

Respiratory Health of Two Cohorts of Terminal Grain Elevator Workers Studied 30 Years Apart

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Introduction We evaluated the respiratory health of two cohorts of grain terminal elevator workers who participated in one of either respiratory health surveys undertaken in 1978 and 2008.

Methods Questionnaire and spirometry data from 584 workers from the 1978 survey and 215 workers from the 2008 survey were compared using logistic regression and general linear modeling.

Results The geometric means of area samples of grain dust averaged 8.28 mg/m³ in 1978 and 2.06 mg/m³ in 2008. Workers in the 1978 survey had a significantly higher prevalence of respiratory symptoms (with the largest adjusted odds ratio of 3.78, 95% CI 2.07–7.25, for shortness of breath), a lower prevalence of atopic conditions and lower mean lung function.

Conclusion Current grain workers had a lower risk of respiratory health consequences and a greater prevalence of atopic conditions than workers surveyed 30 years prior, most likely associated with reduced exposure to grain dust in the terminal elevator environment. Am. J. Ind. Med. © 2010 Wiley-Liss, Inc.

KEY WORDS: grain dust; respiratory health; occupation

INTRODUCTION

Grain dust is a known respiratory health hazard in the grain industry. It has been estimated that for each tonne of grain that passes through a typical elevator three to four pounds of dust are generated [Farant and Moore, 1980]. Grain dust constituents may include plant products, pollens, storage mites, animal matter (from insects, rodents, and birds), inorganic dust and chemicals (such as herbicides and pesticides), and microflora (fungi and bacteria, including

endotoxin). Grain workers typically can be exposed to airborne micro-organisms in concentrations over one million colony forming units per m³ suspended on grain dust [Swan and Crook, 1998].

The amount of grain dust in the working area of the elevator depends on the type, quality or grade, and moisture content of the grain, the type of grain operations performed, and the efficiency of dust controls [Environmental Protection Agency (EPA), 2003]. In 1975 a Vancouver area terminal was partly destroyed by an explosion and fire, due to the fire hazard created by high concentrations of grain dust. Following this, a national health surveillance program was instituted to control dust exposure in grain elevators and monitor the health of workers.

Health effects associated with organic dust exposure in grain handlers include mucous membrane and skin irritation, grain fever (organic dust toxic syndrome), and chronic bronchitis [do Pico, 1994], as well as grain dust asthma, allergic sensitization, and airflow obstruction [Chan-Yeung et al., 1992a]. The purpose of this paper was to evaluate the respiratory health of two cohorts of grain terminal elevator

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workers who participated in either one of two respiratory health surveys undertaken in 1978 and 2008, a time span in which industrial controls were established in terminal grain elevators to reduce grain dust levels.

METHODS

All grain workers employed at terminal grain elevators in the Port of Vancouver were invited to take part in each survey. Subjects completed individual consent forms prior to taking part in the testing procedures, as approved by the University of British Columbia Clinical Research Ethics Board.

Out of ten surveys conducted since 1975, the second (1978) was chosen for comparison with the recent study, since most elevator workers had gained familiarity with the survey procedures and only Vancouver area terminal grain workers participated. Grain workers from four terminal elevators were involved in the 2nd survey and from five terminals in the 10th survey (2008).

Workers who had participated in both studies ($n = 67$) were excluded from the main analysis, as were female workers from the 10th survey ($n = 36$), since only male workers took part in the earlier survey. Comparisons were made between the respiratory health status and personal and occupational characteristics of 584 workers from the 1978 survey and those of 215 workers from the 2008 survey. In a separate analysis, data from 59 workers with complete data who took part in both surveys were compared.

Spirometry was conducted using a 13.5L Collins spirometer (Warren E. Collins, Braintree, MA) in 1978, which was replaced over a decade later by a rolling seal spirometer (S&M Instrument Company, model VRS2000, Doylestown, PA). Percent predicted values for forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV_1) were determined using equations, based on age and height [Crapo et al., 1981], with further adjustment for ethnicity (Caucasian vs. non-Caucasian).

