Demographic Indices of The Wood Workers and Non-Exposed Workers

Variables	Non-exposed workers	woodworkers	
	n =89	n = 86	p-value
	(mean ± SD)	(mean ± SD)	
Age	42.74 ± 9.43	38.55 ± 11.12	(0.009) *
Height	168.36 ± 6.33	171.10 ± 6.68	(0.004) *
Weight	70.92 ± 12.24	68.35 ± 8.21	0.136

P-values in parentheses; *p<0.01 SD: Standard deviation.

Determination of ambient air wood dust

The concentrations of ambient air wood dust measured within eight working hours are shown in Table 2. The particulate matter (PM) measured was greater than 2.5µm. Levels of inhalable wood dust particles measured at the two sites ranged between 0.003 and 0.102 mg/m^3 at an average ambient temperature of 33°C and relative humidity of 67%. Minimum exposure levels were recorded when the workers were engaged in minimal work within the workshop. The maximum exposure levels were recorded when the woodworkers were actively engaged in their work for a long time.

Table 2 Measurement of ambient air wood dust.

Machine	Mean Temp. ^{o}C	Mean %Relative Humidity	Range of Wood dust level (mg/m^3) Min – Max
1	33.2	67.9	0.005 - 1.02
2	33.1	66.7	0.003 - 0.882

Comparison of the Frequency of Respiratory Symptoms of the woodworkers at Workplace and Non-Exposed Workers.

The frequency of respiratory symptoms among the woodworkers compared with non-exposed workers is shown in Table 3. The frequency of all the respiratory symptoms at the workplace was significantly higher in the woodworkers than the non-exposed workers at ($p<0.05$). None of the 89 non-exposed workers studied reported or showed the presence of any of the listed respiratory symptoms. However, among the woodworkers 8% wheezed, 76% sneezed, 34% had dry cough 30% had cough with phlegm, 34% had frequent fever, 10% had shortness of breath at rest, 29% had shortness of breath after exercise, 24% had a loss of voice and 46.5% reported of catarrh/ rhinitis at the workplace. Most of the woodworkers reported discontinuous or no respiratory symptoms on vacation.

Table 3 Comparison of the Frequency of Respiratory Symptoms of the woodworkers at Workplace and Non-Exposed Workers.

Respiratory symptoms	Non-exposed workers N (%)	Woodworkers N (%)	p-value
Use mask			
No	89(100)	77(89.53)	0.001**
Yes	0	9(10.45)	
Wheeze			
No	89(100.00)	79(91.86)	0.006**
Yes	0	7(8.14)	
Sneeze			
No	89(100.0)	20(23.26)	<0.001***
Yes	0	66(76.74)	
Dry cough			
No	89(100.0)	57(66.28)	<0.001***
Yes	0	29(33.72)	
Cough phlegm			
No	89(100.0)	60(69.77)	<0.001***
Yes	0	26(30.23)	
Freq. fev.			
No	89(100.0)	56(65.12)	<0.001***
Yes	0	30(34.88)	
Short breath res.			
No	89(100.0)	77(89.53)	0.001***
Yes	0	9(10.47)	
Short breath ex.			
No	89(100.0)	61(70.93)	<0.001***
Yes	0	25(29.07)	
Loss voice			
No	89(100.0)	65(75.58)	<0.001***
Yes	0	21(24.42)	
Catarrh			

No	89(100)	46(53.5)	<0.001***
Yes	0	40(46.5)	
On Vacation			
No	89 (100)	83(96.5)	0.03*
Yes	0	3(3.5)	

*P-values in parentheses; *p<0.05, **p<0.01, ***p<0.001; No = absence of symptoms; Yes = occurrence of symptoms*

Comparison of Lung Function Indices among Woodworkers and Non-Exposed Workers.

Table 4 shows the student t-test was used to compare the lung function indices (spirometry values) among the woodworkers and non-exposed workers. Although most of the woodworkers had normal VC values, there was a significant change compared with the non-exposed workers. There were insignificant changes with the other lung function indices (FVC, FEV_1, FEV_1/FVC, and PEFR) of the woodworkers compared with the non-exposed workers.

Table 4 Compared Lung Function Indices between Woodworkers and Non-Exposed Workers

Spirometry values (%pred)	Woodworkers Mean (± SD)	Non-exposed workers Mean (± SD)	T	p-value
VC	90.14 ± 13.75	94.20 ± 11.48	2.12	0.036
FVC	94.56±15.01	97.13±13.45	1.19	0.234
FEV1	98.20±17.91	99.73±14.69	0.62	0.538
FEV1/FVC	103±0.10	104±0.13	-0.79	0.429
PEFR	79.55±18.56	80.11±10.17	-0.81	0.449

P-values; p<0.05, SD: Standard deviation.

