

Respiratory Symptoms and Pulmonary Function Changes among Carpet Weavers in Iran

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Respiratory and allergic symptoms were evaluated in 66 Iranian carpet weavers and 66 controls with similar age and gender characteristics using a questionnaire including questions on work-related respiratory symptoms in the past year, allergies, smoking habits, and work exposure duration. A total of 28 carpet weavers (42%) reported work-related respiratory symptoms. Incidences of all respiratory symptoms and most allergic symptoms were significantly higher in carpet weavers than in controls ($p < 0.05$ – $p < 0.001$). Moreover, most respiratory and allergic symptoms in carpet weavers were significantly more prominent during working hours ($p < 0.01$ – $p < 0.001$). Pulmonary function test results of the carpet weavers showed significant impairment compared with controls ($p < 0.05$ – $p < 0.001$). *Key words:* carpet weavers; occupational lung disease; sheep wool exposure; sheep shearing; allergic symptoms.

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The art of carpet weaving in Iran is deeply connected with the culture and the customs of the people. Few studies have been conducted to examine the impact of carpet weaving on the health of workers. It is known that farmers involved in animal production have a higher prevalence of respiratory symptoms than other farmers and other rural residents. Increased respiratory symptoms have been found among animal farmers in North America, Europe, and New Zealand.^{1,2} Animal farmers have a greater risk of respiratory disorders than do people in non-farming occupations.³ Animal farmers are exposed to inorganic dust from soil; organic dust containing microorganisms, mycotoxins, and endotoxins; animal feed particles; allergens; and a variety of chemical agents.⁴ Organic dust exposure is known to cause allergic and non-allergic rhinitis,⁵ organic dust toxic syndrome (ODTS),⁶ and chronic bronchitis, asthma, or an asthma-like syndrome.⁷ May and colleagues first

described an influenza-like syndrome as a febrile reaction to organic dust exposure.⁸ Febrile reactions to inhaled dusts are common and are usually of a toxic rather than an allergic type.

Respiratory disorders among workers in carpet industries have also been reported by investigators in epidemiologic studies, which have shown relationships between the carpet allergens and respiratory illnesses. An animal study showed the alteration in cellular and biochemical markers of pulmonary toxicity in the lung when rats were exposed to carpet dusts.⁹ Another study found that women in the weaving industry have a significant risk of occupational respiratory impairment.¹⁰ Children working as carpet weavers have been shown to have decreased peak expiratory flow rates.¹¹ Another study revealed that the reduction in pulmonary function was correlated with duration of employment among teenage carpet weavers.¹²

In this study, pulmonary function tests and work-related respiratory and allergic symptoms among carpet weavers were compared with those of control subjects. In addition, results of pulmonary function tests of carpet weavers were compared between years 2002 and 2005 to measure the effect of three years of occupational exposure.

METHODS

Study Population

A cross-sectional study was designed to assess respiratory and allergic symptoms and pulmonary function tests in a group of carpet weavers and a control group. Additionally, a retrospective comparison of prior pulmonary function data available for the carpet weavers was performed. The study included 66 carpet weavers (age, mean $\pm$ SD = 40.39 ± 5.09 years; 34 male, 32 female) and 66 matched controls (age, mean $\pm$ SD = 40.48 ± 5.14 years; 34 male, 32 female). The carpet weavers worked in different places, and controls were selected from the same residential district. The subjects in the control group were mainly teachers, nurses, and other medical professionals. All subjects resided in the city of Mashhad, in northeast Iran, and their lifestyles were very similar. Participants were selected through a non-probable purposive method. All participants answered the questionnaire through personal interviews.

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TABLE 1 Characteristics of Control Group and Carpet Weavers

	Control Subjects	Carpet Weavers
Number	66 (34 M, 32 F)	66 (34 M, 32 F)
Age	40.5 ± 5.1 years	40.4 ± 5.1 years
Height	162.2 ± 7.8 cm	162.1 ± 7.9 cm
PCVD*	None	None
PRD†	None	None
Smoking	None	2
Working time	—	1–62 hours
Working duration	—	20–54 years

*Previous cardiovascular disease.

†Previous respiratory disease.

Protocol

A Farsi questionnaire derived from prior investigations was used to assess the respiratory and allergic symptoms.^{13–16} The questionnaire included questions on exposure patterns, respiratory symptoms, rhino-conjunctivitis, skin reactions, past medical history of allergic reactions, drug history, smoking habits, and working hours each week. Asthma was determined by a history of physician-diagnosed asthma, and a question asked whether working aggravated the respiratory and allergic symptoms. Questions to identify the presence of common risk factors such as smoking, atopy, family history of atopy, and history of allergic reactions were asked. The participants answered questions regarding total years employed as carpet weavers. They also were asked whether, for any reason, they had quit working at carpet weaving for more than a year.

