Pulmonary Effects of Exposure to Synthetic Fibers: A Case Study in a Textile Industry in Iran

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A-R-T-I-C-L-E I-N-F-O

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Background & Aims of the Study: Industries continue to develop and use of various types of manmade fibers nowadays. Acrylic fiber is one of the most important synthetic fibers that use in industries. Based on this fact that, little information exists about workplaces exposure to acrylic fibers, purpose of this study is to determine so this study has been done for evaluation of the pulmonary effects of acrylic fiber.

Materials & Methods: This cross sectional study has been done in a textile industry on 60 male workers in Qom province of Iran in 2014. The stratified random sampling was used for sampling, as each hall was regarded a class. The number of subjects who employed in spinning, weaving, finishing and pocketing halls was 26, 12, 12 and 10 respectively. The NIOSH method, 600 was utilized for respirabale dust sampling. Subjects were interviewed and respiratory symptom questionnaire were administrated to all of them. The pulmonary functioning indices were FVC, FEV1/FVC, FEV1 and FEF 25%-75%. The data were statically analyzed using one sample t-test, Pearson Correlation Coefficient Test, one way analysis of variance, where applicable with a preset probability of (P<0.05) by using SPSS V16.

Results: The highest level of personal exposure to the dust was observed in spinning and weaving Halls (9.07-12.45 mg/m3). In the spinning and weaving, the exposure to the respirable dust was less and the exposure to total dust was more than TLV-TWA. There was no significant relation among pulmonary performance and working experience, age, body mass index and using respiratory protection equipment (P>0.05). There is a significant inverse relation between the concentration of respirable dust and the variables related to the respiratory parameters.

Conclusions: The total exposure value in spinning and weaving halls is higher than the TLV-TWA. There is high possibility for the emergence of early stages of disorders related to the obstructions of airways, especially in alveolar duct, in employees who work in the aforesaid halls. Modified engineering controls in these situations are recommended.

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Background

Industries continue to develop and use of various types of manmade fibers especially since restrictions were placed on the use of asbestos, a toxic and carcinogenic mineral fiber (1). Manmade fibers fall naturally into two broad groups; natural polymer fibers (in which the fiber-forming material is of natural origin) such as Rayons, Cellulose Ester fibers, Protein fibers and Silica fibers and in the other hands synthetic fibers (in which the fiber-forming material is made from simpler substances) such as Polyamide, Polyester and Polyvinyl derivative fibers (2).

Acrylic fiber or Polyacrylonitrile (PAN) is a synthetic fiber that closely resembles wool in its character. According to the definition of the ISO fibers composed of linear macromolecules

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having in the chain at least 85% by mass Acrylonitrile (CH$_2$-CHCN) repeating units are Acrylic fibers (3). Worldwide production of Acrylic fibers shows that this type of synthetic fibers is widely used in the world. Acrylic fibers are used for making knitted products such as sweater, socks, bedding textiles such as blankets and pile sheets, home furnishings such as carpets and industrial use (4). Therefore large numbers of workers are occupationally exposed to Acrylic fibers.

Harmful effect of some synthetic fibers like as Vitreous, Aramid and Nylon fibers on humans' body and some clinical animals was well established by some researches (5-9). The main occupational hazard in using Acrylic fibers in textile industry is dust and the chemically is classified as a relatively harmless, nuisance dust with threshold limit value (TLV-TWA) of 10 mg/m3 by American conference of governmental industrial hygienist (ACGIH) (10) or permissible exposure value (PEL-TWA) 15 mg/m3 occupational safety and health administration (OSHA) (11). This type of dust can lead to Lung diseases (12-13). Such diseases are caused through exposure to irritants in work-places, though work-related diseases are preventable (14). Based on the authors' knowledge, to date, no systematic study has been carried out to assess the extent of textile workers exposure to acrylic fibers. Additionally, no information exists as to the respiratory health of workers who exposed to acrylic fibers.

Aims of the study: The aims of this study is two main issues, 1) assessment of the degree of workers' exposure to acrylic fibers and 2) understand and clearing about if exposure to acrylic fiber dusts was associated with any acute or chronic significant decrements in the parameters of pulmonary function.

