ORIGINAL ARTICLE

Longitudinal decline in lung function measurements among Saskatchewan grain workers

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OBJECTIVE: To evaluate the relationship between the long term effects of grain dust and decline in lung function among grain elevator workers in Saskatchewan, studied over a 15-year period.
METHODS: The Grain Dust Medical Surveillance Program was started by Labour Canada in 1978 and longitudinally studied the respiratory health of Canadian grain elevator workers over a 15-year period (1978 to 1993). Data on respiratory symptoms and pulmonary function tests (forced expiratory volume in 1 s [FEV_1], forced vital capacity [FVC]) were collected once every three years; each three-year interval was called a 'cycle'. Data from Saskatchewan were analyzed for this report. A transitional model using the generalized estimating equations approach was fitted using a SAS macro to predict the annual decline in FEV_1 and FVC.
RESULTS: Previous lung function, as one of the covariates in the transitional model, played an important role. Significant predictors of FEV_1 were previous FEV_1, base height, weight, years in the grain industry, current smoking status, cycle II, cycle III and cycle V. Significant predictors of FVC were previous FVC, base height, weight, years in the grain industry, cycle II, cycle III and cycle IV.
CONCLUSIONS: The estimated annual decline in FEV_1 and FVC increased according to length of time in the grain industry among nonsmoking, ex-smoking and smoking grain elevator workers. Lung function values improved after dust control, and yearly declines in FEV_1 and FVC after dust control were smaller compared with yearly losses before dust control.

Key Words: *Generalized estimating equations; Grain workers; Longitudinal study; Lung function*

Déclin longitudinal des mesures de la fonction pulmonaire chez les travailleurs de l'industrie céréalière de la Saskatchewan

OBJECTIF : Évaluer la relation entre les effets à long terme de la poussière céréalière et le déclin de la fonction pulmonaire chez les travailleurs des élévateurs à grains de la Saskatchewan sur une période de 15 ans.
MÉTHODES : Créé en 1978 par Travail Canada, le Programme de surveillance médicale de la poussière céréalière comportait l'étude longitudinale de l'état de santé des travailleurs des élévateurs à grains sur une période de 15 ans (de 1978 à 1993). Des données sur les symptômes respiratoires et les résultats de tests de la fonction pulmonaire (volume expiratoire maximal par seconde [VEMS], capacité vitale [CV]) ont été recueillis tous les trois ans; chaque intervalle de trois ans a été appelé un « cycle ». Les données de la Saskatchewan ont été analysées aux fins de ce rapport. Un modèle de transition faisant appel à des équations d'estimation généralisées a été ajusté à l'aide d'une macro de système d'analyse statistique pour prédire le déclin annuel du VEMS et de la CV.
RÉSULTATS : La fonction pulmonaire antérieure a joué un rôle important comme covariable du modèle de transition. Les facteurs prédictifs importants du VEMS étaient le VEMS antérieur, la taille initiale, le poids, le nombre d'années passées dans l'industrie céréalière, la situation actuelle quant au tabagisme, le cycle II, le cycle III et le cycle V. Les facteurs prédictifs importants de la CV étaient la CV antérieure, la taille initiale, le poids, le nombre d'années passées dans l'industrie céréalière, le cycle II, le cycle III et le cycle IV.
CONCLUSIONS : Selon les estimations, l'importance du déclin annuel du VEMS et de la CV a augmenté en fonction du temps passé dans l'industrie céréalière chez les travailleurs des élévateurs à grains, qu'ils soient fumeurs, non fumeurs ou anciens fumeurs. Après l'introduction de mesures anti poussières, les valeurs de la fonction pulmonaire se sont améliorées et le déclin annuel du VEMS et de la CV a été moins marqué, sans égard au nombre d'années passées dans l'industrie céréalière, comparativement aux pertes annuelles avant l'introduction de ces mesures.

Farmers, grain elevator workers (working in country, terminal and transfer elevators), dock workers, and feed, flour and seed mill workers are exposed to grain dust. Few longitudinal studies have attempted to determine the predictors of annual decline in lung function among grain workers (1-11). Chan-Yeung et al (1), Tabona et al (2) and Enarson et al (3) compared the respiratory health of essentially the same group of grain handlers in the Port of Vancouver with a group of civic workers. They found that the average annual decline in lung function was greater for grain workers than for the control subjects.

Huy et al (7) studied the long term effect of grain dust exposure on the longitudinal decline in lung function among grain elevator workers over a 15-year period. They reported a dose-response relationship between grain dust exposure and a longitudinal change in FEV_1 and FVC, as well as an increase in respiratory symptoms. Huy et al (7) used multiple regression analysis to analyze the data, and they estimated cumulative and average dust exposure based on each worker's detailed job history. McDuffie et al (8) reported the respiratory health status of Canadian grain elevator workers studied longitudinally on two

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different occasions three years apart. There were significant increases in chronic respiratory symptoms of sputum and wheeze over the three-year period (8). The frequency of obstructive dysfunction increased marginally over the three-year period (8). It was also reported that history of smoking and increasing years of employment in the grain industry contributed to a decrease in the proportion of workers with normal pulmonary function.