The questionnaires consisted of common items on chronic respiratory symptoms and conditions [Ferris, 1978], smoking history and occupational environment. Questions on the following chronic symptoms/conditions were asked in an identical manner:

Chronic cough and *chronic phlegm*—usually having a cough (or phlegm) for at least 3 consecutive months; *shortness of breath*—hurrying on level ground or when walking up a slight hill; *occasional wheeze*—having a wheezy or whistling chest occasionally, apart from colds; *current asthma*—having a doctor diagnosis of asthma and having experienced symptoms currently. A *never smoker* had smoked less than 20 packs of cigarettes over a lifetime or less than one cigarette a day for 1 year. An *ex-smoker* had smoked but, as of at least a month ago, had stopped smoking. *Childhood ETS* (Environmental Tobacco Smoke) was

defined as the participant's mother or father having smoked during their childhood.

Allergy skin prick tests were carried out on the forearm. Allergens used in common in the two surveys were house dust mite (*Dermatophagoides farina*), grass mix and cat hair. Histamine was used as the positive control and the negative control was saline. For each allergen, a wheal diameter of 3 mm greater than the negative control, measured 15 min after testing, was considered to be a positive reaction. A subject was considered to be atopic if there was a positive skin reaction to at least one of the skin allergens tested.

Total airborne dust was collected by fixed samplers ("area" samples). Environmental sampling was conducted in the same 2-week period that the questionnaires and lung function tests were administered. In the 1978 study, total dust was measured using closed face, three piece cassettes (SKC, Eighty-Four, PA) fitted with 37 mm polyvinyl chloride (PVC) filters. Closed-face cassettes measure total particulate mass with a 50% cut-off point (50% sampling efficiency) of 40 μ m aerodynamic diameter. The 2008 area samples were quantified using three piece cassettes fitted with type A/E glass fiber filters, rather than PVC filters. All sampling was conducted using battery operated SKC personal sampling pumps calibrated to 2.0 L/min. Sampling trains were attached and secured with adhesive tape to posts or similar stationary objects with the cassette pointing downwards. Each was placed in a specific pre-determined area of the elevator (11 locations in 1978 and 7 locations in 2008) for at least six hours. Location codes for area sampling were unavailable for the 1978 study. Although personal sampling was undertaken at both occasions, in 1978, sampling of total grain dust was done (37 mm cassette with a 50% cut-off point of 40 μ m) whereas in the 2008 survey, a 7-hole aerosol sampler (25 mm filter with a 50% cut-off point of 100 μ m) was used to sample inhalable dust.

Standard statistical methods were employed in the analysis of data using SPSS/PC Version 16.0 (SPSS, Chicago, IL) and STATA Version 6.0 (STATA, College Station, TX). Cross-tabulations were performed using χ^2 testing to compare categorical variables between the two surveys. Student's *t*-test was applied to continuous variables. Logistic regression analysis was used to calculate odds ratios (OR) and 95% confidence intervals (CI) for binary outcomes (symptoms or conditions), after adjustment for available potential covariates: ethnicity (Caucasian or not), age (years), atopy (positive vs. negative), ex- and current smoking versus never smoking, asthma before 16 years (yes vs. no), mother or father smoking versus none (childhood (ETS)).

Adjusted lung function values were calculated using generalized linear models, substituting age with duration of time in the industry as the covariate, since age was taken into account in the predicted lung function equations and the variables of age and time in the industry were highly

correlated ($r = 0.71$). Paired t -tests of actual FEV₁ and FVC values in milliliters were used to evaluate unadjusted lung function changes over time for the separate group of 59 eligible workers who took part in both surveys. For all analyses, a P -value of <0.05 indicates statistical significance.

RESULTS

The participation rate in 1978 was 94%, while in 2008 it was 73.4%. The concentration of area samples of total grain dust differed significantly between surveys, with geometric means and standard deviations for 1978 and 2008 of $2.91 \pm 3.10 \text{ mg/m}^3$ and $0.45 \text{ mg/m}^3 \pm 5.02 \text{ mg/m}^3$ respectively (Table I). The relatively large standard deviations reflected the variety of exposure levels expected in the different locations sampled. There were about twice as many different job titles for the 1978 grain worker cohort (number of job titles = 53) as in the 2008 group (number of job titles = 26), with the three most common job titles being cleaner, millwright, and laborer for both grain worker cohorts.

