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Respiratory effects of work in retail food stores

I. Methodology and exposure assignments

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WEGMAN DH, SMITH TJ, EISEN EA, GREAVES IA, FINE LJ, CHELTON CS. Respiratory effects of work in retail food stores: I Methodology and exposure assignments. *Scand J Work Environ Health* 13 (1987) 203–208. This study was designed to examine whether retail food store employees have an unusual prevalence or incidence of respiratory symptoms or pulmonary function abnormalities attributable to their work environment. The methodology and development of exposure assignments are presented. Employees from 75 supermarkets (a total of 685 meat cutters, wrappers and store clerks) were tested in a base-line survey, and those still available (305) were resurveyed four years later. Each subject completed a standard questionnaire on job history, health history, cigarette smoking, and respiratory symptoms and also performed five forced expiratory efforts on a standardized spirometer. The major air contaminants were identified including the composition and levels of exposures associated with the different ways of cutting plastic film wrap. A cumulative exposure estimate for each subject was made. Parts II and III of this study present the association of these work environment factors with respiratory symptoms and ventilatory function.

Key terms: meat wrapper's asthma, plastic pyrolysis products, polyvinyl chloride, pulmonary function.

In 1973 Sokol et al (22) reported a new syndrome termed "meat wrapper's asthma" and suggested it resulted from the inhalation of fumes emitted during the cutting of polyvinyl chloride (PVC) film. Concern about emissions from the widely used "hot-wire" cutters led to the development of a different instrument, the "cool rod." The latter had larger thermal mass than a wire and could cut the wrap at lower temperatures (13).

Since the original case reports, several examples of meat wrapper's asthma have been described (2, 7, 17, 18, 21, 24), a small number of challenge studies have been performed (2, 5, 8, 17, 18, 20), and population studies on work groups have been undertaken (3, 4, 6, 7, 9, 11, 12, 14, 15, 16, 19, 25). These studies have reported inconsistent findings. Some have seen no unusual respiratory effects, while others have associated the observed effects with use of PVC film, heat-activated adhesive labels, and work in cold environments.

A study was designed (i) to identify the major air contaminants associated with retail food store jobs or work locations including different types of wrap cutting, (ii) to characterize the composition and levels of the exposures, to categorize long-term and current exposures to the major air contaminants, (iii) to examine associations of exposure with respiratory symptoms and pulmonary function, and (iv) to estimate whether current or past exposures affect the rate of change in pulmonary function.

Description of the retail food stores

All of the stores in the study contained (i) a stock display area with shelves and freezer and cold display cabinets; (ii) a meat preparation area with facilities for meat cutting, wrapping, and labeling; (iii) cold storage for meat and dairy products; (iv) a produce preparation area with sinks and counters for preparation, wrapping, and labeling; (v) a dry-goods storage area; and (vi) a checkout or sales area. The meat and produce preparation areas were usually in separate rooms.

The meat preparation rooms were refrigerated to 10°C and had an average relative humidity of 60 % with little variation between stores. Each store had separate ventilation systems for the main customer area and meat preparation areas.

Meat processing area

The meat processing rooms typically had a butcher area with large tables and a band type meat saw. The stores had one to three meat cutters, one or two full-time

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meat wrappers, and sometimes one or two part-time meat wrappers who worked staggered shifts. The meat cutters and managers also did some meat wrapping and labeling.

Meat wrapping was performed by setting the piece of meat on the top tray of the machine, drawing film out until it could be laid over the top of the piece, picking up the piece with the film on top, pulling the partially covered piece toward the operator until enough film had been pulled out to cover the bottom, and then bringing the stretched film down on the film cutter. The edges of the film were tucked under the package and sealed together as the package was briefly set on a heated sealing pad at the front of the machine. An experienced wrapper could package approximately two to four pieces per minute. A typical work pattern was to wrap for an hour or two and then spend a period labeling the packages. Some wrappers also stocked display cases and performed other tasks in the stores as needed. Stocking or clerking tasks were not associated with exposure to airborne hazards.

The following three types of film cutters were observed: heated 0.5–1.0-mm diameter nichrome wire or “hot-wire,” heated 5-mm rod or “cool-rod,” and mechanical. The wire and rod types were designed to be interchangeable with the cutter temperature preset and not controlled by the operator. Both types heated the cutting element by electrical resistance. The mechanical cutters used a serrated blade in a guillotine device.