Some authors (4-6,9) analyzed longitudinal pulmonary function data using first order autoregressive models. These models incorporated previous lung function as one of the covariables and were fitted by the ordinary least squares approach. These models are easy to fit, but they do not consider a within-subject correlation structure. Rosner et al (4) presented a first order autoregressive model in which linear multiple regression was used to relate change in response variables to explanatory variables. They used this method to analyze longitudinal data for the case of a continuous outcome variable (lung function) with lung function testing equally spaced over time. They used both time-independent and time-dependent covariates in their model. Rosner and Munoz (5) extended this model to include unequally spaced responses using nonlinear regression methods. Ware et al (6) described methods for simultaneous cross-sectional and longitudinal analysis. They provided cross-sectional and longitudinal estimates of age-related changes in the ratio of forced expiratory volume in 1 s (FEV_1)/height^2 using first difference models and first order autoregressive models for men and women separately. Pahwa et al (9) used first order autoregressive models to predict the annual loss of lung function among Canadian grain elevator workers who participated in the Grain Dust Medical Surveillance Program (10). Pahwa et al (9) conducted an analysis to study the longitudinal changes in pulmonary function test values in male grain workers over a six-year period, which involved three observations. Their findings were similar to Enarson et al (3). Pahwa et al (9) reported that exposure to grain dust resulted in increased decline in pulmonary function test values (FEV_1 and forced vital capacity [FVC]) among nonsmoking, ex-smoking and currently smoking grain workers. Annual decreases in pulmonary function test values increased with the number of years in the grain industry, and by 20 years in the industry, nonsmoking and smoking grain workers had similar annual declines in lung function.

In this report, a complete data set over five observations encompassing 15 years of exposure was analyzed to study the long term effects of grain dust exposure and the annual decline in lung function measurements. One possible way to analyze the longitudinal lung function data is to use the widely applicable generalized estimating equations (GEE) methodology (11). The GEE approach has been used to study the long term effects of asbestos exposure (12) and cotton dust (13) on lung function. In this paper, this approach was extended to evaluate the relationship between the long term effects of grain dust and the decline in lung function among grain elevator workers in Saskatchewan, studied over a 15-year period.

METHODS

Grain Dust Medical Surveillance Program

In 1976, Labour Canada formulated a national program of health surveillance and environmental monitoring to obtain a complete picture of grain workers' health on a continuing basis. In 1978, Labour Canada issued the guidelines for an environmental and medical surveillance program in the grain industry (10). The Grain Dust Medical Surveillance Program (GDMSP) was one part of the Environmental and Medical Surveillance Program. This longitudinal program was implemented for all employees who had been continuously employed in the grain industry for longer than 90 days during a period of one year or intermittently for a total of six months in three years. Workers were tested every three years. The surveillance program was conducted in eight major phases (14).

The medical surveillance consisted of one or more medical examinations of the worker. Medical examinations and procedures were performed by or under the direction of a licensed physician. An employee who refused to participate in the surveillance program was advised of the risk involved by refusal. The objective of the program was to monitor the worker's respiratory health on a continuing basis while examining its association with dust levels in the work environment. Eight provinces and territories participated in the environmental monitoring and medical surveillance programs. These were divided geographically into five regions: Atlantic (east of Quebec); St Lawrence (Quebec only); Great Lakes (Ontario – east of Thunder Bay); Central (Ontario – Thunder Bay and westward, Manitoba and Saskatchewan); and Mountain (Alberta, British Columbia, Yukon and Northwest Territories). Pulmonary function tests were provided by a variety of private and public organizations in these five Canadian regions. Pulmonary function measurements were collected according to the standards established by Labour Canada (10), and data that conformed to these standards were used for analysis (9). The statistical analysis in this report was confined to Saskatchewan workers.

The GDMSP commenced in 1978. Data on respiratory symptoms and from pulmonary function tests were collected between 1978 and 1993. The data were collected in intervals termed a 'cycle'. The periods of cycles and the number of grain workers who participated in each cycle were: October 1978 to September 1981 – cycle I (n=5702); October 1981 to September 1984 – cycle II (n=5491); October 1984 to September 1987 – cycle III (n=3713); October 1987 to September 1990 – cycle IV (n=2847); and October 1990 to September 1993 – cycle V (n=3079).