With the exception of height, all the personal characteristics differed significantly between the 2nd and 10th grain studies (Table II). Of note was the large increase in atopy from 13.4% of those tested in 1978 to 51.2% in 2008, which was in parallel with the comparative prevalence of hay fever. The 1978 workforce had a much higher proportion of current smokers and a heavier cigarette smoking habit. However, childhood exposure to environmental tobacco smoke was mixed, with the 2008 grain workers having a greater percentage of mothers (but not of fathers) who had smoked.

Almost 40% of workers in 1978 did not wear any mask protection at all, in contrast to the few grain workers (5.6%) in 2008 (Table II). In comparison to 25.7% of the 1978 grain workers who wore masks at least half of the time, masks were

TABLE I. Distribution of Area Grain Dust Measurements by Survey Year (mg/m^3)

	1978 survey	2008 survey
N	154	109
Geometric mean ($\pm$ SD)	2.91 ± 3.10	0.45 ± 5.02
Mean ($\pm$ SD)	6.12 ± 11.94	2.06 ± 6.11
Median	2.65	0.39
Minimum value	0.1	0.005
Lower quartile	1.30	0.17
Upper quartile	5.45	1.20
Maximum value	97.6	50.0

SD, standard deviation.

TABLE II. Personal and Occupational Characteristics of Grain Workers by Survey Year

	1978 survey	2008 survey	P-Value
N	584	215	
Age (mean $\pm$ SD)	38.4 ± 13.3	45.7 ± 10.6	0.00
Height in cm (mean $\pm$ SD)	177.4 ± 6.8	176.7 ± 6.9	0.22
Weight in kg (mean $\pm$ SD)	80.0 ± 11.1	89.0 ± 14.9	0.00
Caucasian (%)	98.1	84.2	0.00
Asthma before age 16 (%)	2.4	4.7	0.10
Atopy (%)	13.4	51.2	0.00
Hayfever (%)	13.9	43.5	0.00
Smoking status (%): never	25.5	46.0	0.00
Ex-smoker	33.0	34.7	
Current smoker	41.4	19.2	
Cigarettes/day (mean $\pm$ SD)	19.6 ± 10.1	11.7 ± 7.3	0.00
Mother smoked (%)	35.8	48.4	0.00
Father smoked (%)	71.4	64.0	0.05
New participants (%)	26.6	25.1	0.68
Years in industry (mean $\pm$ SD)	11.2 ± 9.2	17.7 ± 10.8	0.00
Mask use (ever) (%)	61.2	94.4	0.00

SD, standard deviation.

used most or all of the time by 42.8% of the recent cohort. Of the 2008 grain workers, 73.0% used disposable paper masks and 37.6% used these exclusively. Information on the type of mask used was not available for the 1978 cohort.

There had been a significant decrease in the prevalence of respiratory symptoms between 1978 and 2008 surveys, excluding current asthma (Fig. 1). The prevalence of chronic cough, chronic phlegm, and shortness of breath were particularly high among the 1978 grain worker cohort.

When expressed as odds ratios, the workers from the 1978 survey had over twice the odds of having chronic cough, phlegm and shortness of breath in comparison to those from the 2008 survey, after adjusting for common covariates (Table III). Upon stratification by smoking status (data not shown), the odds ratios comparing the 1978 and 2008 values showed a clear linear trend only for shortness of breath, with the unadjusted odds ratios increasing from 2.4 for never smokers to 3.3 for ex-smokers and 5.2 for current smokers. Smokers in 1978 compared to never smokers in 2008 had the highest odds ratio for shortness of breath of 7.3. Differences in symptoms between surveys were reduced when adjustment was done. In the multivariate model, current smoking was the only factor found to be significantly associated with chronic cough and phlegm and was also significantly related to wheeze (as was ethnicity) and shortness of breath. Having childhood asthma and increasing age were significantly associated with an increased odds of shortness of breath and asthma. Percentages of predicted FEV₁, and especially of FVC, were much lower for the 1978 grain workers cohort,

