American Journal of Industrial Medicine 2:143–151 (1981)

Screening for Occupational Health Hazards in the Rubber Industry. Part II: Health Hazards in the Curing Department

James L. Weeks, ScD, John M. Peters, MD, ScD, and Richard R. Monson, MD, ScD

Multiphasic health testing was provided to 744 rubber workers at a tire manufacturing plant. Sixty-two white males from this population had worked longest in the curing department. Personal exposure to respirable particulates was measured for curing press operators. Outcome on screening tests for curing workers was compared with that of 280 white males at this same plant who had never worked in departments known to include jobs where they could have been exposed to respiratory health hazards. Employment in the curing department is associated with shortness of breath, chest tightness, wheeze, loss of FEV-1 and FVC, decline of FEV-1/FVC, and tingling and numbness in the extremities. These associations are stronger with increased duration of employment in the curing department. This paper further demonstrates the potential for using multiphasic health testing combined with measurements of workplace exposure for identifying occupational health hazards.

Key words: occupational health hazard detection, occupational morbidity among curing workers, multiphasic health testing

INTRODUCTION

This paper is the second designed to evaluate whether multiphasic health testing, combined with assessment of exposure to potential occupational health hazards, is a useful method of identifying job-related health hazards. Details of this study are described in our earlier report [Weeks et al, 1981].

International Union of Electrical, Radio, and Machine Workers, AFL-CIO-CLC, Local 201 (J.L.W.).
University of Southern California School of Medicine, Department of Preventive Medicine (J.M.P.).
Harvard School of Public Health, Department of Epidemiology (R.R.M.).
Address reprint requests to Dr. Richard R. Monson, Department of Epidemiology, Harvard School of Public Health, 677 Huntington Ave., Boston, MA 02115.
Accepted for publication August 3, 1981.

0271-3586/81/0202-0143$03.00

In that study we found, among other things, a higher than expected prevalence of respiratory symptoms and reduced ventilatory function among those workers whose longest employment at this plant was in the curing department. We report here a further investigation of these findings.

In this paper, we used an improved classification scheme for selecting exposed and comparison populations, and therefore we reduce the effects of the classification problems noted in the first report. Workers in the curing department were more likely to encounter the same hazardous exposure than were workers in any other department at this plant. Therefore, classifying them by department approximates classifying them by exposure. For comparison, we selected workers who had never worked in departments known to include jobs where they could have been exposed to respirable particulates.

POPULATION, MATERIALS, METHODS

Population

The study population is 62 white male workers whose longest work experience in this plant was in the curing department. About half of these workers operated manually loaded curing presses in three separate areas of the plant.

The comparison population includes 280 white males who had never worked in any department in this plant known to include exposure to higher than background levels of respirable particulates. "Hazardous" departments (and exposures) were the mill (carbon black, talc, and mill emissions), cutting (oil mist), bead (mill and extrusion emissions), tread (tread tuber emissions and talc), curing (curing press emissions), cleaning (dust from buffing tires), and tube (mill emissions, talc, and curing press emissions).

Methods

To evaluate the association of positive screens with employment in the curing department, we computed the ratio of observed positive screens to an expected number. The expected number was computed by the indirect method and by adjusting for differences in age and smoking in evaluating chest morbidity and for age and smoking in evaluating chest morbidity and for age in evaluating other morbidity [Hill, 1977]. Statistical evaluation of the associations was by Mantel-Haenszel chi-square with one degree of freedom [Mantel and Haenszel, 1959].

To evaluate the loss of ventilatory function associated with duration of employment in the curing department, we did a simple linear regression of loss of FEV-1 and FVC on time in the curing department. Loss on these parameters was estimated by computing the residual (observed minus expected) among the curing workers. Expected values were computed from prediction equations derived by multiple regression of FEV-1 and FVC on age, height, and smoking in the comparison population. We derived three separate sets of prediction equations for FEV-1 and FVC for each of the three smoking categories (never, ex-, and current smokers) including pack-years of smoking in the prediction equations (Table I). We also did a multiple linear regression of decline of FEV-1/FVC on time in curing and pack-years of smoking among the curing workers.