Each package of meat was labeled with a heat-activated label. The labeling machine was electronically connected with a scale so the weight of a package could be determined, the price calculated, and the information printed on the label, which was then cut from the roll and ejected (glue side up) onto a heated metal pad. After a pause (0.5 to 3 s) the operator either pressed the package to the label as it sat on the heating pad or picked the label off the pad by hand and applied it to the package. When the label, on infrequent occasions, stayed on the pad too long it was charred. Thirty-five percent of the stores had automatic labeling machines that optimized heat activation of the label and applied them to the packages directly.

Produce area

Operations in the produce area were similar to those in the meat department. Vegetable and fruit in shipping containers were unpacked, washed, trimmed, and prepared in customer sized units. Some were wrapped with produce wrap film using a procedure similar to the meat wrapping process.

Population

Base-line group

The population selected for the base-line study was identified through the assistance of the four major

food store chains in the greater Boston area. The companies identified all stores that employed more than one meat wrapper full-time within the Boston metropolitan area. A total of 60 stores were identified and visited.

Because turnover in the first two years of employment was known to be high and the study was to be prospective, a two-year minimum employment criterion was used in selecting the subjects. It was recognized that this study design would eliminate from consideration subjects who might develop acute symptoms early in the work experience and then leave. Insurmountable logistic problems would have occurred in identifying subjects' reasons for leaving and their leaving dates among those with less than two years of employment. Therefore, all persons over 25 years of age who were employed for two or more years and who were working in “exposed areas” (the meat, produce, or delicatessen areas) were invited to participate in the study. All full-time and most (> 75 %) employees exposed part-time were eligible and agreed to participate. Since lists of store employees changed on a weekly basis, a precise count of eligible subjects could not be constructed. Workers meeting similar criteria were selected at random from store areas that had no wrapping operations to obtain a comparison group approximately half the size of the “exposed” group. An attempt was made to include a wide range of ages in this comparison group, but systematic stratified sampling was not possible because store lists varied from week to week and age was not recorded on the lists. Fewer than 10 individuals refused to participate.

At the conclusion of this survey the job distributions were reviewed. Due to the relatively small number of stores that employed full-time meat wrappers or full-time refrigerator/freezer workers, the categories of full-time meat wrapper and refrigerator or freezer workers were under-represented. To expand the study population, the original study area was enlarged to include the remainder of eastern Massachusetts and southern New Hampshire. A total of 15 stores were identified at which an additional 53 subjects were tested. Subjects tested in these 75 stores will be referred to as those who participated in the cycle I survey (table 1).

Cycles II and III

Follow-up surveys of the subjects in cycle I were conducted examining for changes in pulmonary function. Between the first and second cycle of tests, the work force experienced a marked reduction in one of the chains and consolidation in the other three. As a result, despite attempts to reduce dropouts by requiring a minimum of two years' employment to enter the study, a substantial number of subjects were not available for resurvey by the second or third surveys.

A random sample of those 516 subjects who had participated in cycle I and who were available at the end

Table 1. Demographic variables for the total study population (N = 685), at the first examination (cycle I).

Variable	Mean	SE	%
Age (years)	43.6	0.4	.
Sex female	.	.	36
Race Caucasian	.	.	97.1
Pack-years of smoking	18.4	0.8	.
Cigarette smoking history			
Current	.	.	51
Ex	.	.	21
Never	.	.	25
Other	.	.	2
Years employed	18.2	0.7	.
Current job			
Meat wrapper	.	.	17.2
Meat cutter	.	.	24.7
Produce/delicatessen worker	.	.	25.2
Not exposed	.	.	32.8

of two years were resurveyed (cycle II) in the same manner as in cycle I. Of the 345 subjects selected to participate 305 were resurveyed. Ten subjects refused and 30 were not working on days the survey team was at the store. Due to limited funds, a full population resurvey was not attempted.

