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A follow-up study of respiratory function in workers exposed to acid aerosols in a food-processing industry

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Abstract A follow-up investigation was performed on 49 female workers studied 2 years earlier in a vegetable-pickling plant. Acute and chronic respiratory symptoms and ventilatory capacity measurements were recorded during the original and the follow-up studies. Maximal expiratory flow-volume (MEFV) curves were recorded during the Monday morning work shift. The forced vital capacity (FVC), 1-s forced expiratory volume (FEV1), and flow rates at 50% and the last 25% of the FVC (FEF50, FEF25) were measured. There were small increases in the prevalence of chronic symptoms between the two studies for both smokers and nonsmokers, but these did not reach statistical significance. Five workers at the time of the initial study had a diagnosis of occupational asthma; only one of these was still working at the time of follow-up. Workers lost to the follow-up had lower lung function than those seen at follow-up. In workers who were followed, larger than expected mean annual declines were noted for all ventilatory capacity parameters in both smokers (FVC 0.070 l, FEV1 0.070 l; FEF50 0.355 l/s, FEF25 0.270 l/s) and nonsmokers (FVC 0.045 l, FEV1 0.045 l, FEF50 0.285 l/s; FEF25 0.130 l/s). The decrease was particularly pronounced for FEF50 and FEF25. The accelerated decline in ventilatory capacity tests noted in the female nonsmokers suggests an independent effect on lung function of work exposure in this environment. Our data confirm that work in the pickling industry, particularly in small, poorly regulated plants, has deleterious effects on respiratory function.

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Introduction

There are few reports on the effects of the work environment on workers employed in the food-pickling industry. Our previous data on respiratory function in workers in a vegetable-pickling and mustard-production facility suggest that occupational exposure in this setting may result in exposure-related respiratory effects (Zuskin et al. 1993). Allergy to mustard and vinegar has been described by Speer (1975). Pryzbilla and Ring (1983) reported the case of a woman who developed respiratory symptoms and allergic reactions after ingesting wine, beer, rum, or vinegar; positive skin-prick reactions to vinegar and acetic acid were obtained in this patient. Rajan and Davies (1989) described reversible airway obstruction and interstitial pneumonitis due to acetic acid inhalation.

In the present follow-up study we investigated the prevalence of respiratory symptoms and ventilatory-capacity changes in workers employed in a pickling plant 2 years after the initial study.

Subjects and methods

Working conditions

Workers were engaged in pickling of different vegetables, such as cucumbers, paprika, tomatoes, cabbages and beets, and in preparing mustard. During this work they were exposed to the vapors of heated vinegar (4–10% acetic acid). In addition, the solution used for pickling contained salt, alum, different natural flavors (including turmeric, xantham gum, corn syrup, and dehydrated onion), different spices (paprika, pepper, ginger, cumen), and citric acid. All workers had similar levels of exposure to these environmental agents since they frequently changed jobs within the plant.

Subjects

The initial cross-sectional study was performed in a group of 152 female pickling workers. At the follow-up study, after a 2-year interval, only 49 were available for the follow-up. The majority of the workers lost to follow-up were removed from the industry because of the economic crisis (61/152; 40%), whereas some left because of health and other reasons. The mean age of the remaining 49 workers was 30.6 years (range 18–41 years), and their mean duration of employment was 10.5 years (range 1–10 years). Of the studied workers, 10 (20.4%) were mild regular smokers, smoking on average 10 cigarettes daily. The mean age of the 103 workers who were lost to follow-up was 32.0 years (range 19–34 years) and the mean duration of their employment was 10.8 years (range 2–17 years). Among the workers lost to follow-up, 29 (28.2%) were mild regular smokers, smoking on average 10 cigarettes daily.