The Working Environment

Curing is a basic process in the rubber industry during which heat (130°C) and pressure are applied to an uncured tire "carcass" inside a mold. The purpose of curing

TABLE I. Prediction Equations for Ventilatory Function Derived From Comparison Groups

		N	R^2
Nonsmokers			
FEV-1	= 0.0566 (Ht) − 0.0221 (Age) − 5.2440	67	0.54
FVC	= 0.0667 (Ht) − 0.0180 (Age) − 6.3075	67	0.50
Ex-smokers			
FEV-1	= 0.0474 (Ht) − 0.0321 (Age) − 0.0092 (PY) − 2.9212	83	0.45
FVC	= 0.0612 (Ht) − 0.0304 (Age) − 0.0112 (PY) − 4.3582	83	0.48
Current smokers			
FEV-1	= 0.0435 (Ht) − 0.0332 (Age) − 0.0109 (PY) − 2.4367	111	0.57
FVC	= 0.0572 (Ht) − 0.0283 (Age) − 0.0096 (PY) − 4.0100	111	0.52

Ht = height (cm).
Age = Age (years).
PY = Pack-years of smoking = packs per day times years smoked.

is to impart certain desirable properties such as toughness, elasticity, and resistance to corrosion, and to mold the tire into its final shape.

Most curing press emissions are released in a puff when the press opens at the end of the curing cycle. Press operators are present at these manually operated presses as they open in order to unload a cured tire, reload the press with an uncured carcass, and restart the cycle. One operator is responsible for 20–60 presses depending on the curing time and other job responsibilities.

Environmental Samples

We measured worker exposure to respirable mass particulates for curing workers in each of the three curing areas of the plant. The sampling protocol is described in Part I.

We took a total of 20 personal samples during each of the three shifts in each of the three curing areas with six samples in each of the two areas and eight in a third. The sampler ran continuously during the work shift including breaks.

RESULTS

Exposure Levels

A two-way analysis of variance of the concentration of curing press emissions by shift and by area of the plant reveals large differences among the three curing areas and negligible differences among the three shifts (Table II). The differences between areas are statistically significant ($p = 0.004$). There is no interaction between shift and area concentrations.

The distribution of concentrations of samples of all measurements of curing press emissions is log-normally distributed. The grand geometric mean concentration is 0.56 mg/m^3 with 95% confidence limits of 0.24–1.29 mg/m^3.

Comparison of Curing Workers and the Comparison Population on Potential Confounding Variables

The comparison population did not differ significantly from the curing workers with respect to average height or weight. Curing workers on the average, however,

TABLE II. Personal Exposure to Curing Emissions (Respirable Mass)

Two-way analysis of variance on ln (concentration mg/m³)

Source of variation	Sum of squares	DF	Mean square	F
Area	5.858	2	2.929	14.52*
Shift	0.156	2	0.078	0.39
Interaction	1.072	4	0.268	1.33
Explained	6.985	8	0.873	4.33**
Residual	2.219	11	0.202	
Total	9.205	19	0.484	

*p = 0.004
**p = 0.01

Concentration of curing emissions by tire curing area (mg/m³)

Area	No. of samples	Geometric Mean (mg/m³)	95% Confidence limits
Large tires (tractor, truck)	8	0.28	0.19, 0.33
Passenger car tires	6	0.54	0.31, 0.94
Passenger car tires	6	1.44	0.89, 2.33
Total	20	0.56	0.24, 1.29

were older and had accumulated more seniority (ie, they had longer total employment at this company) than the comparison population (Table III).

Curing workers who were currently smokers had accumulated more pack-years of smoking than had smokers in the comparison population (Table IV). Curing workers included more men younger than 30 and older than 50 than did the comparison group (Table V). These differences require adjustment for both age and smoking when comparing results of screening tests associated with these variables.

One of the curing group (1.6%) reported a history of hay fever, but 15 of the comparison population did (5.4%). None of the curing workers reported a history of chest injury or operation but eight of the comparison population (2.9%) did.

The two groups were similar with respect to prior employment in dusty jobs outside of this plant, average value of blood and urine constituents, and prevalence of abnormal chest X-rays.