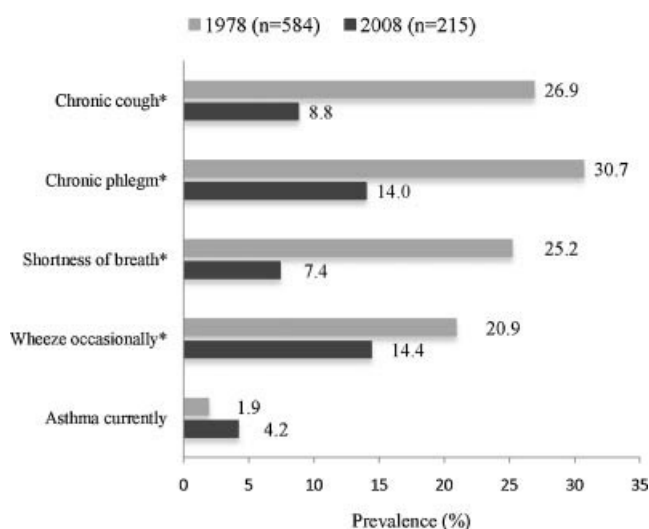


FIGURE 1. Unadjusted prevalence of chronic respiratory symptoms in 1978 versus 2008 surveyed grain workers. *Difference between surveys was statistically significant (P -value < 0.05).

even with adjustment for differences in potential covariates (Fig. 2). As would be expected, the ratio of FEV₁/FVC was higher on average in 1978 due to the relatively low FVC levels. All comparisons of lung function between surveys were also statistically significant for unadjusted values (data not shown).

Table IV compares characteristics of the small subset of workers ($n = 59$) who took part in both surveys. Over the 30-year period, average weight increased by 17 kg and there were 25% fewer current smokers, but little difference in atopy or hayfever. A mean decrement in lung function over time was observed for FEV₁ (29.9 ± 13.7 ml/year) and FVC (23.5 ± 17.0 ml/year). A greater number of individuals reported no longer experiencing respiratory symptoms than those who developed them in the intervening years: the respective numbers out of 59 were 15 versus 2 for chronic cough, 10 versus 3 for chronic phlegm, 9 versus 2 for shortness of breath, and 7 versus 3 for occasional wheeze (data not shown).

TABLE III. Risk of Chronic Respiratory Symptoms, Comparing 1978 ($n = 584$) Versus 2008 ($n = 215$) Surveyed Grain Workers

Respiratory symptoms	OR _{unadjusted}	CI (95%)	OR _{adjusted} ^a	CI (95%)
Chronic cough	3.79	2.29–6.29	2.75	1.50–5.07
Chronic phlegm	2.73	1.78–4.17	2.31	1.37–3.89
Occasional wheeze	1.57	1.02–2.41	1.44	0.84–2.44
Shortness of breath	4.18	2.43–7.20	3.87	2.07–7.25
Asthma currently	0.44	0.18–1.07	1.08	0.32–3.59

^aAdjusted for ethnicity, age, atopy, ex-, and current smoking, asthma before 16 years and childhood environmental tobacco smoke.

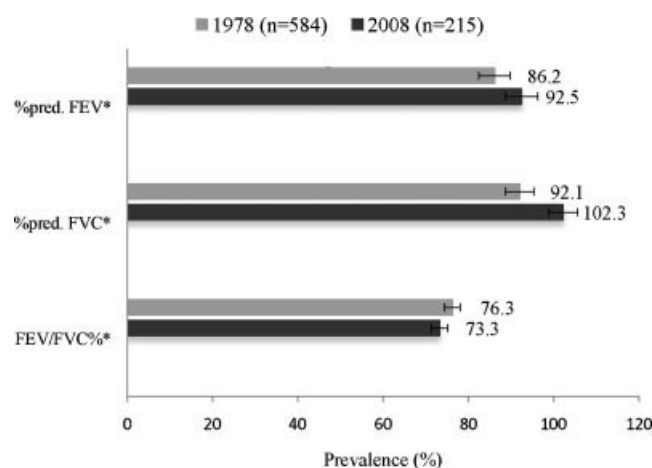


FIGURE 2. Adjusted lung function values¹ by year of survey on grain workers. Adjusted for years in industry, asthma before age 16, atopy, smoking status and childhood ETS. *Difference between surveys was statistically significant (P -value < 0.05).

