Rapid decline in FEV_1 and the development of bronchitic symptoms among 3、new Chinese coal miners

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Abstract

Newly hired Chinese underground coal miners enrolled in a three-year prospective cohort study were previously shown to experience a nonlinear pattern of FEV_1 change over time. Miners in that study experienced a rapid FEV_1 decline during the first year of employment, a plateau during the second year, and partial recovery during the third year of dust exposure. The relationship between these FEV_1 changes and the development of bronchitic symptoms (persistent cough and/or phlegm) were evaluated among 260 miners in the same cohort, using a mixed effect model. Bronchitic symptoms were significantly increased after 11-months and stayed elevated thereafter, with an average incidence of 8.2%. Miners were categorized into four groups determined by smoking status (Sm+ or Sm-) and development of bronchitic symptoms (Br+ or Br-). At 24 months follow-up, miners who both developed bronchitic symptoms and smoked (Br+ Sm+ group) showed the sharpest drop in FEV_1 (losing 235 ml) after controlling for other co-variables, followed by the Br- Sm+ group (-191 ml), Br+ Sm- group (-186 ml), and the Br- Sm- group (-96 ml). Among new coal miners, the development of bronchitic symptoms contributes to a sharp early decline in lung function, as does tobacco smoking.

Key Words Forced expired volume, bronchitis, coal mining

INTRODUCTION

During their first three years of underground employment, a group of Chinese coal miners demonstrated a nonlinear pattern of FEV_1 change. [1] The miners experienced a rapid FEV_1 decline during the first year of employment, a plateau during the second year, and partial recovery during the third year of dust exposure, a pattern consistent with prior reports. [2, 3]

The mechanism for the rapid declines is not known. However, miners frequently report symptoms of bronchitis, and miners with these symptoms have shown significant deficits of lung function. [3-5] The current study investigates the relationship between the development of bronchitic symptoms and the early rapid decline of FEV_1 among this cohort of Chinese coal miners.

METHODS

Participants, health surveys, and environmental monitoring

A three year prospective cohort study was completed among 317 newly hired underground coal miners between October 1995 and January 1999. An initial (pre-employment) and 15 follow-up health surveys were performed by Chinese health professionals at three mine field sites. The initial health survey consisted of an initial questionnaire (IQ), measurement of height and weight, a chest x-ray film, and a spirometry test including bronchodilator (BD) testing to assess airway reactivity. Follow-up health surveys were done on a monthly basis for the first 3 months, bi-monthly for the next 6 surveys, every three months for 5 surveys, and the last follow-up survey was performed at a six-month interval. Follow-up surveys included a follow-up questionnaire (FQ) and spirometry testing (bronchodilator testing was not repeated). This analysis includes the 260 miners who completed at least 5, and up to 15 follow-up surveys.

Spirometry testing was performed at the worksite using a NIOSH dry rolling-seal spirometer (NIOSH, HF6) by Chinese pulmonary function technicians instructed in spirometry standards. [6] Percent predicted FEV_1 (PP FEV_1) was calculated using Mexican-American reference values. [7]

Total and respirable dust area sampling was performed twice a month, in the three underground mines at 24 representative work areas, by mine inspectors using a battery-operated two-stage dust sampler. Each individual miner's exposures to total and respirable dust were estimated monthly, based on the sampling results from the miner's work area.

Grouping by combinations of bronchitic symptoms and smoking status

Bronchitic symptoms were defined as cough and/or phlegm production for 4 or more days per week. Development of bronchitic symptoms referred to workers who denied these symptoms at the initial survey but reported them at follow-up. Miners who reported incident symptoms at 2 or more follow-up surveys were categorized in the group with new onset bronchitic symptoms (Br+). Workers who reported smoking cigarettes at the initial health survey (n=106, 41%) were classified as current smokers (Sm+). Miners were further categorized by combinations of new onset bronchitic symptoms and smoking status into four subgroups of Br-Sm-, Br-Sm+, Br+Sm-, and Br+Sm+ (n=132, 80, 22, and 26).