Data were collected on company, province, region, type of elevator, age, height, weight, smoking information, lung function measurements (eg, FEV_1, FVC, maximum midexpiratory flow rate and FEV_1/FVC ratio), respiratory symptoms (eg, chronic cough, chronic sputum, chronic wheeze and chronic dyspnea), grade change and physician. Chest x-rays were also available in cycle I and cycle II. The data were collected in each province or territory and were sent to Labour Canada. Cycle I and cycle II data were computer coded by Labour Canada. Data for cycles III through V were computer coded by staff at the Environmental Epidemiology Unit, Centre for Agricultural Medicine, University of Saskatchewan, Saskatoon, Saskatchewan. The descriptive statistical analysis for cycle I data was conducted by Labour Canada. The descriptive statistical analysis for cycles II, III, IV and V was conducted at the Centre for Agricultural Medicine, University of Saskatchewan.

Subjects

The distributions of visits of Saskatchewan grain workers in various cycles are given in Table 1. There were 203 grain workers who participated in all five cycles and contributed 1015 observations, 259 grain workers who participated in any four cycles and contributed 1036 observations; 497 grain workers who participated in any three cycles and contributed 1491 observations; 739 workers who participated in any two cycles and contributed 1478 observations; and 2394 grain workers who participated only in any one cycle contributed 2394 observations.

Statistical methods

Means and standard deviations were used to describe the distribution of continuous variables. The χ^2 test was used for comparisons of the categorical variables.

A transitional model using the GEE approach was fitted using a SAS macro (15) to predict the annual decline in FEV_1 and FVC. The GEE approach, reinvented by Liang and Zeger (11), is based on the multivariate quasi-likelihood theory, which can handle the complexities of longitudinal studies, eg, repeated observations for each subject and data missing completely at random. While modelling longitudinal data, the primary objective of regression analysis is to identify the relationship between the expected value $E(\underline{Y})$ of the response variable $\underline{Y}$ and the covariates $\underline{X}_1, \underline{X}_2, \dots, \underline{X}_p$. Modelling the correlation structure is of secondary importance; however, it is necessary to take into account any intrasubject response correlation when making statistical inferences about the regression coefficient $\beta_1, \beta_2, \dots, \beta_p$. If the intrasubject correlation is not taken into account, then such statistical inferences can be seriously in error. Earlier studies (4-6,9) have shown that the previous lung function is an important predictor of current lung function. The main drawback of these autoregressive models was that they ignored the within-subject correlation. The transitional model used in this report to analyze the longitudinal lung function data takes into account the within-subject correlation, as well as considering previous lung function as one of the covariates. The covariates considered in the transitional model were previous lung function, height at baseline, weight, age, years in the grain industry, two dummy variables for smoking (ex-smokers and smokers), four dummy variables for cycle (cycle II, cycle III, cycle IV and cycle V), an interaction term between years in the grain industry and exsmokers, and an interaction term between years in the grain industry and current smokers.

$$(FEV_1)_{ij} = \beta_0 + B_1\times(FEV_1)_{ij-1} + \beta_2\times(\text{base height})_i + \beta_3\times(\text{weight})_{ij} + \beta_4\times(\text{years in grain industry})_{ij} + \beta_5\times(\text{ex-smoker})_{ij} + \beta_6\times(\text{smokers})_{ij} + \beta_7\times(\text{cycle II})_i + \beta_8\times(\text{cycle III})_i + \beta_9\times(\text{cycle IV})_i + \beta_{10}\times(\text{cycle V})_i + \beta_{11}\times(\text{years in grain industry} \times \text{ex-smokers})_{ij} + \beta_{12}\times(\text{years in grain industry} \times \text{smokers})_{ij} + \varepsilon_{ij}$$

where $(FEV_1)_{ij}$, $(\text{weight})_{ij}$, $(\text{age})_{ij}$ and $(\text{years in grain industry})_{ij}$ denote the measurements for i^{th} grain worker at time j.

$(\text{ex-smoker})_{ij}$ and $(\text{smoker})_{ij}$ are binary variables defined as:

$$(\text{ex-smoker})_{ij} = 1 \text{ if } i^{th} \text{ grain worker is ex-smoker at time j}$$
$$= 0 \text{ otherwise}$$
$$(\text{smoker})_{ij} = 1 \text{ if } i^{th} \text{ grain worker is smoker at time j}$$
$$= 0 \text{ otherwise}$$

TABLE 1
Pattern of participation of grain elevator workers in Saskatchewan over 15 years (1978 to 1993)