Respiratory symptoms

Chronic respiratory symptoms were recorded using the British Medical Research Council Committee questionnaire on respiratory symptoms (1960) with additional questions on occupational asthma (World Health Organization 1986; Maestrelli et al. 1992; Godnic-Cvar 1995). For all workers a detailed occupational history as well as questions about smoking habit were recorded. The following definitions were used: (1) chronic cough or phlegm – cough and/or phlegm production for at least 3 months a year for not less than 2 successive years; (2) dyspnea grades – grade 3, shortness of breath when walking with other people at an ordinary pace on level ground; grade 4, shortness of breath when walking at one's pace on level ground; and (3) occupational asthma – recurring attacks of dyspnea and chest tightness and pulmonary-function impairment of the obstructive type as diagnosed by physical examination and spirometric measurement during exposure to dust at or following work and confirmed by medical records. Acute symptoms that developed during a work shift were also recorded for all workers at both studies. The shift-related symptoms studied included cough; irritation or dryness of the throat; secretion, dryness, or bleeding of the nose; eye irritation; and headache.

Ventilatory capacity

Ventilatory capacity was measured by the recording of maximal expiratory flow-volume (MEFV) curves on a spirometer, the Pneumoscreen (Jaeger, Germany). This instrument was calibrated daily according to the guidelines of the American Thoracic Society (Ferris 1978). The same instrument was used at both initial and follow-up studies. The forced vital capacity (FVC), 1-s forced expiratory volume (FEV1), and maximal flow rates measured at 50% and at 25% of the vital capacity above residual volume (FEF50, FEF25) were measured on MEFV curves. Measurements were performed on the 1st working day of the week (Monday) during the work shift. Lung-function testing was performed according to the recommendations of Quanjer et al. (1993). At least three MEFV curves were recorded for each subject and the best value was used as the result of the test. The measured Monday preshift values of ventilatory capacity were compared with the predicted normal values reported for a Croatian population by Mustajbegovic (1992).

Statistical analysis

The results of ventilatory capacity measurements were analyzed using the paired *t*-test for testing of the differences between baseline measurements and predicted values. The chi-square test (or, when appropriate, Fischer's exact test) were used for testing of differences in the prevalence of respiratory symptoms. A value of $P < 0.05$ was considered statistically significant.

Results

Respiratory symptoms

The prevalence of chronic respiratory symptoms among the 49 followed pickling workers was studied separately for smokers and nonsmokers. Data for the the initial and the follow-up survey are presented in Table 1. Increases in prevalence were noted for both smokers and nonsmokers, but these did not reach statistical significance. At the original study, 5/152 workers (3.3%) had been diagnosed as having occupational asthma; by the time of the follow-up study, only 1 of these 5 workers remained. No new case of occupational asthma was diagnosed. For all 5 workers, typical symptoms of occupational asthma started within 1 year of their beginning work in this industry.

There was no significant difference in the prevalence of chronic respiratory symptoms between the workers who were followed and those who participated only in the original study. Table 2 shows the prevalence of chronic respiratory symptoms by smoking habit among the 103 pickling workers lost to follow-up. Smokers had a higher prevalence of chronic phlegm, chronic bronchitis, and dyspnea of grades 3 and 4 than did nonsmokers, but this difference was significant only for dyspnea. By contrast, upper respiratory symptoms (e.g., hoarseness, rhinitis) developed more frequently in nonsmokers than in smokers, but only the difference in hoarseness was significant.

The prevalence of acute, shift-related symptoms by smoking habit is presented in Table 3 for the 49 followed pickling workers and in Table 4 for the 103 pickling workers lost to follow-up. The prevalence noted for most of the symptoms in workers included in the follow-up study was similar to that seen in those who were lost to follow-up. As anticipated, a smoking effect was noted in both groups.

Ventilatory capacity

Measured and predicted ventilatory-capacity test data recorded for the 49 workers at the first and the follow-up study are presented in Table 5. There was a large mean annual decrease in all tests as compared with the predicted annual decreases. Smokers had larger mean annual declines for FVC (0.070 l), FEV1 (0.070 l), FEF50 (0.355 l/s), and FEF25 (0.270 l/s) than did nonsmokers (FVC 0.045 l, FEV1 0.045 l, FEF50 0.285 l/s; FEF25 0.130 l/s). Comparison of measured with predicted ventilatory-capacity tests (% of predicted) indicated larger decreases at the follow-up study than anticipated. This was particularly pronounced for FEF50 and FEF25. As compared with the predicted value, in smokers there was a decrease in FVC from 95.2% to 91.6%, in FEV1 from 93.6% to 89.4%, in FEF50 from 93.9% to 83.1%, and in FEF25 from 95.1% to 75.0%.