Once funding was secured to complete the prospective study, a resurvey of the entire cohort was undertaken four years after the base line (cycle III). Of the 346 subjects identified as still employed, 316 were resurveyed. At least two and as many as four attempts were made to contact all subjects personally. Because of varying work schedules and travel distances, seven subjects were never contacted. Of the remaining, 23 subjects refused testing in cycle III. Characteristics of the combined group (resurveyed in either or both the second and fourth year, total = 433) are presented in table 2.

Assessment of respiratory health effects

Questionnaire

All the subjects were administered a standard validated questionnaire (10). The questionnaire collected information on medical, smoking, allergy, and work histories. Questions detailing types of allergy and the asthma history were added. Trained technicians administered the questionnaires.

The questionnaire responses were used for determining past respiratory symptoms, allergies, and chest disease. The following definitions applied: *nasal irritation* (history of nonseasonal sneezing attacks or itchy, runny or stuffy nose), *eye/throat irritation* (history of nonseasonal irritation, itching or burning in eyes or throat apart from a cold), *usual cough* (usually have a cough), *usual phlegm* (usually bring up phlegm from the chest), *frequent wheeze* (chest sounds wheezy or whistling on most days or nights), *chest tightness* (chest tight or breathing difficult as often as

Table 2. Selected variables by follow-up status (as of cycle I).

Variable	Retest (N = 433)			Lost (N = 252)		
	Mean	SE	%	Mean	SE	%
Age (years)	42.8	0.5	.	45.1	0.8	.
Sex female	.	.	35	.	.	39
Race Caucasian	.	.	97	.	.	98
Pack-years smoking	17.8	0.9	.	19.4	1.3	.
Never smokers	.	.	25	.	.	25
Years employed	17.9	0.5	.	18.6	0.8	.
Current job						
Meat wrapper	.	.	17	.	.	18
Meat cutter	.	.	27	.	.	20
Produce/delicatessen worker	.	.	25	.	.	25
Not exposed	.	.	30	.	.	37
Pulmonary function ^a						
Percentage of predicted FEV _{1.0}	104	1	.	104	1	.
Percentage of predicted FVC	102	1	.	103	1	.
Percentage of predicted FEV _{1.0} /FVC	96	0.5	.	96	0.6	.
Health history						
Hypertension	.	.	13	.	.	21
Respiratory allergy	.	.	12	.	.	8
Asthma	.	.	6	.	.	5
Bronchitis	.	.	10	.	.	14
Respiratory symptoms						
Usual cough	.	.	18	.	.	24
Usual phlegm	.	.	20	.	.	26
Chest tightness	.	.	12	.	.	9
Frequent wheeze	.	.	6	.	.	6
Chronic bronchitis	.	.	8	.	.	11

^a FEV_{1.0} = forced expiratory volume in 1 s, FVC = forced vital capacity.

once a week), *breathlessness on stairs* (shortness of breath when walking up two flights of stairs), and *chronic bronchitis* (yes to "usual phlegm twice a day for 4 d per week," yes to "bring up phlegm at all on getting up, or first thing in the morning" and in either case do so on most days, for as much as three months at a time, for three or more years).

In addition, each subject's personal and family history of allergy or asthma and history of chest illness or injury was noted in the following ways: *allergy to inhaled materials* (allergic reaction to pollen, ragweed, dust, or animals confirmed by a physician or the subject ever told by a physician that he/she had hay fever or allergic rhinitis); *history of asthma* (ever had asthma); *history of chest illness/injury* (subject ever told by a doctor that he/she had bronchitis or emphysema or bronchiectasis, or a chest injury); and *cardiovascular disease* (subject ever told by a doctor that he/she had high blood pressure or heart disease).

Pulmonary function tests

The forced vital capacity (FVC) was recorded on a spirometer (Collins' Survey Spirometer) with a paper speed of 32 mm/s. The equipment was volume-calibrated before each testing session. Before cycle III, equipment was added to the spirometer (Warren E Collins Eagle I) to provide automated calculation of the study parameters of interest [FVC, and forced ex-

piratory volume in 1 s ($FEV_{1.0}$)). Automated and hand-read tracings were compared for 51 normal subjects. The mean differences were not found to be significantly different by the paired "t" test.