Pulmonary function tests of the carpet weavers and control subjects were conducted using a spirometer with a pneumotachograph sensor (Model ST90, Fukuda, Sangyo Co., Ltd. Japan). Pulmonary function testing was performed using the acceptability standards outlined by the American Thoracic Society (ATS), with subjects in a standing position and wearing nose clips.¹⁷ All tests were carried out between 1000 and 1700 hours.

Pulmonary function tests were performed three times in each subject. The highest level for forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), peak expiratory flow (PEF), maximal mid-expiratory flow (MMEF), and maximal expiratory flow at 75%, 50%, and 25% of FVC (MEF₇₅, MEF₅₀, and MEF₂₅) were taken independently from the three curves. Pulmonary function data were available for FVC, FEV₁, PEF, and MMEF from a study conducted in 2002 in 62 of the 66 carpet weavers.

Data Analysis

The PFT values and ages were expressed as means ± SD and data of respiratory and allergic symptoms as percentages of each group having the corresponding symptoms. Differences in the data of symptoms between carpet weavers and controls and also between rest and work periods were tested by calculating relative risk and 95% confidence Intervals (RR; 95% CI). The PFT values of the carpet weavers and controls were compared using unpaired *t* tests; PFT values of the carpet weavers between 2002 and 2005 were compared using paired *t* tests. A two-sided *p* value of 0.05 was the criterion for statistical significance. All analyses were performed with SPSS software (version 11.5, SPSS Inc., USA).

RESULTS

Symptoms of Carpet Weavers and Controls

A total of 28 carpet weavers (42%) reported work-related respiratory symptoms. Breathlessness (33%) and cough (30%) were the most common symptoms, and 18% of the carpet weavers reported wheezing. Respiratory symptoms were significantly more frequent in carpet weavers than in controls for wheezing and sputum, *p* < 0.05, for breathlessness *p* < 0.001 and for cough, *p* < 0.005, (Table 2). Most allergic symptoms also occurred significantly more often in the carpet weavers (itchy eye, *p* < 0.05; runny nose, *p* < 0.005).

TABLE 2 Respiratory and Allergic Symptoms in Control Subjects and Carpet Weavers

	Control Subjects (<i>n</i> = 66)		Carpet Weavers (<i>n</i> = 66)		RR	95% CI	Significance of Difference
	No.	%	No.	%			
Respiratory symptoms							
Cough	7	10.6	20	30.3	2.7	1.4–5.1	<i>p</i> < 0.005
Sputum	6	9.1	14	21.2	2.3	1.1–4.8	<i>p</i> < 0.05
Breathless	8	12.1	22	33.3	2.7	1.5–5.0	<i>p</i> < 0.001
Wheezing	5	7.6	12	18.2	2.6	1.1–5.9	<i>p</i> < 0.05
Allergic symptoms							
Sneezing	5	7.6	10	15.1	1.9	0.8–4.2	NS
Runny nose	4	6.1	13	19.7	3.3	1.4–8.0	<i>p</i> < 0.005
Itchy eye	2	3.0	7	10.6	3.7	1.0–12.7	<i>p</i> < 0.05
Urticaria	3	4.5	2	3.0	0.6	0.1–2.4	NS

TABLE 3 Symptoms in Carpet Weavers in Rest and Work Period

	Rest Period (n = 66)		Work Period (n = 66)		RR	95% CI	Significance of Difference
	No.	%	No.	%			
Respiratory symptoms							
Cough	0	0	8	12.1	Infin.*	Infin.–Infin.	$p < 0.001$
Sputum	0	0	3	4.5	Infin.	Infin.–Infin.	NS
Breathless	1	1.5	11	16.7	8.5	2.0–35.8	$p < 0.001$
Wheezing	0	0	5	7.6	Infin.	Infin.–Infin.	$p < 0.01$
Allergic symptoms							
Sneezing	1	1.5	5	7.6	4.0	0.9–18.4	NS
Runny nose	0	0	8	12.1	Infin.	Infin.–Infin.	$p < 0.001$
Itchy eye	0	0	5	7.6	Infin.	Infin.–Infin.	$p < 0.01$
Urticaria	1	1.5	1	1.5	1.0	0.1–7.0	NS

*Infinity.

There was no significant difference in the incidences of urticaria and sneezing between carpet weavers and controls (Table 2). Respiratory and allergic symptoms were similar in males and females.

Symptoms during Working Hours and Non-work

Almost all carpet weavers had pronounced respiratory and allergic symptoms during the work shifts. Most respiratory and allergic symptoms in carpet weavers were significantly more pronounced during working hours compared with non-working periods ($p < 0.01$ – $p < 0.001$, Table 3).