Table 1 Prevalence of chronic respiratory symptoms in 49 pickling workers studied at the first (I) and the follow-up (II) study by smoking habit[a] (*NS* Difference not statistically significant; $P > 0.05$)

Smoking habit	*n*	Measurement	Mean age (years)	Mean exposure (years)	Chronic cough	Chronic phlegm	Chronic bronchitis	Dyspnea grades 3 & 4	Occupational asthma	Chest tightness	Sinusitis	Rhinitis	Hoarseness
Smokers	10	I	25.7 ± 7	5.8 ± 5.1	3 30.0% NS	3 30.0% NS	2 20.0% NS	2 20% NS	0 0 NS	3 30.0% NS	4 40% NS	2 20.0% NS	2 20.0% NS
		II	27.7 ± 7	7.8 ± 5.1	5 50.0%	3 30.0%	2 20.0%	2 20.0%	0 0	4 40.0%	4 40.0%	3 30.0%	3 30.0%
Non-smokers	39	I	31.8 ± 11.1	11.7 ± 10.0	8 20.5% NS	4 10.3% NS	4 10.3% NS	6 15.4% NS	1 2.6% NS	10 25.6% NS	3 7.7% NS	13 33.3% NS	15 38.5% NS
		II	33.8 ± 11.2	13.7 ± 10.2	11 28.2%	6 15.4%	4 10.3%	7 17.9%	1 2.6%	12 30.8%	3 7.7%	13 33.3%	15 38.5%

[a] Age and exposure date are presented as mean values ± SD

Table 2 Prevalence of chronic respiratory symptoms in 103 pickling workers tested only at the first study by smoking habit[a] (*NS* Difference not statistically significant; $P > 0.05$)

Smoking habit	*n*	Mean age (years)	Mean exposure (years)	Chronic cough	Chronic phlegm	Chronic bronchitis	Dyspnea grades 3 & 4	Occupational asthma	Chest tightness	Sinusitis	Rhinitis	Hoarseness
Smokers	29	23.6 ± 9.1	3.34 ± 8.1	6 20.7%	7 24.1%	5 17.2%	19 56.5%	1 3.4%	5 17.2%	3 10.3%	9 31.0%	3 10.3%
				NS	NS	< 0.01	NS	NS	NS	NS	NS	< 0.01
Non-smokers	74	35.3 ± 14.6	13.7 ± 12.8	16 21.6%	9 12.2%	7 9.5%	15 20.3%	3 4.1%	18 24.3%	18 24.3%	27 36.5%	33 44.6%

[a] Age and exposure are presented as mean values ± SD

Table 3 Prevalence of acute shift-related symptoms in 49 pickling workers studied at the first (I) and the follow-up (II) study by smoking habit (*NS* Difference statistically insignificant; ($P > 0.05$)

Smoking habit	Measurement	Cough	Dyspnea	Throat		Eye irritation	Nose			Headache
				Irritation	Dryness		Secretion	Dryness	Bleeding	
Smokers $n = 10$	I	7 70.0% NS	6 60.0% NS	4 40.0% NS	5 50.0% NS	5 50.0% NS	5 50.0% NS	2 20.0% NS	0 0 NS	5 50.0% NS
	II	8 80.0%	7 70.0%	5 50.0%	5 50.0%	5 50.0%	5 50.0%	2 20.0%	0 0	5 50.0%
Non-smokers $n = 39$	I	27 69.2% NS	22 56.4% NS	20 51.3% NS	15 38.5% NS	20 51.3% NS	13 33.3% NS	6 15.4% NS	4 10.3% NS	18 46.2% NS

Table 4 Prevalence of acute shift-related symptoms in 103 pickling workers tested only at the first study by smoking habit (*NS* Difference not statistically significant; $P > 0.05$)

Smoking habit	*n*	Cough	Dyspnea	Throat		Eye irritation	Nose			Headache
				Irritation	Dryness		Secretion	Dryness	Bleeding	
Smokers	29	15 51.7% NS	7 24.1% < 0.05	5 17.2% < 0.05	5 17.2% < 0.05	10 34.5% NS	0 0 < 0.01	2 6.9% NS	1 3.4% NS	5 17.2% < 0.01
Non-smokers	74	41 55.4%	34 45.9%	29 39.2%	28 37.8%	32 43.2%	27 36.5%	14 18.9%	6 8.1%	32 43.2%

