Spirometric Measurement among Polyurethane Foam Mattress-making Workers of India

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Abstract

Background: The polyurethane foam (PUF) mattress-making workers are exposed to isocyanates which are known respiratory toxicants and cause effect on pulmonary volumes and flows. Thus, the study was with a rationale to measure the changes in pulmonary flow and volumes due to isocyanates among PUF mattress-making workers. **Materials and Methods:** The study included 183 male workers from seven PUF making units of western and northern India. Using the interview technique as a tool for data collection, demographic and occupational details of the subjects were recorded on the predesigned and pretested pro forma. The mean of spirometric parameters was compared using one-way ANOVA and *t*-test. The relation between spirometric parameters and anthropometric parameters was analyzed using the correlation coefficient. **Results:** The spirometry showed that out of 183 participants, 165 (90.2%) subjects had normal spirometry, 13 (7.1%) had restrictive impairment, and 4 (2.2%) had obstructive impairment. All the mean spirometric values showed a declining trend with increasing age, while only forced expiratory volume in first second and forced vital capacity$_{25\%–75\%}$ showed a declining trend with increasing duration of employment. The spirometric measurements had a negative correlation with age and positive correlation with height. **Conclusion:** The spirometric values representing the airway flow were affected. The associated factors include age and duration of exposure.

Keywords: Isocyanates, mattress workers, polyurethane foam, spirometry

Introduction

The industrial workers are exposed to various chemicals at their workplaces that may exist in the form of dust, gas, vapors, mist, etc., mostly through inhalation route often affecting the respiratory system. In the polyurethane foam (PUF) mattress-making industry, toluene di-isocyanate (TDI) which is commonly used as a raw material is one such respiratory toxicant.[1]

The processes in the mattress-making industry include "foaming" where the raw materials (TDI, ethylene glycol, and CO_2) are mixed to create the PUF which is then cut into pieces by block cutting machines and kept in the open area for curing. Foaming process exposes the workers to a maximum concentration of gaseous isocyanate while those working at the loading/unloading section are exposed to isocyanate in the form of foam dust.

Isocyanates are known agents for causing occupational asthma.[2,3] Inhalation of di-isocyanate vapors is also associated with numerous pulmonary disorders, such as eosinophilic airway inflammation, airway hyper-responsiveness, and hypersensitivity pneumonitis.[4-7] Thus, these toxicities of isocyanate also result in impairment of the pulmonary functions.

Spirometry is an important diagnostic as well as prognostic test, particularly for occupational respiratory diseases. It is a simple and inexpensive method to measure disorders of respiratory tract.[8] The type of respiratory pathology and its severity can be assessed through changes in major pulmonary function parameters like forced expiratory volume in first second (FEV_1), forced vital capacity (FVC), FEV_1/FVC%, and peak expiratory flow rate.[9,10] However, the percentage predicted value of these parameters is considered a much better indicator of respiratory disorders.[11,12] In addition, the changes

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in the smaller airways can also be assessed as indicated by the parameters such as $FEF_{25\%–75\%}$.

There is a scarcity of information about the respiratory conditions of PUF mattress-making workers from India where units are small or medium scale units and thereby lack the measures suggested for the occupational health of the employed workers. Thus, the present study was undertaken among the male workers of PUF mattress-making units to study the effect of isocyanate exposure on the spirometric parameters and the factors associated with such effects.

Materials and Methods

The present cross-sectional study included 183 male workers from seven PUF mattress-making units of western and northern India. All the workers working in selected polyurethane units on the day of study and consented were included in the study. The ethical approval was obtained from the Institutional Ethics Committee and written informed consent of all the study participants was obtained before initiating the study. Demographic, occupational, and clinical details of the participants were recorded on the predesigned and pretested pro forma.