Chest Morbidity Among Curing Workers

The prevalence of certain chest and other symptoms among curing workers was higher than expected (Table VI). We observed elevated O/E ratios for shortness of breath, difficulty climbing more than one flight of stairs, chest tightness, wheeze, cough, and sputum production.

Curing workers with 10 or more years in the curing department were more likely to report shortness of breath, shortness of breath while climbing stairs, signs of heart disease, chest tightness, and wheeze, suggesting a dose-response relationship (Table VI). The O/E ratios for the occurrence of cough and sputum production of those workers with 10 or more years in curing were unchanged with increased length of employment in the curing department.

Simple linear regression of residual ventilatory function (observed minus expected for FEV-1 and FVC) on time in the curing department shows a loss of FEV-1 at about 12 ml per curing year (p = 0.036) and a loss of FVC at about 12 ml

TABLE III. Basic Information About Curing and Comparison Groups

	Curing workers N = 62		Comparison group N = 280	
	Mean	SD	Mean	SD
Age (years)	45.9	12.02	42.4[a]	10.30
Height (cm)	174.3	5.68	174.5	6.44
Weight (kg)	84.3	11.71	81.8	11.36
Seniority (years)	23.3	11.49	16.4[b]	10.65
Time in curing (years)	16.8	10.18	–	–

[a] $p < 0.05$ (t-test on means between curing and comparison groups).
[b] $p < 0.01$.

TABLE IV. Comparison of Curing Workers and Comparison Group by Smoking Habits

	Curing		Comparison	
Smoking habits	N	%	N	%
Never Smoked	14	22.6	71	25.4
Ex-Smoker	17	27.4	87	31.1
Current Smoker	31	50.0	122	43.6
Total	62		280	
	$\chi^2 = 0.849$, 2 d.f., $p = 0.62$			
Pack-years of ex-smokers				
<5	5	29.4	23	26.4
5 - 19	7	41.2	38	43.7
≥ 20	5	29.4	26	29.9
Total	17		87	
	$\chi^2 = 0.068$, 2 d.f., $p = 0.97$			
Pack-years of smokers				
< 20	9	29.0	52	42.6
20 - 59	15	48.4	65	53.3
≥ 60	7	22.6	5	4.1
Total	31			
	$\chi^2 = 12.024$, 2 d.f., $p = 0.002$			

TABLE V. Comparison of Curing and Comparison Groups Stratified by Age

	Curing		Comparison	
Age strata	N	%	N	%
< 30	13	21.0	40	14.3
30 - 39	6	9.7	85	30.4
40 - 49	9	14.5	69	24.6
≥ 50	34	54.8	86	30.7
Total	62		280	
	$\chi^2 = 20.323$, 3 d.f., $p = 0.0001$			

TABLE VI. Signs of Chest Morbidity Among Curing Workers

	All curing workers (N = 62)				Curing workers with 10 or more years in curing (N = 41)			
Screening test	O[a]	E[b]	O/E	95% C.L.[c]	O	E	O/E	95% C.L.
Shortness of breath (ever)	5	3.4	1.5		5	2.9	1.8	
Shortness of breath on 1 - 2 flights of stairs	8	9.0	0.9	0.4 - 1.8	7	7.2	1.0	0.5 - 2.0
Shortness of breath on 1 flight of stairs	4	1.3	3.2		4	1.1	3.7	
Signs of heart disease	8	7.6	1.1	0.5 - 2.1	8	5.3	1.5	0.8 - 3.0
Wheeze	20	12.3	1.6	1.1 - 2.5	15	9.0	1.7	1.0 - 2.7
Cough	16	12.5	1.3	0.8 - 2.1	12	10.6	1.1	0.6 - 2.0
Sputum	9	5.5	1.7	0.9 - 3.1	7	4.6	1.5	0.7 - 3.2
Chest tightness	13	4.2	3.1	1.8 - 5.2	12	2.8	4.3	2.6 - 7.2

[a]Observed number reporting this problem.
[b]Expected number, based on comparison population, adjusted for age and cigarette smoking.
[c]95% confidence limits around the O/E ratio, based on χ^2 analysis. (Not calculated when $0 \leq 5$).