Data analysis

Group comparisons of participant characteristics and spirometry indexes were made between miners who developed vs. those did not develop bronchitic symptoms, using t-tests for continuous variables, and chi-square tests for dichotomous variables. Each miner's longitudinal change of FEV_1 (slope) was calculated using simple linear regression across the repeated measures. The significance of differences in FEV_1 slope among the four groups was tested by analysis of variance (ANOVA). A mixed effects model was also used to investigate the patterns of FEV_1 change over time in groups of Br+ vs. Br-, and also among groupings of Br-Sm-, Br+Sm-, Br-Sm+, and Br+Sm+. The health outcome variable was the repeated measurement of FEV_1. The major interest centered on the significance of differences between or among groups in FEV_1 change over the period of study, controlling for baseline age (both linear and quadratic), height, pack-yrs of cigarettes smoked, room temperature during testing, and mean respirable dust concentration. Interaction terms for both group*linear time and group*quadratic time were included in the model.

RESULTS

Table 1 displays participant characteristics, spirometry indices and bronchodilator test results at the initial survey, as well as the FEV_1 slope over the three years of follow-up. FEV_1 declines among miners who developed bronchitic symptoms were greater than those who did not develop these symptoms (-65 vs. -23ml/yr, $p<0.05$). Demographic parameters and spirometry indices at the initial survey were similar for the two groups except that the Br+ group had a higher percentage of ever smokers, a slightly greater increase in FEV_1 post-bronchodilator, and a somewhat lower FEV_1/FVC ratio, compared to the Br- group.

Table 1. Group comparison of demographic and spirometry parameters at the initial survey, and three year FEV1 slope

Grouping	All subjects N=260	Development of Bronchitic symptoms	
		Yes (Br+, n=48)	No (Br-, n=212)
Mean age, yr (SD)	22.3 (2.5)	22.8 (2.9)	22.2 (2.5)
Height, cm (SD)	169.7 (4.6)	169.9 (4.2)	169.7 (4.5)
Weight, kg (SD)	62.7 (5.6)	63.2 (5.4)	62.6 (5.6)
Current smokers, n (%)	106 (40.8)	26 (54.2)	80 (37.7)*
Mean pack-yrs (SD)	0.63 (1.7)	0.81 (1.6)	0.59 (1.7)
Mean FEV_1, L (SD)	4.46 (0.51)	4.44 (0.53)	4.47 (0.50)
Mean FVC, L (SD)	5.29 (0.58)	5.40 (0.60)	5.26 (0.57)
FEV_1/ FVC , % (SD)	84.6 (7.2)	82.4 (7.2)	85.1 (7.1)*
PP FEV_1 , % (SD)	103.4 (10.3)	103.3 (10.4)	103.5 (10.3)
Δ FEV_1-BD, % (SD)	3.1 (5.7)	4.5 (4.4)	2.8 (5.9)*
BD responders, n (%) †	9 (3.5)	3 (6.3)	6 (2.8)
FEV_1 Slope (L/year) ††	-0.030 (0.116)	-0.065 (0.098)	-0.023 (0.119)*

* P<0.05;

† BD responders showed > 12% increase in FEV1 from pre- to post- bronchodilator.

†† Individual rate of change in FEV1, calculated by simple linear regression over 3 years;

The FEV_1 changes over three years among the groups of Br-Sm-, Br-Sm+, Br+Sm-, and Br+Sm+ averaged -8, -46, -57, and -73 ml/yr, respectively. The mean slope for the Br-Sm- group differed significantly from the Br+Sm+ group (ANOVA, p=0.0114).

All the chest x-ray film results were within normal limits; no further analyses were done.

Fig. 1 illustrates the rate of new onset bronchitic symptoms at each follow-up survey. Bronchitic symptoms were significantly increased at the 11-month survey and stayed elevated thereafter, with an overall average incidence of 8.2%.

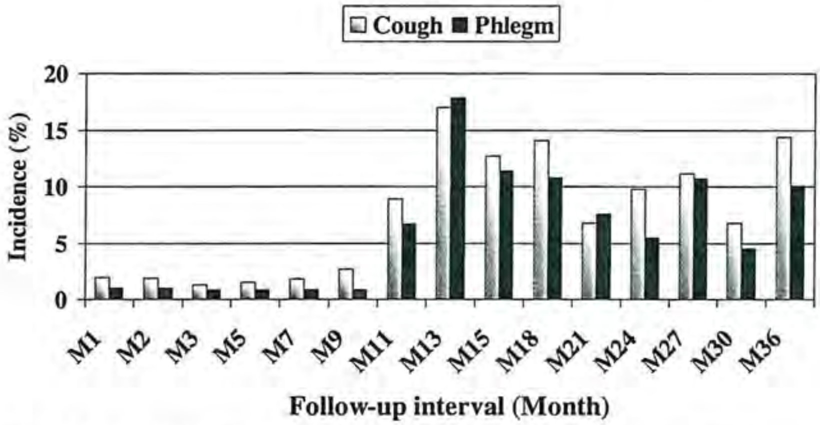

Fig.1 Incidence of bronchitic symptoms at each follow-up survey among new miners

Table 2 lists the parameter estimates obtained after adjusting in the model analysis for baseline age and the time-dependent variables of height, pack-years of smoking, room temperature during testing, and mean respirable dust concentration. Linear and quadratic time trends for FEV_1, and the group*time interaction terms were all highly significant for both groups; and the Br+ group lost more FEV_1 over time.