The Spirovit SP-10 (Maker Schiller AG, Switzerland) was used to measure the spirometric parameters. After daily calibrating the spirometer according to the procedure given in the catalog, three successive recordings of FVC, FEV_1, $FEF_{0.2–1.2}$, and $FEF_{25\%–75\%}$ were made in standing posture and the nose clip was used. The readings showing the highest value were taken for further analysis considering it as the participant's best effort. The FEV_1/FVC ratio (FEV_1%) was calculated from the same tracings. Body height and body weight were measured in bare feet on a standard scale. Predicted FVC for each individual was calculated using Kamat's equation.[13]

On the basis of the predicted and observed values, the pulmonary function impairment was labeled as "obstructive" "restrictive" and "combined" according to the standard definition.[14] The FVC and FEV_1 were expressed in liters, $FEF_{25\%–75\%}$ and $FEF_{0.2–1.2}$ in lit/sec, and FEV_1/FVC ratio was expressed as %. Body mass index (BMI) was calculated in kg/m^2 and categorized as per the WHO classification.[15] Age and duration of exposure were arbitrarily categorized into groups. Statistical analysis was carried out using the statistical software package SPSS Version 25.0 (IBM, New York, US). The mean of spirometric parameters was compared using one-way ANOVA and *t*-test. The relation between spirometric parameters and anthropometric parameters was analyzed using correlation coefficient.

Results

The basic characteristics of the study participants are depicted in Table 1. The distribution of mean spirometric values according to study variables is shown in Table 2. It was found that the mean values of all the five spirometric parameters had a declining trend with the increasing age. A declining trend in the mean values of spirometric values with increasing duration of exposure by virtue of occupation was also observed. However, the difference was statistically significant only for FEV_1 and $FEF_{25\%–75\%}$. The smokers had lower values for all the parameters as compared to nonsmokers though nonsignificantly. Further, the supervisory staff and maintenance workers had higher mean values as compared to the highly exposed workers employed in cutting or loading/unloading processes. Surprisingly, the workers involved in foaming considered to be exposed to the highest concentration of chemicals had the highest values for almost all the studied spirometric parameters, but all the differences were statistically nonsignificant. Similarly, those having symptoms had lower values than those free from symptoms though statistically nonsignificant.

The correlation of spirometric values according to anthropometric parameters such as age, height, weight, and BMI is shown in Table 3. A statistically significant negative correlation was observed between age and all the spirometric parameters, while a positive correlation was observed between height and spirometric parameters. Only FVC and FEV_1 were found to be positively correlated with weight and the correlation was statistically significant.

Discussion

The categorization of spirometry on the basis of FVC and FEV_1/FVC ratio showed that out of 183 participants, 165 (90.2%) subjects had normal spirometry, 13 (7.1%) had restrictive impairment, 4 (2.2%) had obstructive impairment, and only one participant had restrictive as well as obstructive pulmonary function impairment. Such a high proportion of participants having normal spirometry can partly be attributed to one-point measurement only owing to the migrant nature of the workers. Earlier studies have also shown occupational asthma among polyurethane workers and >15% decline in FEV_1 on one of the days of spirometric testing over the 5-year period.[16] Similarly, in another study among thirty PUF

Table 1: Basic characteristics of the study population

Characteristics	*n*=183
Mean age (years)	29.21±9.3
Median duration of job (years)	5.0
Median income (Rs.)	4500
Number of smokers, *n* (%)	31 (16.9)
Number of tobacco chewers, *n* (%)	91 (49.7)
Number of alcohol drinkers, *n* (%)	63 (34.4)
Number of vegetarians, *n* (%)	74 (40.4)
Mean height (cm)	163.55±6.9
Mean weight (kg)	53.96±9.3
Mean observed FVC (l)	3.24±0.57
Mean observed FEV_1 (l)	2.83±0.57
Mean observed FEV_1% (%)	86.82±10.14
Mean observed $FEF_{0.2-1.2}$ (l/s)	5.85±1.72
Mean observed $FEF_{25\%-75\%}$ (l/s)	3.58±1.19

FEV1: Forced expiratory volume in 1 s, FVC: Forced vital capacity, FEF: Forced expiratory flow