Cycle number					Grain workers (n)
I	II	III	IV	V	
Observations with baseline cycle I					
×	×	×	×	×	203
×	×	×	×	–	98
×	×	×	–	×	74
×	×	–	×	×	36
×	–	×	×	×	12
×	×	×	–	–	181
×	×	–	×	–	122
×	–	×	×	–	11
×	×	–	–	×	78
×	–	×	–	×	6
×	–	–	×	×	1
×	×	–	–	–	303
×	–	–	×	–	10
×	–	×	–	–	14
×	–	–	–	×	3
×	–	–	–	–	1399
Observations with baseline cycle II					
–	×	×	×	×	39
–	×	×	×	–	28
–	×	×	–	×	19
–	×	–	×	×	36
–	×	–	×	–	74
–	×	×	–	–	67
–	×	–	–	×	187
–	×	–	–	–	385
Observations with baseline cycle III					
–	–	×	×	×	15
–	–	×	×	–	25
–	–	×	–	×	6
–	–	×	–	–	85
Observations with baseline cycle V					
–	–	–	×	×	50
–	–	–	×	–	245
Observations at cycle V					
–	–	–	–	×	280

Goodness-of-fit

For longitudinal data analysis, Vonesh and Chinchilli (16) provided a measure of concordance between fitted and observed responses that is similar to the coefficient of determination, R^2, used in univariate linear regression settings. In addition, they provided a measure of concordance between assumed and true covariance structure, and the pseudo-likelihood ratio test to test the null hypothesis that assumed and true covariance structures are equal.

Vonesh and Chinchilli's goodness-of-fit criteria (16) were used to decide the goodness-of-fit of a model and covariance structure. These goodness-of-fit criteria are discussed in detail in Pahwa (17). Initially, six transitional models were fitted using different within-subject covariance structures (17). Based on Vonesh and

TABLE 2
Descriptive statistics (mean ± SD) of demographic variables by cycle in a study evaluating the relationship between the long-term effects of grain dust and decline in lung function among grain elevator workers in Saskatchewan, studied over a 15-year period

	Cycle I	Cycle II	Cycle III	Cycle IV	Cycle V
Age (years)	33.14±13.57	34.48±12.89	35.50±2.49	35.64±0.73	36.47±9.99
Height (cm)	174.39±6.36	175.97±6.21	174.86±5.90	176.02±6.28	176.24±6.79
Weight (kg)	81.88±13.61	83.53±13.77	84.89±13.34	83.95±13.95	85.18±13.67
Years in grain industry	8.74±10.11	11.39±9.79	12.62±9.81	12.91±8.81	14.03±8.33
FEV_1 (L)	4.04±0.79	4.19±0.72	4.01±0.72	4.20±0.71	4.25±0.73
Nonsmokers	4.25±0.73*	4.38±0.65*	4.25±0.61*	4.40±0.65*	4.42±0.69*
Ex-smokers	3.79±0.84	4.03±0.75	3.81±0.77	4.07±0.75	4.10±0.76
Current smokers	4.02±0.77	4.17±0.71	3.96±0.72	4.13±0.70	4.20±0.73
FVC (L)	5.22±0.94	5.37±0.80	5.11±0.81	5.32±0.83	5.34±0.84
Nonsmokers	5.32±0.84*	5.43±0.80*	5.27±0.76*	5.44±0.79*	5.46±0.84*
Ex-smokers	5.09±0.99	5.27±0.81	4.96±0.83	5.22±0.86	5.17±0.84
Current smokers	5.21±0.91	5.38±0.80	5.10±0.80	5.30±0.82	5.36±0.81

**P<0.001. Note: Smokers and ex-smokers had significantly lower forced expiratory volume in 1 s (FEV_1) and forced vital capacity (FVC) values compared with nonsmokers within each cycle*

TABLE 3
Estimates of regression coefficients (± SE [robust]) from the transitional models for dependent variables of forced expiratory volume in 1 s (FEV_1) and forced vital capacity (FVC)

	FEV_1 estimate	FVC estimate
Constant	–0.407±0.102*	–1.404±0.156†
Previous FEV_1 (L)	0.893±0.007†	0.808±0.009†
Base height (cm)	0.006±0.001†	0.015±0.001†
Weight (kg)	–0.002±0.0003†	–0.002±0.0004†
Years in grain industry	–0.004±0.001†	–0.007±0.001†
Ex-smokers‡	–0.001±0.016	0.004±0.023
Smokers‡	–0.022±0.011§	–0.015±0.015
Cycle II¶	0.077±0.009†	0.119±0.014*
Cycle III¶	–0.198±0.009†	–0.263±0.014†
Cycle IV¶	0.006±0.009	0.057±0.013†
Cycle V¶	–0.025±0.010§	–0.026±0.014
Years in grain industry × ex-smokers	–0.001±0.001	–0.002±0.001
Years in grain industry × smokers	–0.002±0.001	0.0001±0.001

**P<0.001; †P<0.0001; ‡Reference category nonsmokers; §P<0.05; ¶Reference category cycle I*

Chinchilli's goodness-of-fit criteria, among all of the models, a transitional model (without age in the model) with independence covariance structure was decided to be the most parsimonious, and was used to predict the mean annual decline in FEV_1 and FVC.