Woodworkers with normal lung function indices.

Table 5 shows that more than 75% of the woodworkers had lung function (VC, FVC, FEV_1, and FEV_1/FVC,) values above the normal except PEFR which was 54%.

Table 5 Wood Workers with normal lung function indices

Parameters	Woodworkers Mean %predicted values	Number of Woodworkers with normal values (%) n=86
VC	90.14	68 (78)
FVC	94.56	74 (85)
FEV_1	98.20	74 (82)
FEV/FVC	1.03	77 (89)
PEFR	79.55	47 (54)

Discussion

Level of Wood Dust Exposure

The level of inhalable wood dust at the workplace of the woodworkers measured in this study was in the range of 0.003 – 1.02 mg/m^3. This is low compared with the documented permissible exposure level of countries such as the USA, European Union, Australia, and New Zealand (0.5 mg/m^3 - 5.0 mg/m^3). Moreover, it was also found to be within the lower limits or below some documented exposure levels at which respiratory symptoms have been recorded in other studies. Gripenback et al. [2] reported various respiratory symptoms in woodworkers exposed to wood dust levels ranging from 0.2 – 7.4 mg/m^3. Bohadana et al.[3] observed bronchial hyper-reactivity in woodworkers exposed to dust levels between 2.96 –12.74 mg/m^3. Also, Ennin [4] reported the high frequency of respiratory symptoms in woodworkers exposed to dust levels ranging between 0.19 - 0.71 mg/m^3. This study recorded a high relative humidity at the study site which may contribute to the low wood dust exposure level. High humidity damps inhalable wood dust to increase weight and fall under gravitation force hence reducing the inhalable dust concentration in the air. In the present study, more than 60% of the woodworkers reported no respiratory symptoms at the workplace. Comparing the present study with other previous studies this study suggests that low dust exposure may account for the less frequent respiratory symptoms in woodworkers. This is consistent with the suggestion of Liou et al. [1], that a high level of wood dust exposure to woodworkers leads to occupational respiratory hazards. The present study suggests that high relative humidity may contribute to a low level of wood dust exposure, and this may further contribute to less frequent respiratory symptoms and normal lung function values in the woodworkers.

Frequency of Respiratory Symptoms in woodworkers

Respiratory symptoms in woodworkers are often initiated by irritant stimulation and inflammatory reaction of the airways resulting from an allergic response. A high frequency of respiratory symptoms at the workplace was observed in the woodworkers as compared with the no respiratory symptoms reported in the non-exposed workers. This result is consistent with other studies that have reported a high frequency of respiratory symptoms in woodworkers [5, 9 17-19). This study also observed that more of the woodworkers sneezed or had catarrh /rhinitis at the workplace than other respiratory symptoms. This is consistent with the findings of Jacobsen et al [20] and Soongkhang and Laohasiriwong [17].This finding can be attributed to the presence of irritant molecules or mechanical irritation by the wood dust. However, except for sneezing and catarrh, a greater number of the woodworkers reported no respiratory symptoms at the workplace. This is consistent with the previous study findings [3, 21, 22] who found few or none of the woodworkers in their studies with respiratory symptoms. In addition, most of the woodworkers reported discontinuous or no frequent respiratory symptoms during vacation. This is consistent with the finding of Boskabady et al. [27] who observed that most respiratory and allergic symptoms in carpenters significantly increased during work compared to their rest period. Moreover, the present study observed that virtually all the woodworkers did not wear nose masks while they work, which exposed them to much inhalable dust from the ambient air. This study suggests that the reduced number of woodworkers reporting for respiratory symptoms may be attributed to the low level of wood dust exposure to the woodworkers.

Lung Function Indices Compared between Wood Workers and Non-Exposed Workers

Reduction in the lung function indices is characteristic of respiratory disorders. In the present study, all the lung function values of both woodworkers and the non-exposed workers were within the normal reference range. This suggests that there was no significant negative health effect of the wood dust on the respiratory system of the woodworkers. This is consistent with previous studies [8, 21] who found no negative effects of wood dust on the lungs of the woodworkers they studied. In contrast, other studies have reported a significant reduction in lung function indices and negative health effects in woodworkers [17-19]. Ennin [4] in a study at the Accra Timber Market, reported a significant reduction in the lung function indices of the woodworkers, however, most of the woodworkers were within the normal range. The variation in the results of different studies may be attributed to either the different wood species and/or the different levels of wood dust exposure to woodworkers. The present study, therefore, suggests that a low level of wood dust exposure can contribute to the normal lung function status in woodworkers.