Table 5 Ventilatory capacity in 49 pickling workers studied at the first (I) and the follow-up (II) study by smoking habit [a] (*NS* Difference not statistically significant; $P > 0.05$)

Smoking habit	Measurement	*n*	FVC (l)	% Predicted	FEV1 (l)	% Predicted	FEF50	% Predicted	FEF25	% Predicted
	I		3.73 ± 0.82 NS	95.2	3.09 ± 0.60 NS	93.6	4.21 ± 0.70 NS	93.9	2.55 ± 0.74 < 0.05	95.1
Smokers		10	3.92[b] ± 0.27 < 0.01		3.30[b] ± 0.25 < 0.05		4.48[b] ± 0.13 < 0.01		2.68[b] ± 0.16 < 0.01	
	II		3.59 ± 0.88	91.6	2.95 ± 0.67	89.4	3.50 ± 0.95	83.1	2.01 ± 0.54	75.0
	I		3.37 ± 0.51 < 0.01	96.0	2.75 ± 0.50 < 0.05	95.4	3.74 ± 0.98 < 0.01	88.0	1.92 ± 0.97 < 0.01	86.5
Non-smokers		39	3.51[b] ± 0.25 < 0.01		2.88[b] ± 0.25 < 0.01		4.25[b] ± 0.14 < 0.01		2.22[b] ± 0.16 < 0.01	
	II		3.28 ± 0.51	93.4	2.66 ± 0.42	92.4	3.17 ± 0.71	87.3	1.66 ± 0.60	74.8

[a] Data represent mean values $\pm$ SD
[b] Predicted values

These decreases were also noted for nonsmokers (FVC from 96.0% to 93.4%, FEV1 from 95.4% to 92.4%, FEF50 from 88.0% to 87.3%, FEF25 from 86.5% to 74.8%).

Table 6 presents ventilatory-capacity data recorded for the 103 pickling workers at the initial study who were subsequently lost to follow-up. Their values for FEF50 and FEF25 were decreased as compared with the predicted values. In smokers the percentage of the predicted value was 73.5% for FEF50 and 72.9% for FEF25. Similar data were obtained for nonsmokers (FEF50 83.6%, FEF25 69.4%). Comparison of the measured/predicted values (% of predicted) at the initial study between workers who were included in the follow-up study and those who were lost to follow-up revealed that those lost to follow-up had significantly lower function.

Table 6 Ventilatory capacity in 103 pickling workers studied only at the first study by smoking habit

Smoking habit	*n*	FVC (l)	% Predicted	FEV1 (l)	% Predicted	FEF50 (l/s)	% Predicted	FEF25 (l/s)	% Predicted
		3.16		2.46		3.11		1.91	
		±0.45	91.6	±0.44	86.9	±1.01	73.5	±0.58	72.9
Smokers	29	<0.01		<0.01		<0.01		<0.05	
		3.23[a]		2.57[a]		3.57[a]		1.54[a]	
		±0.47		±0.35		±0.97		±0.60	
		3.23		2.57		3.57		1.54	
		±0.47	90.7	±0.35	88.0	±0.97	83.6	±0.60	69.4
Non-smokers	74	<0.01		<0.01		<0.01		<0.01	
		3.56[a]		2.92[a]		4.27[a]		2.22[a]	
		±0.27		±0.24		±0.12		±0.11	

[a] Predicted values

These differences were particularly pronounced for FEF25 (49 follow-up workers 88.3%; 103 workers lost to follow-up 70.4%).

Environmental pollutants

The concentration of ambient acetic acid measured in the workroom varied from 19 to 40 mg/m^3. A total of ten measurements were performed for an average value of 30 mg/m^3 (the Croatian recommended standard is 25 mg/m^3 as the maximal allowable level).