PFT Values of Carpet Weavers and Controls

All PFT values of the carpet weavers were significantly lower compared with those of the control group ($p < 0.05$ – $p < 0.001$, Table 4). The PFT values of male and female carpet weavers were significantly lower than those of controls. Moreover, PFT values of carpet weavers in 2005 were also significantly lower than those in 2002 ($p < 0.001$ for all values except FVC; Table 5). The PFT values in Table 4 are for 66 carpet weavers; in Table 5 the data are for 62 of the 66 current-study carpet weavers.

DISCUSSION

The results show significantly greater incidence of respiratory symptoms and lower pulmonary function test values in the carpet weavers compared with control subjects, and also demonstrate significantly increased allergic symptoms among the carpet weavers, indicating that irritant materials related to wool may cause allergy in carpet weavers. The respiratory and allergic symptoms were significantly greater while the carpet weavers were at work, compared with non-work periods. The PFT values of carpet weavers in 2005 were also significantly diminished from those obtained in 2002, suggesting that exposure to the work environment of carpet weavers may cause respiratory and allergic symptoms and impairment in lung function.

Animal products can lead to work-related symptoms among farmers.^{2,7,18–20} Working in animal-confinement areas with direct contact with animal products results in exposure to a wide array of agents.¹⁸ Animal farmers are exposed to potential respiratory hazards, although they are healthier than the rest of the population and tend to smoke less.¹ Selection of an appropriate comparison population is a common concern for studies of work-related symptoms among people exposed to animal products. It is important to consider that expo-

TABLE 4 Pulmonary Function Test Results of Control Subjects and Carpet Weavers*

	Control Subjects (n = 66)	Carpet Weavers (n = 66)	Significance of Difference
FVC	98.95 ± 18.63	84.62 ± 55.05	$p < 0.05$
FEV ₁	101.32 ± 18.65	75.42 ± 16.21	$p < 0.001$
MMEF	97.86 ± 19.76	65.52 ± 22.89	$p < 0.001$
PEF	95.13 ± 18.39	74.00 ± 17.45	$p < 0.001$
MEF ₇₅	101.58 ± 19.80	73.63 ± 21.32	$p < 0.001$
MEF ₅₀	100.43 ± 27.17	71.35 ± 25.25	$p < 0.001$
MEF ₂₅	108.91 ± 27.00	70.93 ± 27.84	$p < 0.001$

*Values are means ± SD of percentages predicted. FVC = forced vital capacity; FEV₁ = forced expiratory volume in 1 second; MMEF = maximal mid-expiratory flow; PEF = peak expiratory flow; MEF₇₅, MEF₅₀, and MEF₂₅ = maximal expiratory flow at 75%, 50%, and 25% of FVC, respectively.

TABLE 5 Pulmonary Function Test Results of Carpet Weavers in 2002 and in 2005*

	2002	2005	Significance of Difference	Change (mL)
FVC	89.0 ± 12.7	84.6 ± 55.0	NS	131.4 ± 293.1
FEV ₁	87.7 ± 17.4	75.9 ± 16.0	<i>p</i> < 0.001	575.6 ± 390.3
MMEF	83.3 ± 26.0	74.8 ± 23.2	<i>p</i> < 0.001	320.3 ± 172.9
PEF	89.4 ± 22.5	73.9 ± 17.4	<i>p</i> < 0.001	435.4 ± 249.5

*Values are means ± SD of percentages predicted. FVC = forced vital capacity; FEV₁ = forced expiratory volume in 1 second; MMEF = maximal mid-expiratory flow; PEF = peak expiratory flow.

sure to multiple agents may create an additive or even a synergistic effect. The adverse impact of a variety of exposures on carpet workers is important to assess. In the present study, we investigated only the effect of exposure to sheep wool.

Our findings suggest that employment in the carpet weaving industry may be responsible for the development of adverse respiratory changes. Many workers complained of acute and chronic respiratory symptoms in this industry. Among the carpet weavers, 42% reported work-related respiratory symptoms, and their PFT values were significantly lower compared with those of controls.

Previous studies have shown elevated respiratory and allergic symptoms and lower PFT values among people employed as carpet weavers, consistent with the results of the present study. An investigation showed that a large number of workers in a carpet-weaving factory suffered from a disease indistinguishable from byssinosis, including a reduction in MEF values compared with controls, even though wool was used almost exclusively, the only cotton being the warp.¹² Another study demonstrated that long-term exposure to dust in carpet weavers is associated with significantly diminished pulmonary function in a higher prevalence of respiratory symptoms, and the weavers showed signs of airway obstruction compared with workers not exposed to dust. Women in the weaving industry have significant work-related respiratory impairment.¹⁰ Responses to a symptom questionnaire and the finding of workers with across-shift FEV₁ decrements demonstrate that cotton workers are also at increased risk for respiratory function impairment.²¹ However, in the early stages of wool processing, the overall frequency of respiratory work-related symptoms is low and does not seem to be related to the stages of processing. The workers have primarily complained of nasal and/or ocular symptoms.²² The effect of exposure to wool on the respiratory system is increasingly demonstrated to be associated with duration of exposure.