Materials & Methods

This cross-sectional study was carried out at a textile industry in Qom province of Iran in 2014. Significant error was considered 5

percent. The maximum of acceptable error in measuring the average pulmonary function is set equals to 1 ml. As well as, due to the resulted standard deviation in pilot measuring of the related industry, σ^2 were 25 and the minimum required samples for the society was determined as 54 people. However due to the comparisons between groups and the presence of auxiliary variables, this number increased to 60. In accordance with the analytical studies, for each case, one control should have been considered, and the number of people in control group was considered as 60 people. Thus from 120 workers who employed in 4 different halls, 60 male subjects are selected.

$$n = (\frac{z_{1-\frac{\alpha}{2}} \times \sigma}{d})^2 = \frac{(1.96)^2 \times (5)^2}{1} = 96.04$$

$$n' = \frac{n}{1+\frac{n}{N}} = \frac{96}{1+\frac{96}{120}} = 53.33 \approx 60$$

In order to selecting subjects the stratified random sampling method was used. According to the method the number of subject in spinning, weaving, finishing and pocketing halls were 26, 12, 12 and 10 respectively. It is worthy of mentioning that samples of less than one year working experience and those who have chronic cardiovascular and pulmonary diseases were removed from the samples. Simultaneously, 60 healthy men were chosen randomly for control group from the administrative departments of the textile industry and from among those who were not exposed to PAN. Both groups were volunteer subjects. The study was conducted in accordance with the Helsinki declaration. All participants signed an informed consent form before commencement of the study.

The prevalence of respiratory symptoms and changes in lung function values were studied in both groups by cooperation of the Specialized Center for Occupational Medicine Services and an occupational medicine physician. It is worthy of mentioning that in order to minimize

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the effects of confounding variables, workers with working experience of less than one year and with chronic respiratory, asthma, allergies and history of infectious diseases excluded from the study. Subjects were interviewed and respiratory symptom questionnaire, as suggested by the American Thoracic Society (ATS, 1978) (15) were administrated to all of them. This standardized questionnaire included questions on respiratory, nasal and eye symptoms, smoking habits, medical and family history of each subject. Additionally, it contained detailed occupational history and specific questions regarding all jobs held before employment at the plant under study, particularly those associated with the risk of respiratory morbidity. These, were then used to obtain symptom prevalence data among exposed and non-exposed groups.

Measurement of PAN Dust

To assess the extent to which workers had been exposed to PAN dust, personal dust monitoring for airborne inhalable (particle size ≥ 5 μm) and respirable fractions (particle size < 5 μm) was carried out at different saloon. According to the studies of authors, to date, No specified standard sampling method exists for occupational exposure to PAN. Therefore, routine gravimetric sampling method was used for personal monitoring. NIOSH Manual Analytical Method 0600 was used for this purpose (16). To evaluate the airborne dust concentration, a 10 ml aluminum cyclone produced by SKC Company calibrated by a digital automatic calibrator connected to a filter holder equipped with a 25 mm PVC filter with 5 micrometer pore-size through which the air was aspirated by a sampling pump at a constant flow rate of 2.5 liters per minute was used. For comparing the dust exposure measuring data with the Threshold Limit Value-Time Weighted Average (TLV-TWA) provided by ACGIH (American Conference of Governmental Industrial Hygienists) and Permissible Exposure Limit (PEL) provided by OSHA (Occupational Health and Safety

Administration), the sampling was done in breathing zone of employees for 8 hours. It worthy of mentioning that the factory production rate in most of the time was constant so that the measured dust data would be compared to threshold limit values without any extra calculation. Dust concentration expressed in mg/m^3 was calculated from changes in the filter (for respirable fraction) or cyclone collector weight (for inhalable fraction), as measured by a digital scale at a sensitivity of 0.001 mg, before and after sampling, divided by the volume of air sampled. In order to remove the possible errors of changes in samples caused through handling, the samples were weighted immediately in the laboratory of studied industry. Additionally the sampling was adapted due to the related atmosphere so as to remove confounding variables such as temperature and barometric pressure.