The $FEV_{1.0}$ was measured by back-extrapolation according to the method established by the American Thoracic Society (1). All spirometry testing was conducted during the workshift without a noseclip and with the subject sitting. Five satisfactory trials were required of each subject. Unsatisfactory trials were rejected at the time of testing. The subject was asked to continue the FVC maneuver for a total of 10 s. The FVC and $FEV_{1.0}$ measurements were adjusted to conditions of body temperature and pressure saturated with water vapor (BTPS). A test was judged satisfactory provided the differences between the two largest $FEV_{1.0}$ and FVC values were less than 200 ml or 5 % of the largest value. By this rule, 96 % of the subjects had acceptable values.

Losses to follow-up

The cycle I data from the "lost" group were compared to cycle I data for those who were retested. Persons were counted as lost only if they were not retested in either of the later examinations (cycle II or cycle III).

When those retested were compared with the lost group (table 2), the differences were small. There was a higher proportion of unexposed subjects and a lower proportion of meat cutters who were lost to follow-up. Meat cutters are the skilled workers of the industry and the unexposed (eg, clerks) are the least skilled. The differences in health history and respiratory symptoms were not significant, and the pulmonary function measures were equivalent.

It was likely that the store closings and consolidations led to losses which were primarily involuntary and not related to health. There do not appear to have been major selection biases operating against the detection of a work-related health effect as a result of loss of those who could not be retested.

Environmental exposures

Previous studies have shown that the amount of particulate and hydrogen chloride (HCl) emissions appeared to be related to cutting temperatures, and that the cool rod had much lower levels of emissions than the wire (13, 27). Detailed laboratory studies by our group and others permit prediction of approximate exposures from the operating temperature of wrap cutting instruments (23, 26). These also show the effect of work practices on the amount of emissions and the variations in air concentrations with time. Extensive field studies examined personal exposures of workers by job title and work location that showed significant differences in the time-weighted average exposures.

Polyvinyl chloride wrap

The film used in the grocery industry is not pure PVC. Its composition is closely regulated by the United States Food and Drug Administration. A small number of additives may be present within limited ranges (24). For example, plasticizers, generally phthalate, adipate or citrate esters, are added up to 30 % of the total material in the film along with smaller amounts of stabilizers and lubricants.

Adhesive labels

In most formulations of adhesive label plasticizer the main ingredient [most commonly dicyclohexyl phthalate (DCHP)] is present at about 60 % by weight. A variety of thermoplastic and elastomeric polymers may be added, along with other organic additives and inorganic stabilizers in small amounts. Specific component identifications are proprietary information not subject to regulatory control.

Development of the exposure variable

In an attempt to characterize the airborne exposures of the meat wrappers and other personnel, the emissions of specific sources, the personal exposures of the workers, and the physical conditions in the work environment were studied.

The meat wrappers had the highest exposures to respirable aerosol from the wrap; 32 % of the personal samples contained detectable dioctyl adipate (DOA), which had a geometric mean of 14.6 μg of DOA/ m^3 , whereas only 26 % of the meat-cutter samples contained detectable DOA (geometric mean 11.7 $\mu\text{g}/\text{m}^3$).

Microbial exposures in the meat room were not different from those in the ambient air or other store areas. No other sources of routine exposure to air contaminants could be identified.

Exposure "level"

A study of labeling operations in our laboratory indicated significant particulate emissions, containing phthalic anhydride and other decomposition products, could be produced by over-heated labels. Such over-heating was difficult to document because these events occurred very infrequently, as indicated by the low frequency of detectable amounts of the label plasticizer (DCHP) in the personal samples. The only exposure which was consistently present in sufficient quantity to measure was that caused by emissions from the hot wires used in wrapping operations. Meat wrappers using hot-wire cutters had detectable DOA in 55 % of their personal samples, while those using cool rods had only 10 %. The principal exposure variable evaluated in the epidemiologic study was the relative intensity of exposure to emissions from wrapping operations using hot-wire cutters.

The laboratory simulations showed that the emissions from wrap cutting may contain substantial concentrations of hydrogen chloride (1–10 ppm) and respirable particulates (0.5–10 mg/m³) when the wire temperatures exceed 190°C, as measured by the Thermo-Ohm sensor. Workers using wire cutters at temperatures above 190°C were likely to be exposed to gaseous and particulate irritants. Hot wires were generally operating at or above 190°C, while cool rods were close to 150°C. Therefore exposure depended on type of cutter and how much wrapping was done.