Table 2: Distribution of spirometric values according to the study variables

	n	FVC (l)	FEV_1 (l)	FVC/FEV_1 (%)	$FEF_{0.2-1.2}$ (l/s)	$FEF_{25\%-75\%}$ (l/s)
Age group						
<20	39	3.19±0.65	2.92±0.59	89.2±15.3	5.79±1.3	3.89±0.99
21-30	73	3.42±0.49	2.99±0.51	87.3±8.1	6.29±1.60	3.81±1.28
31-40	49	3.12±0.58	2.68±0.53	85.9±6.8	5.63±1.95	3.31±1.11
≥40	22	2.98±0.50	2.46±0.57	83.1±10.4	4.97±1.83	2.84±1.05
F-ratio; P		4.89; 0.003*	7.39; 0.000*	1.92; 0.127	3.99; 0.009*	5.79; 0.001*
Duration of exposure (years)						
≤5	101	3.28±0.58	2.92±0.56	87.8±11.6	5.95±1.68	3.74±1.19
6-10	42	3.27±0.58	2.86±0.56	87.7±5.9	6.05±1.69	3.74±1.22
≥11	40	3.09±0.51	2.59±0.54	83.4±9.1	5.37±1.77	3.01±1.05
F-ratio; *P*		1.69; 0.188	4.94; 0.008*	2.83; 0.062	2.08; 0.127	5.97; 0.003*
Smoking habits						
Nonsmokers	31	3.07±0.80	2.70±0.75	84.7±17.3	5.57±1.94	3.41±1.41
Smokers	152	3.27±0.51	2.86±0.52	87.3±7.9	5.90±1.67	3.61±1.15
F-ratio; *P*		3.29; 0.071	2.22; 0.138	1.61; 0.206	0.92; 0.34	0.73; 0.395
BMI group						
Undernourished	52	3.19±0.66	2.89±0.64	88.0±14.2	5.92±1.76	3.88±1.34
Normal	117	3.27±0.54	2.83±0.55	86.2±8.3	5.79±1.72	3.44±1.13
Overweight	14	3.11±0.49	2.67±0.44	87.9±4.8	5.96±1.56	3.60±1.03
F-ratio; *P*		0.64; 0.527	0.87; 0.422	0.68; 0.508	0.13; 0.878	2.52; 0.083
Department of work						
Vertical cutting	42	3.08±0.56	2.69±0.54	87.2±7.5	5.60±1.75	3.45±1.35
Foaming	24	3.32±0.56	2.92±0.52	89.3±4.9	6.08±1.62	3.75±1.02
Loading/unloading	52	3.18±0.67	2.79±0.68	85.7±15.2	5.56±1.74	3.49±1.25
Circular cutting	17	3.10±0.51	2.74±0.47	88.1±6.5	6.18±1.84	3.46±1.19
Supervisory staff	41	3.42±0.41	2.97±0.47	86.1±8.5	6.21±1.67	3.79±1.11
Maintenance	7	3.59±0.59	3.07±0.57	85.3±4.7	5.67±1.53	3.48±1.13
F-ratio; *P*		2.46; 0.035*	1.57; 0.172	0.56; 0.73	1.061; 0.384	0.545; 0.742
Symptoms						
Present	8	3.32±0.52	2.75±0.66	82.2±10.5	5.41±1.95	2.94±1.29
Absent	175	3.23±0.57	2.84±0.56	87.0±10.1	5.87±1.71	3.61±1.19
F-ratio; *P*		0.16; 0.692	0.19; 0.668	1.78; 0.184	0.55; 0.46	2.37; 0.125

*Significant. FEV1: Forced expiratory volume in 1 s, FVC: Forced vital capacity, FEF: Forced expiratory flow