Pulmonary function test

Pulmonary function tests (PFTs), including forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1), FEV_1/FVC and forced expiatory flow at 25% -75% ($FEF_{25\%-75\%}$) followed guidelines given by the ATS (17) and measured with a portable calibrated Vitalograph spirometer (Vitalogarph-Compact, Buckingham- England) on site. The spirometer was calibrated twice a day with 1-liter syringe in accordance to the standard protocol for the instrument used. The mean percentage predicted value was based on subject age, body mass index (BMI), sex, and ethnic group as calculated and adjusted by the spirometer device. Subjects were requested not to take shower or smoke for at least two hours prior to the test. Additionally, they were trained to become familiar with the maneuvers. The standing height and weight of each subject measured in his normal working clothes. Before the test they rested in a sitting position for about 5 minutes. They were then asked to stand in front of the spirometer, as comfortable as possible, and a nose clip was put on. At least, three acceptable maneuvers were performed. If

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subject showed great variability among the various FVC volumes, up to 5 maneuvers were obtained (18). The largest volumes (as percentage predicted lung function) were selected for analysis (19). The percentage predicted lung values were observed capacities a measured by a spirometer divided by predicted or expected capacities multiple by 100. Spirograms were evaluated and interpreted by occupational medicine physician.

The data were statistically analyzed using one sample t-test, Pearson Correlation Coefficient Test, one way analysis of variance, where applicable (with a preset probability of (P<0.05). Experimental results are presented as arithmetic Mean±SD. Statistical tests were conducted using SPSS V16.

Results

In the present analysis, 60 samples were chosen randomly and after the initial evaluation, 59 cases were confirmed (according to the research method, one subject was removed from samples for having less than one year of working experience). Among those male workers who were finally chosen, 25 persons worked in the spinning hall, 11 persons worked in weaving hall, 12 persons worked in the finishing hall and 10 persons worked in the pocketing hall. According to the results attained through the questionnaires and their pre-employment medical examination records, it was found that none of those employees were smokers and none suffered from pulmonary disorders (Table 1)

Table 1) studied variables in case and control groups

Variable	n	Case Group Mean ± SD*	Min	Max	Control Group Mean ± SD*	Min	Max
Age (year)	59	29.25±4.9	20	41	33.5±4.9	26	42
BMI	59	24.2±3.3	18.01	31.1	24.7±3.4	18.9	30.4
Current Age of Employee (year)	59	*4.61±4*	1	14	4.6±2.2	1	8
Employee's age at previous work (year)	34	4.4±3.8	1	15	2.7±2.5	0	12
Average overtime in month (hour)	59	74.8 ±35.5	0	150	0	0	0
Regular sport activity (hour)	59	0.2±0.37	0	1	0.06±0.23	0	1
Respirable (mg/m^3)	59	0.02±0.01	0	0.06	-	-	-
FEF$_{25\%-75\%}$ (L/S)	59	4.39±0.7	2.7	5.7	4.7±0.7	35	6.3
FVC (L))	59	4.75±0.5	3.47	5.72	4.9±0.6	3.9	6.39
FEV$_1$ (L)	59	4.04±0.4	3	4.87	4.2±0.5	3.4	5.6
FEV$_1$/FVC (%)	59	84.9±6.91	74.7	123.06	85.2±4.7	74.9	93.1

All workers work in three rotational shift works, and one of them (1.69%) had a secondary job. Among those 59 subjects participating in the study 57.62%, prior to their employment in textile industry, had worked in other industries, however, in accordance with their pre-employment examination in textile industry, their previous job(s) had caused them no health problem. In turn 33.9%, 18.4% and 23.73% of participant used respiratory protection equipment for 2-4 hours (25-50%),

for 4-6 hours (50-75%) and for 6-8 hours (75-100%) during their working time.

There was a significant difference among respirable dust and total dusts between of spinning and finishing halls in one side and pocketing hall in the other side (P=0.001), however there is no significant difference between the average of personal exposure to dust in spinning and weaving halls (P=0.89) (Table2).

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Table 2) The average of personal exposure to total and respirable dust

Particles	Hall	No.	Average	Standard Deviation	Min	Max	Standard (mg/m³) ACGIH	Standard (mg/m³) OSHA
	Spinning	26	0.03	0.01	0.01	0.06	3	5
	Weaving	11	0.03	0.01	0.01	0.05	3	5
Respirable	Finishing	12	0.00	0.00	0.00	0.01	3	5
	Pocketing	10	0.00	0.00	0.00	0.00	3	5
	Total	59	0.02	0.01	0.00	0.06	3	5
	Spinning	26	10.53	1.00	9.07	12.04	10	15
	Weaving	11	10.98	0.93	10.01	12.45	10	15
Total	Finishing	12	0.01	0.00	0.01	0.02	10	15
	Pocketing	10	0.01	0.01	0.01	0.04	10	15
	Total	59	6.69	5.25	0.01	12.45	10	15

There was a difference, between the averages of the total dust in spinning and weaving halls with 10 mg/m³ threshold limit value (P≤0.05), the average of the total dust were higher. It was less than 15 mg/m³ (PEL-TWA for total dust) provided by OSHA.