TABLE VII. Simple Linear Regression of Residual Lung Function on Time Spent in Curing (T)

		p
ΔFEV-1	= 0.194 − 0.012 (T)	0.036
ΔFVC	= 0.212 − 0.012 (T)	0.042

ΔFEV-1 = loss of FEV-1 (L).
ΔFVC = loss of FVC (L).

per curing year ($p = 0.042$) (Table VII). The loss is in addition to loss of ventilatory function associated with aging or smoking.

Multiple linear regression of FEV-1/FVC on time in curing and pack-years of smoking showed a small but statistically significant decline of this measure of ventilatory function with both variables (Table VIII).

Three of the curing workers (4.8%) and 19 of the comparison population (6.8%) did not perform the ventilatory function test. Two of the comparison group were handicapped, and of the 17 remaining, 11 had a variety of respiratory complaints, which may explain their nonparticipation. All nonparticipating curing workers had showed signs of respiratory disease as well. This nonparticipation should not bias our estimates of ventilatory function.

Other Morbidity

Reports of tingling and numbness in the extremities and irritation of the mucosa were more common than expected among curing workers. For curing workers with 10 or more years in the curing department, these associations are stronger. Although reports of red or brown urine were more common than expected, the number of cases was very small (Table IX).

DISCUSSION

Our objective in this study was to evaluate further whether multiphasic health testing combined with measurements of workplace exposure is a useful method of identifying job-related health hazards. In our earlier report we observed that

TABLE VIII. Multiple Linear Regression of FEV-1/FVC on Time in Curing and Pack-Years of Smoking

Variable	Coefficient	SE	F
Time in Curing (T)	−0.002260	0.00093	5.85
Pack-Years of Smoking (PY)	−0.000846	0.00038	4.91
Constant	0.825500		

Analysis of variance:

Source of variation	D.F.	Sum of squares	Mean square	F	p
Regression	2	0.07979	0.03989	9.89	<0.005
Residual	54	0.21790	0.00404		

TABLE IX. Signs of Other Morbidity Among Curing Workers

	All curing workers (N = 62)				Curing workers with 10 or more years in curing (N = 41)			
Screening test	O[a]	E[b]	O/E	95% C.L.[c]	O	E	O/E	95% C.L.
Nausea	19	18.5	1.0	0.7 - 1.6	10	10.5	1.0	0.5 - 1.8
Headaches	11	10.5	1.0	0.6 - 1.9	7	5.9	1.2	0.6 - 2.5
Dizziness	12	13.7	0.9	0.5 - 1.5	8	8.9	1.2	0.4 - 1.8
Tingling in extremities	20	14.1	1.4	0.9 - 2.2	16	8.3	1.9	1.2 - 3.1
Numbness in extremities	25	13.0	1.9	1.3 - 2.8	20	8.2	2.4	1.6 - 3.7
Irritation of mucosa	14	9.6	1.5	0.9 - 2.5	9	4.7	1.9	1.0 - 3.6
Pain while urinating	2	1.9	1.1		1	1.5	0.7	
Red or brown urine	3	1.1	2.7		3	1.0	2.9	
Abdominal pain	8	8.6	0.9	0.5 - 1.9	5	5.3	0.9	

[a]Observed number reporting this problem.

[b]Expected number, based on comparison population, adjusted for age.

[c]95% confidence limits around the O/E ratio, based on χ^2 analysis. (Not calculated when O < 5).

employment in the curing department is associated with increased respsiratory morbidity. In this study, we were able to clarify these findings and to compensate for problems of classification. Our results are consistent with other reports of health hazards to curing workers, which supports the validity of our approach.

Fine and Peters [1976 a, b] reported chronic bronchitis among active curing workers and chronic obstructive pulmonary disease for workers with more than 10 years of exposure to curing press emissions. Dyspnea (grade 3) and wheezing were also present among these workers, although infrequent. This population also had an acute and a chronic loss of FEV-1 and FVC associated with exposure to curing press emissions at an exposure level of 1.6 mg/m^3 (RM).