Table 3: Correlation of spirometric parameters with anthropometric parameters

Spirometric parameters	Age	Height	Weight	BMI
FVC	−0.225**	0.442**	0.274**	0.055
FEV_1	−0.331**	0.0364**	0.151*	−0.038
FEV_1%	−0.184*	−0.116*	−0.092	−0.038
$FEF_{0.2-1.2}$	−0.181*	0.172*	0.118	0.045
$FEF_{25\%-75\%}$	−0.303**	0.148*	−0.004	−0.079

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level. FEV_1: Forced expiratory volume in 1 s, FVC: Forced vital capacity, FEF: Forced expiratory flow, BMI: Body mass index

workers, spirometric changes of bronchial obstruction of a mild degree were observed in five workers.[17]

All the spirometric parameters have shown a declining trend with increasing age. Aging results in structural changes to the thoracic cage thereby causing a reduction in chest wall compliance. Causing FVC to decrease.[18] This was further substantiated by the significant negative correlation between spirometric parameters and age. Earlier studies among workers exposed to TDI have also reported similar findings.[17,19]

A significant decline in FEV_1 and $FEF_{25\%-75\%}$ was observed with increasing duration of employment indicating that both the larger and smaller airways are affected due to cumulative exposure to isocyanates in PUF mattress-making industry. Initially, isocyanates may exert an effect through bronchial hyper-responsiveness and bronchospasm which, with continual exposure, may result in permanent changes such as formation of mucosal plugs.

The smokers had lower values for all the parameters though statistically nonsignificant, probably due to few smokers in the study group. Furthermore, as the industries do not allow smoking in their premises, the lower prevalence of smoking could be due to underreporting. However, smoking is a well-known factor causing irritation of the respiratory mucosa resulting in hypertrophy of mucosal epithelial cells as reported in earlier studies.[20]

The analysis of effect of BMI on spirometric values revealed that overweight participants had lower values of FVC as compared to those who had normal BMI. The difference was statistically nonsignificant. The earlier studies have reported that the obesity decreases the lung compliance by elevating the position of the diaphragm in the thoracic cavity causing a decline of pulmonary function.[21,22] and by fat accumulation on the chest, wall thereby affecting the normal function of intercostal muscles.[23] It is also reported that the release of inflammatory markers in the lung such as leptin will affect mainly the lung tissue rather than airways.[24] This could be the reason why smaller airway parameters were not affected by BMI in the current study.

During the making of PUF, the foaming process gives rise to maximum exposure to isocyanates and thereby expected to result in maximum reduction of spirometric values. Surprisingly, the spirometric values were not lowest among the "foaming" workers. This could be due to the smaller sample size of foaming process workers. Foaming is considered as a specialized process and very few skilled workers are employed in it. Working in multiple processes could be another reason for nonsignificant variation in spirometric values according to process. The supervisory or maintenance workers, who are considered to be nonexposed or least exposed, had higher values than other process workers such as cutting, foaming, and loading/unloading.

The study had several limitations. The pre- and postshift personal monitoring could have given the individual exposure status as well as degree of change attributable to work. This could not be done due to feasibility issues. However, the area monitoring revealed that in foaming and block cutting areas, the levels of TDI were beyond the permissible levels of 0.5 ppm suggesting higher exposure. In addition, smaller sample size for some categories of variables requires precautions while generalizing the results.

Exposure to such chemicals, particularly in low concentration, results in the initiation of sensitization which may exhibit as overt symptom or disease after a latent period extending from several months to years. As many of these workers are migrant workers, they are not available for long-term follow-up. This might have resulted in the underestimation of the magnitude of problem. Thus, it is also recommended to develop a central database of these workers for long-term follow-up.

Conclusion

Thus, the spirometric values, particularly those representing the airway flow, were significantly affected. The associated factors include age and duration of exposure. Thus, it is recommended that the workers' respiratory health should be periodically monitored using clinical examination and spirometry as a tool. Further, those found to have abnormal spirometric values should be relocated to the processes resulting in no or minimal exposure and they should be thoroughly investigated and appropriately treated if required.

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Conflicts of interest

There are no conflicts of interest.

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