Four variables named $FEF_{25\%-75\%}$, FVC, FEV_1 and FEV_1/FVC were culled for determining the correlation between employees' pulmonary function and their current type of work, then they were analyzed through unidirectional variance analysis method on the basis of weighted least squares method.

Pairwise comparisons between groups through Bonferroni method shows that there is a significant statistical difference between the FEF of employees working in spinning and weaving saloons and those working in pocketing and finishing saloons. There was no paired mean difference between other groups.

Additionally due to the results of post-hoc test and 95% confidence intervals for differences between averages, the average difference between 25-75% FEF of the control group and the worker of spinning and weaving was significant (P≤0.05).

Regarding Pearson Correlation Coefficient Test, there is a significant statistical correlation between respirable dust and variables related to respiratory parameters (Table3) as the increase in respirable dust leads to the decrease of respiratory parameters. In order to determine the correlation of employees' pulmonary functions with their working duration, Pearson Correlation Coefficient Test was used too, thereby according to the results of the said test, there was no significant correlation between employees' working duration and variables related to respiratory parameters (Table3).

Table 3) Results of the test examining the relation between respirable dust, working duration and employees' pulmonary functions

Variable		Res	FVC	FEF	FEV₁	FEV/FVC
Respirable dust	The Correlation Coefficient	1	-0.315	-0.343	-0.327	-0.332
	P-value	-	0.015	0.008	0.012	0.08
Working Duration (year)	The Correlation Coefficient	1	0.08	0.02	0.16	0.04
	P-value	-	0.53	0.86	0.22	0.7

relying on the least squares, for comparing the mean difference between FEV_1, FVC and

FEV_1/FVC on the basis of work type shows that there is no significant statistical difference

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between groups (case and control) (P>0.05). Therefore in accordance with the results of the present study, there was no linear correlation between employee's age and their pulmonary performance.

For examining the association between pulmonary functions and using respiratory protection equipment, statistically no significant difference was observed between the pulmonary function and the mean time of using respiratory protection equipment, thereby the results showed that all FEV_1/FVC, FEV_1, FVC and $FEF_{25-75\%}$ parameters in people who used respiratory protection equipment during 75-100% of their working-hours, are higher than in other people. There was also no significant relation between the employees' pulmonary function and their body mass index (BMI) (P>0.05). According to the results of study except for FEV_1/FVC, significant positive linear correlation was seen between workers' monthly overtimes and changes in their pulmonary variables.

Discussion

Based on the personal monitoring that have been done in studied halls, the highest level of respirable and total dust have reported for spinning and weaving halls. The results of the present study are conformed to the results attained by Salari et al, examining the common existence of pulmonary disorders in Yazd textile factories' workers (20). Personal exposure to respirable dust in finishing hall is low, there is no exposure in the pocketing hall, and the total dust in the pocketing hall is more that the value measured in the finishing unit; however the difference between two last values was not significant (0.007). Thus it is possible to categorize finishing and pocketing halls into one class and spinning and weaving halls into another class. The values of exposure to respirable dust in four understudy halls and concentration of the total dust in two halls of pocketing and finishing is much less than the

TLV-TWA. However the exposure to the total dust in spinning and weaving halls, compared to the TLV-TWA, is more than the $10mg/m^3$ and the value is less than 15 mg/m^3 PEL-TWA provided by OSHA, although this exposure value increases considering the employees' mean monthly overtime which is more than 2-3 hours a day.

As it is expected and according to the results of the present study, there is a significant inverse relation between the concentration of respirable dust and the variables related to the respiratory parameters, since any increase in the amount of respirable dust leads to the decrease of respirable parameters. This finding conforms to the result of other research studying the fact that long exposure to cotton dust leads to obstructive pulmonary diseases (21-24).

Determining the relation between employees' pulmonary function and their work type, four $FEF_{25\%-75\%}$, FVC, FEV_1 and FEV_1/FVC indices were used to analysis. No result(s) of the unidirectional variance analysis test, based on the least weighted squares, showed any significance difference between working groups (case and control) comparing the mean values of FVC, FEV_1 and FEV_1/FVC (P≥0.05). The results of the said study conform to other previously done studies (25). Among the measured spirometry indices, only the $FEF_{25\%-75\%}$ index of the employees working in spinning and weaving halls was statistically and significantly different from that of pocketing and finishing halls' employees. Paired mean difference among other groups was not statistically significant. Additionally in accordance with the results of mean differences, the $FEF_{25-75\%}$ mean difference of the control group with spinning and weaving jobs was statistically significant (P≤0.05).