Lednar et al [1977] reported that early retirement due to respiratory disability was associated with operating curing presses. Fraser and Rappaport [1976] reported that curing press emissions contain toxic constituents. Volkova and Bagdinov [1969] and Volkova et al [1970] reported the occurrence of numbness and tingling in the extremities among curing workers in the Soviet Union.

Our findings of numbness and tingling are consistent with those of Volkova. Irritation of the mucosa and reports of red or brown urine have not been reported previously.

Given differences in exposure, our findings of loss of FEV-1 and FVC, and of the prevalence of wheeze are consistent with reports cited above. Our observations of cough and sputum production are somewhat weaker than those reported. Shortness of breath and chest tightness, observed in the present population, are similar to reports of dyspnea noted above.

Differences in exposure may explain differences in measures of morbidity between this population and that studied by Fine and Peters. Not all of our group were exposed to the same concentration of emissions, and some were barely exposed at all. Furthermore, some workers who had worked longest in curing were not working in that department at the time of the survey and could have recovered from any prior effects. And exposure levels at this plant were lower than those measured by Fine and Peters.

Selection bias may also affect our results. This group of curing workers includes only one worker who had any hay fever and none with a history of chest injury or operation, whereas the prevalence of these conditions is greater in the comparison group. This suggests that some workers may have never entered the curing department for reasons of health. Consistent with this selecting-out process, two former curing workers had been assigned to light duty jobs for reasons of health.

CONCLUSION

We used data gathered with multiphasic health testing combined with industrial hygiene measurements of workplace exposure to identify possible health hazards among curing department workers in a tire manufacturing plant. An improved classification scheme enabled us to associate employment in the curing department with respiratory and nonrespiratory morbidity: shortness of breath; chest tightness; wheeze; loss of FEV-1, FVC, and FEV-1/FVC; tingling and numbness in the extremities; and reports of red or brown urine. These associations became stronger with increased duration of employment in the curing department, and they clarify associations observed in our earlier report.

ACKNOWLEDGMENTS

The authors wish to acknowledge the technical assistance of Lou DeBerardinis, Cindy Rubin, and Donna Spiegelman. Thanks are also due to W. A. Burgess and Colin Begg for helpful criticisms, Beth Rosenberg for preparing the manuscript, and Health Examinetics for conducting the health testing.

This investigation was supported by the joint agreement between the United Rubber, Cork, Linoleum, and Plastic Workers of America, AFL-CIO-CLC, Local No. 17, and the Mansfield Tire and Rubber Co., Mansfield, Ohio; and by the Occupational Safety and Health Education and Resource Center, NIOSH grant No. 5 T15 OHO7096.

REFERENCES

Fine LJ, Peters JM (1976a): Respiratory morbidity in rubber workers. I. Prevalence of respiratory symptoms and disease in curing workers. Arch Environ Health 31:5–9.

Fine LJ, Peters JM (1976b): Respiratory morbidity in rubber workers. II. Pulmonary functions in curing workers. Arch Environ Health 31:6–10.

Fraser DA, Rappaport S (1976): Health aspects of the curing of synthetic rubbers. Environ Health Perspec 17:45–53.

Hill AB (1977): "A Short Textbook of Medical Statistics." London: Hodder and Stoughton.

Lednar WM, Tyroler HA, McMichael AJ, Shy CM (1977): The occupational determinants of chronic disabling pulmonary disease in rubber workers. J Occup Med 19:263–268.

Mantel N, Haenszel W (1959): Statistical aspects of data from retrospective studies of disease. J Natl Cancer Inst 22:719-748.

Volkova ZA, Bagdinov ZM (1969): Occupational hygiene problems associated with vulcanization in the rubber industry. Gigiena I Sanitarija (USSR) 34:33-40.

Volkova, ZA, Milkov LE, Lopukhova LM, Mulyar Y, Makarenko L, Shakhova TK (1970): Work conditions and the state of health of workers engaged in hot vulcanization of footwear rubber. Gigiena Truda I Professional'nye Zabolevaniya (USSR) 1:31-34.

Weeks, JL, Peters JM, Monson RR (1981): Screening for occupational health hazards in the rubber industry. Part I. Am J Ind Med 2:125-142.