Conclusion

This study reveals that the woodworkers exposed to the mixed tropical hardwood dust shows less frequent respiratory symptoms and normal lung function status due to the high relative humidity and a well-ventilated workshop which may have contributed to a low level of wood dust exposure to woodworkers. Moreover, the study reveals that the woodworkers are at a higher risk of sneezing, catarrh, and dry cough.

Declarations

Ethical approval and consent to participate

The study was carried out in accordance with the guidelines and principles of the Helsinki's Declaration of research involving human participants. The basic ethical principles such as respect for persons; beneficence; and justice were adhered to in the performance of the study. The study received ethical approval from the Committee on Human Research, Publication and Ethics (CHRPE) of the School of Medical Sciences of KNUST and Komfo Anokye Teaching Hospital (KATH) Kumasi. The participation in the study was voluntary and respondents could withdraw at any stage of the data collection process. The anonymity of participants was ensured by using codes for individual answered questionnaire received.

Consent for publication

Not applicable

Availability of data and Materials

The datasets used in the study are available and can be deposited publicly if such is required.

Competing interest

The authors declare that they have no competing interests.

Funding

Partial funding support was obtained from the Central University Research and Training Development Fund.

Author's contributions

IEE made major contributions to the conception and design of the study. OMAF and FAY made a substantial contribution to the study design and management of the research activities. IEE and RSM analysed the data and drafted the manuscript. All authors were involved in critical revision for important intellectual content and approved the finalmanuscript.

Acknowledgement

I am also very grateful to Dr Samuel Dwumor of the Biostatistical Department of School of Public Health, College of Health Sciences, the University of Ghana for his assistance in the statistical analysis. I wish to express my profound gratitude to Mr Oscar of the Physiology Department of SMS KNUST. To the Executives of the Sokoban Wood Workers Association and Oforikrom Wood Workers Association all of Kumasi, the Director of Security Services of KNUST, the Headteachers of KNUST Primary and Junior High Schools for organizing and encouraging their workers and teachers to participate in the study, thank you. To all the participants who were engaged in this study, I am very grateful.

References

1. Liou SH, Cheng SY, Lai FM, Yang JL. Respiratory symptoms and pulmonary function in mill workers exposed to wood dust. American journal of industrial medicine. 1996 Sep;30(3):293-9.
2. Gripenbäck S, Lundgren L, Eklund A, Liden C, Skare L, Tornling G, Grunewald J. Accumulation of eosinophils and T-lymphocytes in the lungs after exposure to pinewood dust. European Respiratory Journal. 2005 Jan 1;25(1):118-24.
3. Bohadana AB, Massin N, Wild P, Toamain JP, Engel S, Goutet P. Symptoms, airway responsiveness, and exposure to dust in beech and oak wood workers. Occupational and environmental medicine. 2000 Apr 1;57(4):268-73.
4. Ennin EI. The effect of wood dust on the lung function of woodworkers at the Accra timber market. (M. Phil.Thesis), College of the Health Sciences University of Ghana. Lambert Academic Publishers. 2009.
5. Tobin EA, Ediagbonya TF, Okojie OH, Asogun DA. Occupational exposure to wood dust and respiratory health status of sawmill workers in South-south Nigeria. Journal of Pollution Effects & Control. 2016 Feb 9:1-6.
6. Enarson DA, Chan-Yeung M. Characterization of health effects of wood dust exposures. American Journal of Industrial Medicine. 1990;17(1):33-8.
7. Meo SA. Lung function in Pakistani wood workers. International journal of environmental health research. 2006 Jun 1;16(03):193-203.
8. Baran S, Swietlik K, Teul I. Lung function: occupational exposure to wood dust. European Journal of Medical Research. 2009 Dec;14(4):1-4.
9. Nde F, Mbatohou H, Nebo J, Djomo A, Tsafack P, Brouwer CD. Respiratory symptoms and pulmonary function test among informal sector workers exposed to wood dust in Douala, Cameroon. J Allerg Therapy. 2015;6(6):1-4.
10. Woods B, Calnan CD. Toxic woods. British Journal of Dermatology. 1976 Jul;94:1-
11. Johard U, Eklund A, Dahlqvist M, Ahlander A, Alexandersson R, Ekholm U, Tornling G, Ulfvarsson U. Signs of alveolar inflammation in non-smoking Swedish wood trimmers. Occupational and Environmental Medicine. 1992 Jun 1;49(6):428-34.
12. Long H, Shi T, Borm PJ, Määttä J, Husgafvel-Pursiainen K, Savolainen K, Krombach F. ROS-mediated TNF-α and MIP-2 gene expression in alveolar macrophages exposed to pine dust. Particle and fibre toxicology. 2004 Dec;1(1):1-8.
13. Määttä J, Lehto M, Leino M, Tillander S, Haapakoski R, Majuri ML, Wolff H, Rautio S, Welling I, Husgafvel-Pursiainen K, Savolainen K. Mechanisms of particle-induced pulmonary inflammation in a mouse model: exposure to wood dust. Toxicological Sciences. 2006 Sep 1;93(1):96-104.
14. Balmes J, Becklake M, Blanc P, Henneberger P. American Thoracic Society Statement: Occupational contribution to the burden of airway disease. American journal of respiratory and critical care medicine. 2003 Mar 1;167(5):787.