The important finding of the present study is that the values of carpet weavers' PFTs in 2005 were significantly diminished relative to those of 2002. In both 2005 and 2002 the least affected PFT value was FVC and the most affected was MMEF. Reduction in MEF was also shown to be correlated with duration of work and was significantly lower in 2005 than in 2002. A pre-

vious study has shown reduced MEF values in adult women weaving wool carpets compared with controls.¹⁰

MEF can be used to assess small-airway narrowing even when FVC is reduced.²³ In contrast to PEF and FEV₁, it is effort-independent and represents lung function in the smaller airways and so is affected in the mildest of airflow obstruction.²⁴ A reduced MEF in an otherwise normal spirogram has been shown to be a useful indicator of the presence of bronchial hyper-responsiveness.²⁵ It suggests early disease in the peripheral airways of asymptomatic patients.²⁶ Therefore, the reduction in MEF among carpet weavers and continued reduction in this test value with work duration may indicate the occurrence of small-airway disease and asthma in workers exposed to sheep wool. Such airflow obstruction in peripheral airways may serve as a basis for recurrent episodes.²⁷

The decrease in PFT of carpet weavers over three years shown in Table 5 is significant, and more than that expected by aging alone. Durations of occupational exposures of workers in different processes have shown a direct correlation of duration with the degree of respiratory symptoms.²⁸ The effect of exposure to wood dust or other irritant agents over the years is not identical to that of exposure to sheep wool, and is less in the beginning years of working compared with occupation after several years.²² However, the declines in PFT values of the carpet workers between 2002 and 2005 were quite large. If the carpet weavers had been experiencing an average rate of decline in FEV₁ of 190 mL per year for 20 years, they would have been so severely impaired they would not be able to work today, and would certainly not have had FEV₁ values that were 75% of predicted, as shown in Table 5. There are two possible explanations: 1) there was a unique change in exposures between 2002 and 2005 that had not been in effect for the 17 years of employment prior to 2002; or 2) there was some difference in technique, operator error, miscalibration, etc. during the spirometry in 2002 versus 2005 that accounted for such a large difference. The latter explanation does not seem to be the case because the spirometer was continuously calibrated, the operator was more experienced in 2005, and the carpet weavers were more familiar with the PFT measurement procedures. Regarding the first explanation, the workplaces of most of the carpet weavers were



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poorly ventilated, with significant dust pollution, throughout the three-year period, but industrial hygiene data are not available to prove the point. Therefore, the large decline in PFT values in carpet weavers over the three-year period requires further investigation. The workers need more medical investigations, including HRCT scans to look for interstitial fibrosis. If there was a change in the work environment that caused this significant decrease in PFT measurements between 2002 and 2005, protective measure must be introduced in the work environment.

One explanation for such a large, rapid decline in lung function is extrinsic allergic alveolitis/hypersensitivity pneumonitis, which should be investigated in further studies. Wool may be contaminated with endotoxin, which may be the cause of illness rather than the wool material itself.²⁹ Radon and Winter measured endotoxins in sheep wool, finding an endotoxin content of 58.2–193.9 EU/mg wool.³⁰ Thus, endotoxin exposure during sheep shearing might be a significant factor in causing symptoms and PFT findings. The contaminating endotoxin in wool may be responsible for

the development of respiratory and allergic symptoms and reduction of PFT values in people exposed to wool through shearing. However, this hypothesis will need to be examined in further studies.

Since the carpet weavers in this study worked with dyed yarn that was used in weaving the final product, it is possible that the dyes or other chemicals used to treat the wool may be the cause of respiratory irritation or allergies. Wool-yarn dyers showed respiratory symptoms of 41.8%, followed by carpet washers (36.1%), carpet weavers (27.6%), and carpet finishers (20.0%). This may be due to the different natures of the occupational exposures, e.g., dyers and washers are more exposed to chemicals; carpet weavers and carpet finishers are primarily exposed to dust containing the fibers of wool and cotton.³¹ The induction of respiratory symptoms in reactive-dye workers, including those in the wool industry, has been demonstrated.^{32,33} Carpet weavers may also be exposed to dust mites, which may cause some of these findings.

Although the rate of smoking among the carpet weavers and controls in the present study was much



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lower than the rate in the larger Iranian population (7%),³⁴ the absence of smokers among workers and the control group occurred by chance, not by selection.

In conclusion, the results of the present study demonstrate that carpet weaving in Iran is associated with a high frequency of work-related respiratory and allergic symptoms, particularly during work hours. Pulmonary function tests show significant impairment among carpet weavers compared with controls. Moreover, the study demonstrated a significant reduction in PFT values over a three-year period among carpet weavers.

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