RESULTS

Table 2 shows the subject demographics, years in the grain industry and lung function test values at each of the five cycles. The mean age of grain workers was 33.14 years at cycle I and 36.47 years at cycle V. The difference of 3.34 years in mean age over the 15-year study period indicates that older grain workers either retired or quit the grain industry and that younger workers joined the industry. The mean number of years in the grain industry also indicates entry and exit into the grain industry – 14.03 at cycle V and 8.74 at cycle I. Table 2 shows the comparison of lung function measurements by smoking status within each cycle. Smokers and ex-smokers had significantly lower FEV_1 and FVC values compared with nonsmokers within each cycle.

Univariate regression analysis conducted for each cycle separately showed that age, height and years in the grain industry were significantly associated with FEV_1 when each of these factors was introduced, one at a time, into the regression model. When these models were fitted for FVC, in addition to the above mentioned factors, weight was also significantly associated with FVC. Based on these results, the potential predictors of the lung function variable (FEV_1 or FVC) in the multivariate longitudinal model were age, height, weight, years in the industry, smoking status and cycle effect. Base height was used in these models, while other covariates were used as time-varying.

Data from Saskatchewan only were used to fit transitional models. In these models, two dummy variables were used for smoking status (these compared ex-smokers and nonsmokers; and current smokers and nonsmokers); four dummy variables were used to study the effect of cycle (the reference category was cycle I); two interaction terms were used for years in the grain industry and exsmokers, and years in the grain industry and current smokers. The transitional model for the prediction of FEV_1 (or FVC) also had previous FEV_1 (or previous FVC) as one of the covariates in the model, in addition to the above-mentioned independent variables. The estimates of the parameters (± SE) for these two transitional models for the prediction of FEV_1 and FVC are given in Table 3. Similar findings were observed when transitional models were fitted for FEV_1 and FVC. The significant predictors for FEV_1 were previous FEV_1, base height, weight, years in the grain industry, current smoking status, cycle II, cycle III and cycle V. The effect of cycle on FEV_1 was studied by comparing the effect of dummy variables cycle II, cycle III, cycle IV and cycle V with cycle I. The regression coefficient for cycle II was positive, indicating that there could be a learning effect from cycle I to cycle II. The coeffi-

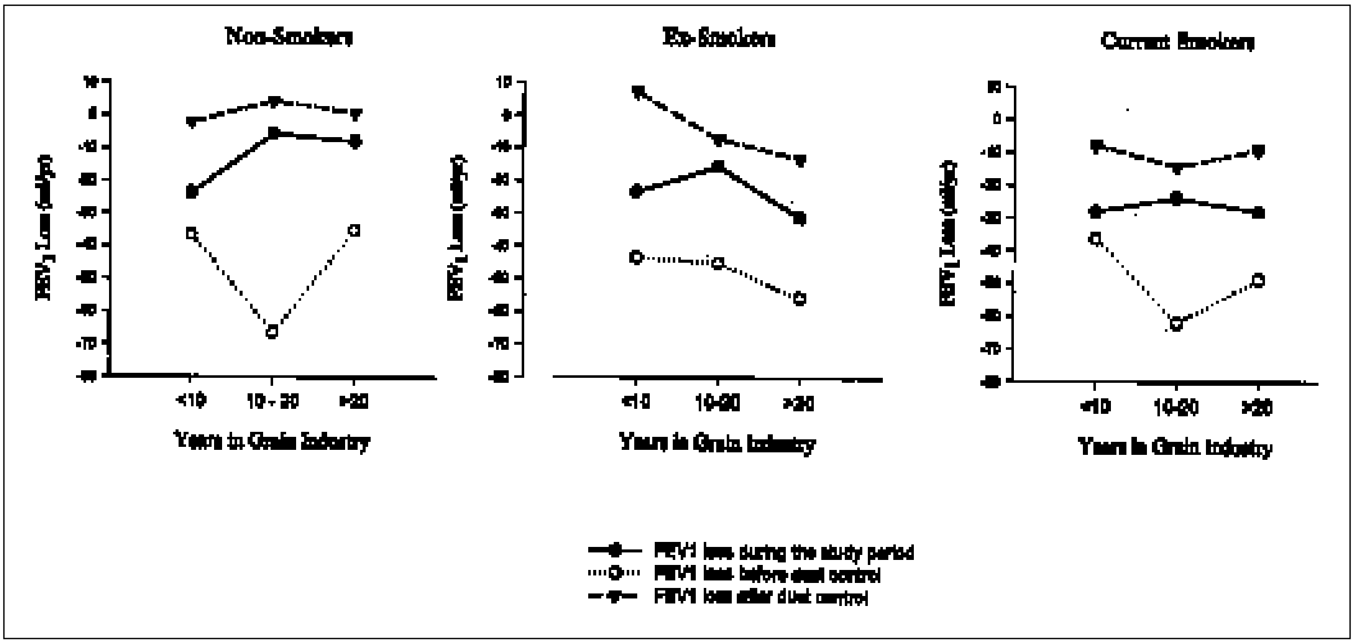

Figure 1) *The yearly decreases in forced expiratory volume in 1 s (FEV_1) by smoking status and years in the grain industry, during the study period, and before and after dust control*