The concentration of total organic dust measured in the workroom varied from 2.5 to 7.8 mg/m^3 and the respirable fraction varied from 0.7 to 2.9 mg/m^3 (Croatian maximal standard 3 mg/m^3 for total organic dust and 1 mg/m^3 for the respirable fraction of organic dust).

Discussion

Our data indicate that occupational exposure in the pickling industry is associated with an excess of acute and chronic respiratory as well as other work-related symptoms. This study confirms our original observations and suggests that exposure to respiratory irritants in such a work environment over extended periods may cause the development of chronic lung diseases accompanied by changes in lung function (Zuskin et al. 1993). Newman Taylor (1996) has recently described that respiratory irritants may have a direct toxic effect on the airways. Inhaled respiratory irritants provoke an acute inflammatory response with injury to the epithelial cells of the airways. The clinical responses associated with such changes may include cough (from stimulation of afferent nerve endings in the airway mucosa), mucus secretion (by submucosal and goblet cells), and airway narrowing. Among our workers a large number complained of cough during the work shift (36/49; 73.5%). Both smokers (8/10; 80.0%) and nonsmokers (28/30; 71.8%) were equally affected.

Among the 152 workers initially seen we identified a total of 5 (3.3%) cases of occupational asthma; these workers had no evidence of preexisting respiratory disease and no past respiratory complaint. Symptoms started on average 1 year after the beginning of work in this industry. Irritant-induced occupational asthma (reactive airways dysfunction syndrome, RADS) has recently been described to develop after acute inhalation of respiratory irritants at toxic concentrations (Brooks et al. 1985; Newman Taylor 1996). RADS has also been described in hospital employees exposed to 100% acetic acid (Kern 1991). Our workers were exposed to low concentrations of respiratory irritants (heated acetic acid, 4–10%), but this exposure occurred on a daily basis for long periods. Occasionally, when workers are working directly above the open vats (for instance, when mixing or adding vegetables to the brine pickling solution) they inhale high concentrations of acetic acid vapors. We suggest that the airway disease that develops in the pickling industry may be a variant of irritant-induced occupational asthma, e.g., a form of RADS. Bardana (1995) has mentioned that related respiratory disorders such as chronic rhinitis and sinusitis may be a natural accompaniment to RADS. All our subjects with occupational asthma had chronic rhinitis and sinusitis.

In the cases of the 5 workers who complained of asthmatic symptoms, specific etiologies were not established. None of these workers complained of preexisting asthma or allergic disease, suggesting that their symptoms were due to environmental exposures. However, this was not confirmed by specific challenge testing and, therefore, the association is only presumptive.

Workers with occupational asthma had large across-shift decreases in FEV1 (−21% to 28%), FEF50 (−29% to 32%) and FEF25 (−42% to 46%). In a previous study of confectionary workers exposed to the vapors of alcohol we found similar large decreases in ventilatory-capacity tests over the work shift as well as lower than predicted baseline lung function (Zuskin et al. 1994). The one subject with occupational asthma among the pickling workers who participated in the follow-up study had a positive methacholine test.

Exposure to environmental pollutants in the pickling industry was associated with a measurable deterioration of lung function during a 2-year period. The data on the

workers of the present study indicate a greater than predicted annual decline in all ventilatory capacity tests. Epidemiology studies report an expected annual decline of up to 0.025 l for FVC, up to 0.25 l for FEV1, up to 0.031 l/s for FEF50, and up to 0.034 l/s for FEF25 (Cherniack and Raber 1972; Schoenberg et al. 1978; Knudson et al. 1983; Quanjer 1983; Miller et al. 1986;). The annual losses measured in the present study are similar to those obtained in a follow-up study of textile workers exposed to cotton and hemp dusts (Zuskin et al. 1991, 1994).

We conclude that although this 2-year interval may be too short a period for the detection of changes in the prevalence of respiratory symptoms, we do document lung-function changes; the data suggest that this group is experiencing an accelerated decline in lung function. The environmental pollutants in the pickling industry are multiple. It is therefore not possible on the basis of the current study to determine specific pollutants responsible for the observed effects. To prevent the development of respiratory disorders in workers in this type of industry, we suggest the implementation of medical surveillance to identify workers at risk as well as environmental preventive measures (e.g., closed vats, good ventilation system, and the wearing of protective masks).

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