Table 2. Parameter estimates, standard errors, and p values obtained from mixed-effects model analysis of repeated measures of FEV1

Effect	Grouping	Estimate (liters)	Standard Error	P value
Baseline Age (yr)		0.2571	0.1130	0.0229
Age*Age (yr^2)		-0.0059	0.0024	0.0134
Height (cm)		0.0214	0.0040	<0.0001
Pack-yrs		-0.0166	0.0130	0.2035
Respirable dust (mg/m^3)		-0.0002	0.0002	0.4520
Temp (℃)		0.0102	0.0003	<0.0001
Group	Br-	-2.0874	1.4976	0.1635
Group	Br+	-2.1256	1.5005	0.1567
Time*group	Br-	-0.0121	0.0011	<0.0001
Time*group	Br+	-0.0159	0.0023	<0.0001
Time*Time*group	Br-	0.0003	0.00003	<0.0001
Time*Time*group	Br+	0.0003	0.00006	<0.0001

A mixed-effects model analysis was also performed after stratifying the new coal miners by combinations of symptom development and smoking status. The patterns of FEV_1 change for the groups are illustrated in Fig. 2. The Br-Sm- group lost less FEV_1 over time than the other groups. Among these new coal miners, both the development of bronchitic symptoms (Br+) and tobacco smoking (Sm+) contributed to a sharp early decline in lung function.

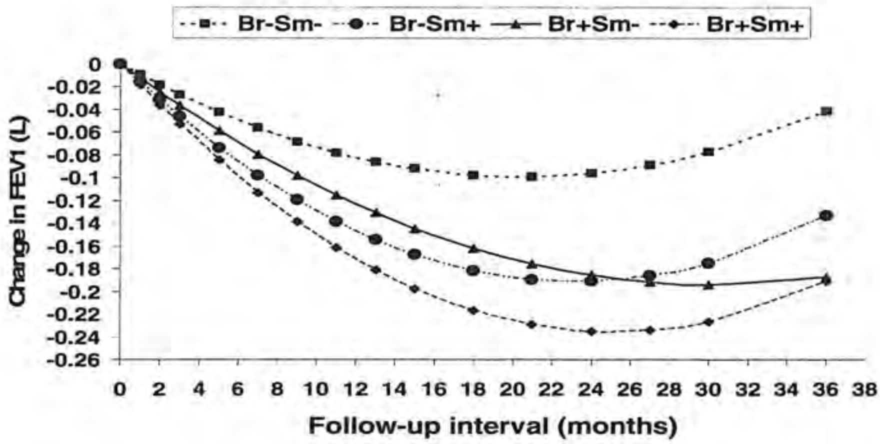

Fig.2 Change in FEV1 by combinations of bronchitic symptoms (Br+ vs. Br-) and smoking status (Sm+ vs. Sm-)

DISCUSSION

Newly hired underground coal miners experience an early rapid loss in lung function, although the mechanisms of this are not known.[1 2 3] The current study investigated the relationship of these early FEV_1 changes to the development of bronchitic symptoms. FEV_1 losses were nearly three times as large for miners who developed bronchitic symptoms as for those who did not. Smoking miners who developed the symptoms (the Br+Sm+ group) lost significantly more FEV_1 than nonsmokers who did not develop bronchitic symptoms (the Br-Sm- group). Additionally, a partial FEV_1 recovery in third year was not seen for miners who developed bronchitic symptoms but did not smoke (Br+Sm- group).