cient for cycle III was –0.198 (P<0.01), indicating that FEV_1 decreased significantly from cycle I to cycle III. By changing the reference category, three different models were fitted to compare each cycle with the previous cycle (eg, cycle III with cycle II, cycle IV with cycle III and cycle V with cycle IV). Comparison of cycle III with cycle II using a Wald test showed that FEV_1 decreased significantly (z=23.28, P<0.0001). Significant improvements were observed in FEV_1 values from cycle III to cycle IV (z=6.31, P<0.0001), which might have been due to the implementation of dust control measures in most of the elevators by the end of cycle III (19). FEV_1 did not decrease significantly (z=–0.20, P=0.84) from cycle IV to cycle V; again, this could be due to dust control measures. The interaction between smoking and exposure years was significant, so it is hard to interpret the effects of exposure years and smoking status separately. The predicted annual reduction in FEV_1 values by smoking status and by years in the industry were computed using the transitional model with independence covariance structure given in Table 3.

The yearly decreases in FEV_1 by smoking status and years in the grain industry are shown in Figure 1. Dosman et al (18) reported that 70% of elevators had achieved dust control by 1986. Based on this information, annual declines in FEV_1 were calculated before dust control (ie, based on the first three cycles – cycle III ended on September 30, 1987) and after dust control (ie, based on cycle IV and cycle V). The declines are shown before dust control and after dust control (Figure 1). The graphs before dust control indicate that: for the subjects who were in the industry for less than 10 years, the annual decreases in FEV_1 were greater in ex-smokers than in nonsmokers and current smokers; the nonsmokers and current smokers who were in the industry for 10 to 20 years had a greater annual decrease in FEV_1 than did the ex-smokers; and in workers who had been in the industry for 20 years or more, the yearly decline in lung function test values was similar in ex-smokers and current smokers, and greater than the yearly decline in nonsmokers. The graphs after dust control indicate that there was improvement in the lung function of grain workers in all smoking and exposure categories.

The transitional model with independence covariance structure was used to predict the annual decline in FVC (17). Comparison of cycle III with cycle II (z=–22.57, P<0.0001) showed that the FVC decreased significantly over the years before dust control measures were implemented in the industry. As observed for FEV_1, there were improvements in FVC from cycle III to cycle IV (z=8.83, P<0.0000) and a decrease in FVC from cycle IV to cycle V that was not significant (z=–1.79, P=0.07); this could be due to dust control measures. Predicted annual reductions in FVC values stratified by smoking status and years in the industry were computed using the transitional model with the independence covariance structure given in Table 3. These yearly losses by smoking status and years in the grain industry are shown in Figure 2. The declines are shown before and after dust control. The graphs before dust control indicate that: for the subjects who were in the industry for less than 10 years, the annual loss in FVC was very similar in all three smoking groups; the nonsmokers who were in the industry for 10 to 20 years had greater annual loss in FVC than either smoking group; for workers who were in the industry for 20 years or more, yearly declines in the FVC test value were highest for ex-smokers. The graphs indicate that yearly decreases in FVC after dust control were much smaller than before dust control.

Two other models (one for the prediction of FEV_1 and the other for the prediction of FVC) were fitted using one dummy variable to study the effect of dust control. The results were not statistically significant for FEV_1, but they were significant for FVC (results not shown).