15. Iyawe VI, Ebomoyi MI. Current developments in the physiology and management of asthma. Nigerian Journal of Physiological Sciences. 2005;20(1):19-29.
16. Okwari OO, Antai AB, Owu DU, Peters EJ, Osim EE. Lung function status of workers exposed to wood dust in timber markets in Calabar, Nigeria. African Journal of Medicine and Medical Sciences. 2005 Jun 1;34(2):141-5.
17. Soongkhang I, Laohasiriwong W. Respiratory tract problems among wood furniture manufacturing factory workers in the northeast of Thailand. Kathmandu University Medical Journal. 2015;13(2):125-9.
18. Löfstedt H, Hagström K, Bryngelsson IL, Holmström M, Rask-Andersen A. Respiratory symptoms and lung function in relation to wood dust and monoterpene exposure in the wood pellet industry. Upsala journal of medical sciences. 2017 Apr 3;122(2):78-84.
19. Thepaksorn P, Fadrilan-Camacho VF, Siriwong W. Respiratory symptoms and ventilatory function defects among Para rubber wood sawmill workers in the South of Thailand. Human and Ecological Risk Assessment: An International Journal. 2017 May 19;23(4):788-97.
20. Jacobsen G, Schaumburg I, Sigsgaard T, Schlunssen V. Non-malignant respiratory diseases and occupational exposure to wood dust. Part I. Fresh wood and mixed wood industry. Annals of Agricultural and Environmental Medicine. 2010;17(1):15-28.
21. Borm PJ, Jetten M, Hidayat S, Van de Burgh N, Leunissen P, Kant I, Houba R, Soeprapto H. Respiratory symptoms, lung function, and nasal cellularity in Indonesian wood workers: a dose-response analysis. Occupational and environmental medicine. 2002 May 1;59(5):338-44.
22. Fransman W, McLEAN DA, Douwes J, DEMERS PA, Leung V, Pearce N. Respiratory symptoms and occupational exposures in New Zealand plywood mill workers. Annals of occupational hygiene. 2003 Jun 1;47(4):287-95.
23. Halpin DM, Graneek BJ, Lacey J, Nieuwenhuijsen MJ, Williamson PA, Venables KM, Taylor AN. Respiratory symptoms, immunological responses, and aeroallergen concentrations at a sawmill. Occupational and Environmental Medicine. 1994 Mar 1;51(3):165-72.
24. Dahlqvist M, Ulfvarson U. Acute effects on forced expiratory volume in one second and longitudinal change in pulmonary function among wood trimmers. American journal of industrial medicine. 1994 Apr;25(4):551-8.
25. GLiNDMEYER HW, Lefante JJ, Jones RN, Rando RJ, Weill HA. Cotton dust and across-shift change in FEV1 as predictors of annual change in FEV1. American journal of respiratory and critical care medicine. 1994 Mar;149(3):584-90.
26. Rusca S, Charrière N, Droz PO, Oppliger A. Effects of bioaerosol exposure on work-related symptoms among Swiss sawmill workers. International archives of occupational and environmental health. 2008 Feb;81(4):415-21.
27. Boskabady MH, Rezaiyan MK, Navabi I, Shafiei S, Arab SS. Work-related respiratory symptoms and pulmonary function tests in northeast iranian (the city of Mashhad) carpenters. Clinics. 2010;65(10):1003-7.