DISCUSSION

The two cohorts of grain workers, tested 30 years apart, were clearly distinct in their respiratory health. The mean percentage of predicted values of FEV₁, FVC and their ratio (taking into account differences in smoking habits and childhood exposure to ETS, duration of employment in the industry, atopy, and childhood asthma) were lower in the 1978 cohort of grain workers. On average, workers in the more recent survey were 7.3 years older than the 1978 cohort and had worked longer in the industry. More rapid lung function decline among older workers as compared to younger co-workers was previously noted in a past study of British Columbia grain handlers [Tabona et al., 1984]. It would be expected that with an older cohort there would

TABLE IV. Personal Characteristics and Lung Function of Grain Workers Studied in Both 1978 and 2008 ($n = 59$)

	1978 survey	2008 survey
Age (mean $\pm$ SD)	25.3 $\pm$ 5.0	55.3 $\pm$ 4.3
Height in cm (mean $\pm$ SD)	176.9 $\pm$ 7.0	174.9 $\pm$ 7.4
Weight in kg (mean $\pm$ SD)	75.6 $\pm$ 11.5	92.6 $\pm$ 24.5
Atopy (%)	33.3	36.8
Hayfever (%)	13.8	19.0
Current smoker (%)	36.2	10.3
Cigarettes/day (mean $\pm$ SD)	15.8 $\pm$ 4.9	13.3 $\pm$ 9.8
Years in industry (mean $\pm$ SD)	4.1 $\pm$ 2.8	32.7 $\pm$ 7.6
Mask use (%)	74.6	88.1
FEV ₁ (L/s)	4.3	3.4
FVC (L)	5.1	4.4
FEV ₁ /FVC ratio (%)	84.1	77.1

SD, standard deviation.

have been lower lung function; yet, on average the opposite was true. Likewise, total duration of employment in the grain industry, which is directly related to accumulated dust exposure, has been found to be one of the significant predictors of FEV₁ annual decline [Pahwa et al., 1994]. Yet, the 2008 grain workers cohort had a longer duration of employment in the industry, albeit with lower grain dust levels, but better respiratory health.

Along with poorer lung function, the risk of chronic respiratory symptoms was much higher in the earlier cohort. For shortness of breath, the relative odds was 3.5 times greater for the grain workers studied in 1978 as opposed to 2008. The opposite trend of a higher prevalence of atopic conditions including asthma, atopy and hayfever, was more apparent in the 2008 group of grain workers. The lower dust levels over time may have enabled affected workers to remain on the job.

Shortness of breath and FVC showed the greatest discrepancy between the two grain worker cohorts. It has been shown in analyses of previous cross-sectional studies of British Columbia grain workers that the effect of grain exposure on FVC was greater than that of FEV₁, suggesting that grain dust may affect lung parenchyma as well as the airways [Chan-Yeung et al., 1992a]. Broder et al. [1980, 1984] characterized changes in lung function in grain workers as a restrictive ventilatory deficit. Huy et al. [1991] demonstrated a dose-response relationship between grain exposure in BC terminal elevators and symptoms of phlegm and dyspnea, as well as reduced lung function, particularly FVC.

The small subset of grain workers who were tested at both surveys 30 years apart generally showed expected decreases with aging in FEV₁ and FVC over time of approximately 30 ml/year and 24 ml/year respectively. This compares to FEV₁ declines in two large adult community cohorts [Xu et al., 1995] averaging 20 and 33 ml/year for never-smokers and 24 and 39 ml/year for ex-smokers respectively for the US and Netherlands studies. Of the 59 grain workers with repeat visits, a larger percentage no longer had symptoms 30 years later than developed symptoms with time. This may relate to the change in smoking status as well as reduced exposure to grain dust.

Our finding of worse respiratory health outcomes experienced by the early, more heavily exposed cohort of grain workers is supported by the longitudinal study of Pahwa et al. [2008] in which the greatest loss of FEV₁ and FVC was experienced among Canadian grain elevator workers with the longest time in the grain industry (at least 20 years, as a surrogate of greater exposure) regardless of smoking status. The decline in lung function was faster in the period (pre-1987) prior to implementation of dust control measures.