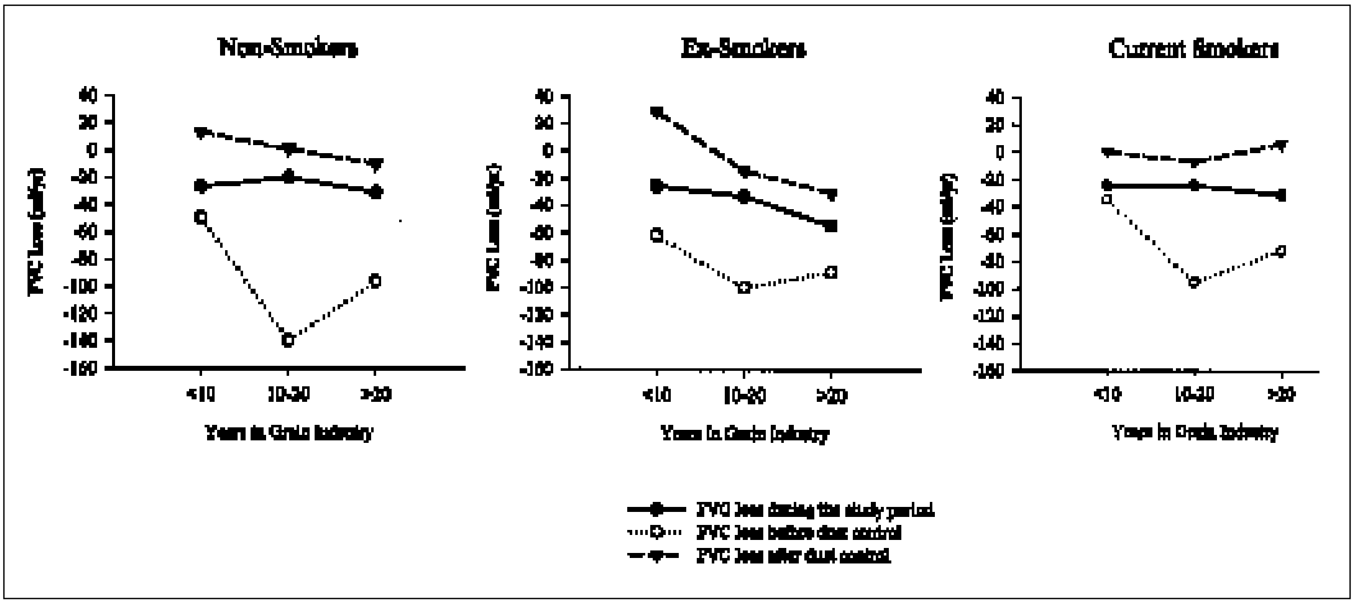

Figure 2) *The yearly losses in forced vital capacity (FVC) by smoking status and years in the grain industry, during the study period, and before and after dust control*

DISCUSSION

In the present paper, we evaluated the relationship between the long term effects of grain dust and the decline in lung function measurements among grain elevator workers in Saskatchewan, studied over a 15-year period. We found that the yearly loss in lung function test variables amplified with increasing years in the industry among nonsmoking, ex-smoking and smoking grain workers, and that the decline in lung function during the first three cycles was much faster compared with the decline in cycles IV and V. Our analysis showed that previous lung function, as one of the covariates in the transitional model, played an important role.

Pahwa et al (9) used first order autoregressive models to analyze longitudinal lung function data from the first three cycles of the GDMSP, obtained from all of the provinces and territories that participated in this program. Because there was no control group for grain workers, Pahwa et al (9) compared the yearly losses in FEV_1 in the grain workers with yearly losses in nonsmoking men in the 'six cities study' in the United States (6). The mean FEV_1 values were higher in the younger age groups of grain workers; however, after a certain age, these values were smaller compared with the general male population in the six cities study. The predicted annual loss of FEV_1 was reported to be higher in the grain workers for all age groups, indicating that grain dust has an adverse health effect on the respiratory system of grain workers. Based on an evaluation of the first three cycles in the program, Dosman et al (18) reviewed the results of Labour Canada's environmental and medical surveillance program for elevator workers. Although there were acknowledged limitations associated with the data, they recommended that an exposure level greater than 5 mg/m^3 could have negative respiratory health effects. Huy et al (7) studied the association between grain dust exposure and lung function values. They reported that the annual declines in FEV_1 for workers in the high exposure group (mean exposure greater than 9 mg/m^3), intermediate exposure group (4 to 9 mg/m^3) and low exposure group were 34.1 mL/year, 21.1 mL/year and 10.4 mL/year, respectively. Huy et al (7) concluded that dust levels should be kept below 4 mg/m^3 to minimize chronic health effects. Recommendations for reducing the effect of grain dust on the lungs were summarized by Becklake et al (19): Labour Canada and the grain industry should review the current Canadian standards for grain dust exposure in the workplace; the permissible exposure limit should be lowered to 5 mg/m^3 to control the short term health effects of grain dust; and the Labour Canada surveillance program should be continued, while regional differences in the effects of grain dust on workers should be studied and exposure-response relationships should be established. A cross-sectional analysis of the dust and spirometric data showed an inverse dose-response relationship (18). These relationships were investigated using a longitudinal approach in this report. One major limitation of the surveillance program was that dust concentrations at the workplace that were available over several time points could not be matched to individual workers to investigate dose-response relationships between dust and spirometric data using a longitudinal approach.