Bronchospasm remains a plausible mechanism for the early losses in lung function among dust-exposed individuals. In this study, we did not observe a consistent association between initial bronchodilator response and the early FEV_1 declines seen among these new coal miners. However, bronchodilator testing was done only at the initial survey, so the results cannot provide direct evidence about this hypothesis. We speculate that the early sharp declines in lung function observed in this and other studies of dust-exposed workers may be related to the development of airway hypersecretion. The associated bronchial gland enlargement and increased mucous production may result in a reduction in the caliber of the large conducting airways, as observed in association with bronchitic symptoms by Hankinson and colleagues.[5]

In summary, these results suggest that among new coal miners, the development of bronchitic symptoms contributes to a sharp early decline in lung function, as does tobacco smoking, and may represent an important risk for development of COPD in later life (as seen in Br+Sm- group, in particular). The findings have implications in medical screening for coal mining and other dusty work: during the first several years of employment increased testing may be helpful to document the development of bronchitic symptoms and the declines in FEV_1, and because of the nonlinear patterns, caution is required in extrapolating early FEV_1 changes.

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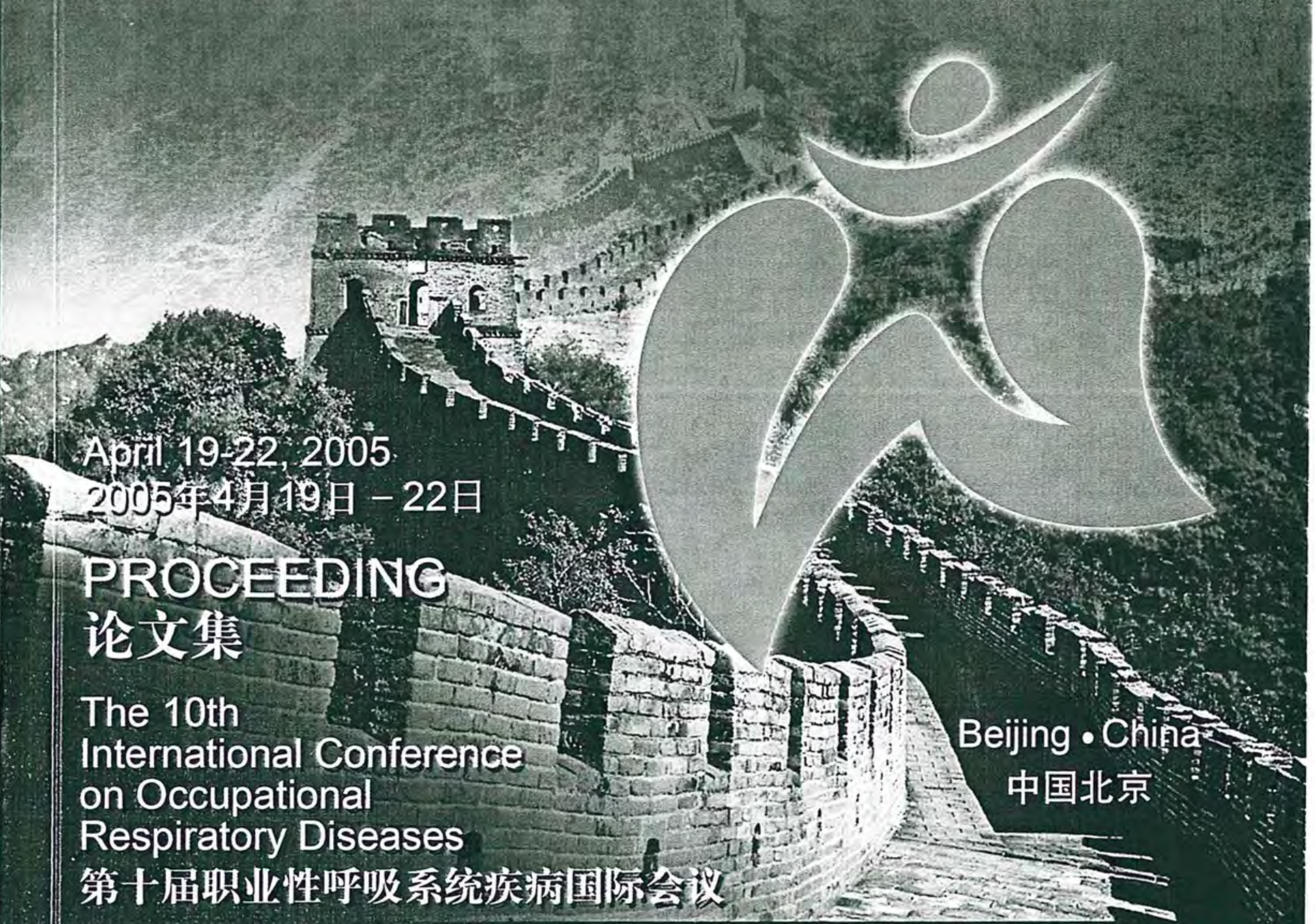

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