Although direct comparisons are not possible due to differences in the extent and location of air quality

monitoring, the average area total dust concentrations in 1979 was six times higher than found in 2008, with levels of 8.28 and 2.06 mg/m³, respectively. In 1976, Canadian regulators arbitrarily set the exposure limit for total grain dust at 10 mg/m³, a value assigned to nuisance dust [Broder et al., 1979]. However, grain dust is biologically active: it is a heterogeneous mixture of inorganic soil particles, plant fragments, insect and mite parts, viable and non-viable microorganisms and their components, such as endotoxins, glucans, allergens or mycotoxins [Halstensen et al., 2007]. As both acute and chronic effects on the lungs are observed at exposure levels below 10 mg/m³ [Chan-Yeung et al., 1992b], grain dust cannot be considered only as a nuisance dust.

Excessive exposure to grain dust due to poor industrial hygiene controls in the terminal elevator and lack of appropriate personal protection equipment would be important considerations in explaining the discrepant respiratory health outcomes in the two cohorts. One measure of personal protection is the use of masks, which had increased in 2008. Although inefficient, disposable paper masks were used by the majority of those workers.

In addition to higher levels of occupational exposures to respiratory hazards, a consideration is that smoking habits were much worse in the earlier cohort, with 41% being current smokers, averaging 20 cigarettes per day in 1978, as opposed to 19% in 2008 being current smokers, averaging 12 cigarettes per day. The majority of studies demonstrate that the effects of smoking and grain dust on lung function are additive [Chan-Yeung et al., 1992b]. This relationship is supported by our findings on shortness of breath when stratifying by smoking status. The cohort "grain exposure" effect resulted in an odds of 2.4 among never smokers; 5.2 among smokers; and 7.3 among smokers in the earlier cohort versus never smokers in the later cohort, demonstrating additivity. Comparisons of symptoms and lung function for the entire group of workers were statistically adjusted for smoking status to attempt to account for the known influence of smoking status on respiratory health.

A limitation to the study is a lack of a comparison group to evaluate cohort differences in respiratory health over the long term. Previous cross-sectional studies with comparison groups have found grain workers to be at higher risk to respiratory symptoms and reduced lung function than unexposed workers [do Pico et al., 1984; Chan-Yeung et al., 1992b]. Short-term longitudinal studies showed a greater loss in lung function in grain workers than in unexposed controls, irrespective of smoking habits [Chan-Yeung et al., 1981; Broder et al., 1985]. It would be expected that unexposed controls with comparable personal characteristics, studied at the same two points in time, would show fewer differences in respiratory symptoms and in lung function.

Another limitation is the lack of pre-employment lung function testing which would allow for a more definitive

evaluation of the impact of grain dust exposure. The healthy worker effect could be relevant to both cohorts, given the cross-sectional nature of each study; however the lower participation rate in the 2008 survey may affect representativeness. Pre-screening to prevent hiring of vulnerable workers would be more likely in the more recent study, when employers were more knowledgeable about predictors of health problems. In the earlier study, the higher dust exposure would discourage workers with greater sensitivity to the effects of grain dust from continued employment. The possibility is supported by the much lower prevalence of atopic disorders in the 1978 cohort of grain workers.

In conclusion, current grain workers had a lower risk of respiratory health consequences than workers surveyed 30 years earlier, most likely associated with reduced exposure to grain dust in the terminal elevator environment. Our findings support recommendations for a reduction from the current Canadian permissible exposure limit of 10 mg/m³ (adopted in 1978) in order to prevent respiratory health consequences attributable to grain exposure. In this regard, Becklake et al. [1996] had suggested a maximum exposure level of 5 mg/m³ for grain dust, which is conservative, considering the current American Conference of Governmental Industrial Hygienists ACGIH and WorkSafeBC Threshold Limit Values of 4 mg/m³ for grain dust (Oats, Wheat or Barley) [OSHA, 2010; WorkSafeBC, 2010].

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