Based on the report of Dosman et al (18), dust control was achieved in 70% of the grain elevators by implementing dust collection, ventilation, mechanical controls and other operational procedures by 1986. Based on this information, cycle III (which ended in September 1987) was used as a cut-off point in our analysis to determine whether there was any improvement in lung function (FEV_1 and FVC) after dust control (cycle IV and cycle V). In this report, only data from the province of Saskatchewan were used. After the dust was controlled in grain elevators, improvement in the respiratory health of grain workers was noticed. The slight improvements in the mean values of FEV_1 and FVC (Table 2) from cycle I to cycle II could be due to the learning effect. It would have been useful to test whether this learning effect had any effect on the regression coefficients. Glindmeyer et al (20) and Nakadate and Kagawa (21) did not find that the learning effect biased the estimates of the regression parameters. Glindmeyer et al (20) compared the cross-sectional results at each visit with longitudinal changes by analyzing the same data. They found that the cross-sectional results were different from the longitudinal results. This difference remained even when the first visit was removed to reduce the learning effect on longitudinal estimates. Figure 2 showed that after dust control was implemented (ie, after cycle III), there were significant reductions in FVC.

There were some limitations in the Labour Canada programs. First, the level of dust to which each worker was exposed at the time of spirometric tests was not available. Second, due to confidentiality reasons, no identifiers on the grain elevator workers were available to correlate with the environmental data, so these data could not be matched with individual workers' medical health information.

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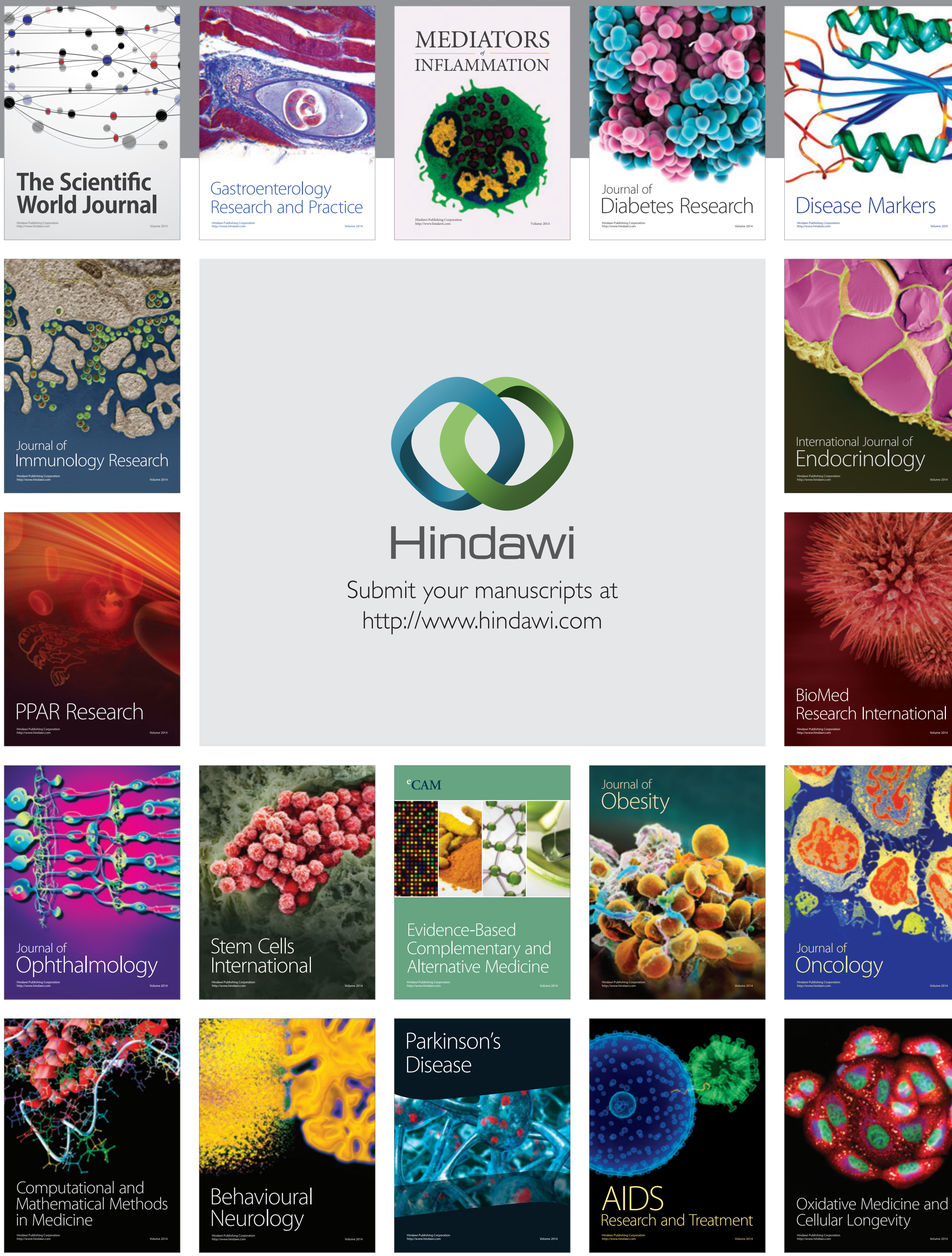
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