The $FEF_{25\%-75\%}$ value is a more precise variable for recognizing the early stages of respiratory airways obstruction, especially in alveolar duct (26); the said issue can show why the said index is significant compared to other indices and the control group. From the above results it

can be concluded that there are some early stages for some disorders related to the respiratory airways obstruction especially in alveolar duct in employees who work in spinning and weaving halls, however as this parameter is much different in common people, any change in the said parameter should be interpreted cautiously and with more examinations.

It is noteworthy that regarding all aforementioned indices, spinning and weaving halls' employees (having the highest level of exposure to dust) in turn have the lowest pulmonary functioning values, however pocketing and finishing hall's employees (having the lowest level of exposure to dust) had the highest pulmonary functioning values. There was also a significant and positive linear correlation between mean monthly overtimes and pulmonary functioning variable. As it is expected, there is a relation between employees' pulmonary functioning and exposure to dust, in a manner that those employees who are more exposed to pollutions have lower respiratory capacities compared to those employed in jobs with less exposure to pollution and dust.

The lack of significant difference between groups, though there is a significant difference among FVC, FEV_1 and FEV_1/FVC values, can be justified through considering employees' personal exposure to 10 mg/m^3 standard level and the relatively high difference with 15 mg/m^3 standard level. Threshold limit values are some limits which whether they are observed, the employee(s) will face no disorder/disease in long-term (10). Indeed the said values are the amount of harmful factors that man's body is able to refine them in its biotransformation process. In the present study and among the studied group, the exposure level to the total dust, provided by ACGIH, compared to that provided by OSHA, appeared to be more precise, an issue that needs to be more studied.

The above issue was studied in other research, Murtazavi et al., studying employees exposure to rock wool and its impact on their pulmonary function, found that despite more exposure, there is no significant statistical difference between the mean pulmonary functioning capacities in FEV1, FVC and VC indices. The mean values of FEV1, FVC and VC indices are significantly different from the normal values, thereby FEV_1/FVC, FEV1/VC values are different from normal values (27). In accordance with the results of the present study, no linear correlation was observed among employees' age and their pulmonary functioning variables. In Mehrparvar and his colleagues' study, a significant difference was found between spirometry indices (in employees exposed to natural fibers) and the age of the employees (28). In another study in China, it was found that textile industry employees' age can affect FEV_1 index (23). Salari also in his analysis found a direct relation between the age and the sufferance from pulmonary disorders (20). The difference between the results of the present study and other researches can be explained through regarding the difference between those fibers being exposed to and young employees in the studied industry by this work (20±4.9). To determine the relation between employees' pulmonary functioning and their current working hours, Pearson Correlation Coefficient test was applied; considering the results of the present analysis, no significant statistic difference was observed between working hours and variables related to the respiratory indices. Also, in a study on the 473 textile employees who exposed cotton and synthetic fibers, it is found that FEV1 and FEV1/FVC values are significantly related to working experience variable (25). In another study, the effect of working experience on the decrease of FEV1 spirometry indices and the value of FEV1/FVC became significant (28). The non-significant results attained from the pulmonary functioning relation with current working

experience in the present study can be justified through considering reasons such as separating employees working experience into to current working experience and previous work experience, difference in particles and low working experience of the studied employees.

It is commonly accepted that there is a direct relation between body mass and pulmonary diseases (29,30). However, the results of the present study showed that there is no significant relation between employees' pulmonary functioning and body mass index. It is possible to introduce integrity of the studied group as a reason for the present nonconformity among some results of this research and other research's results (31).

Conclusion

Finally it can be stated that personal exposure level to respirable dust in the studied workers of textile industries is less than the standard level, additionally any increase in concentration of respirable dust leads to decrease of respiratory indices. Based on this fact that personal exposure to total dust was more than the TLV-TWA level in spinning and weaving halls, it can be concluded that the most amount of dust in diameters are more than 5µm in the studied industry. The present study suggests that ventilating systems for spinning and weaving halls should be evaluated and necessary measures should be taken to improve them.

Footnotes

Conflict of Interest:

The authors declared no conflict of interest.

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