Therefore, for comparing the relative risk of effects, a worker's relative respiratory dose was considered best estimated, in the epidemiologic evaluation, by a combination of the type of wrapping equipment in the store and the time spent wrapping. Because a job description did not identify the type of cutting instrument, the use of job category alone to classify exposure would likely have resulted in a substantial misclassification of exposure. In addition some wrapping is occasionally done by meat cutters and others whose principal job is not wrapping. Classifying exposure by the type of cutting instrument does not eliminate a small amount of misclassification due to a few hot wires that had temperatures below 190°C and a few cool rods that had temperatures exceeding 190°C. Still, the simple exposure classification into cool rods and hot wires was considered the optimal strategy.

Job group

History of time spent in 37 different job categories, especially time spent in wrapping jobs and time spent in the vicinity of wrapping operations, was recorded.

Meat wrapping was distinguished from produce and delicatessen wrapping because the latter were performed at ambient temperatures. Measurements of ambient temperatures showed that meat wrappers worked at an average temperature of 11.6°C and meat cutters worked at 9.9°C. The difference reflects the presence of a few wrappers who were not in the meat room, or who moved between meat rooms and the rest of the store. The produce workers and the clerks, in contrast, worked in mean ambient temperatures of 16.3°C and 18.3°C, respectively. The few unexposed workers who spent time in refrigerated or freezer environments were selected as the "cold only" group. Although no average ambient temperature estimates could be made for this group, their reported histories led to the decision to classify them separately from the wrapping area workers and the nonwrapping area referents.

Exposure grouping

A classification was created to represent cumulative exposure to wrapping emissions over the full working career. A variable was formed which summed the hours for all types of exposure, a weighting factor being assigned to each type of exposure.

With the use of the job history, the subjects who wrapped (direct exposure) were separated from those who worked in the immediate vicinity of wrapping operations (indirect exposure), and the type of instrument used for wrap cutting was accounted for.

The time spent in each type of exposure was obtained from two sources. Personnel records were used for the estimation of hours worked per year, and field observations of work practices were used to estimate the portion of a day spent wrapping. These latter estimates were confirmed by the field environmental study observations when personal sampling was performed.

Some misclassification of instrument used probably occurred since (i) some workers changed stores several times during the study (sometimes to stores not environmentally evaluated), (ii) most stores changed from hot-wire to cool-rod cutting at some unrecorded time during the study, and (iii) many stores had more than one machine without a record of their use. The full-time wrapper almost invariably used the primary machine; hence the most highly exposed individuals were probably classified correctly.

The determination of weighting factors for direct and indirect exposures was based on the findings of the environmental evaluation of the different exposures. The absolute magnitude of the factors were arbitrary; they were intended only to indicate the relative intensity of exposure. In general they were based on the time-weighted average (TWA) levels being proportional to the total emissions per day and the low mass emissions from the cutter being dissipated rapidly with distance (so indirect exposures would be substantially lower than the direct exposures of the meat wrappers).

Meat room TWA exposure to aerosol, corresponding to indirect exposure of the meat cutters to cool rod emissions, was arbitrarily set at 1.0. The other factors were 1.25 for indirect exposure to hot wires, 2 for direct exposure to cool rods, and 4 for direct exposure to hot wires.

Each worker's total cumulative exposure to hot-wire wrapping was calculated for total cumulative exposure (CE) as follows:

$$\text{Total CE} = \sum_j (t_j w_j) + \sum_i (t_i w_i),$$

where t_i and t_j are times spent in jobs with direct and indirect exposures, respectively, and w_i and w_j are the respective weights.

Total cumulative exposures to cool-rod wrapping alone were also examined in this manner; however, the historical exposures to cool rods were small relative to hot-wire exposures because of their recent introduction. As a result, historical exposures were distinguishable primarily by hot-wire wrapping, and hence they were the basis for the evaluation of the effects of long-term employment. Having developed this measure of exposure, we then proceeded to examine associations between exposure and health outcomes. Parts II and III of this study present the results when the methods

were used to examine the association of the work environment factors with respiratory symptoms and ventilatory function.

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