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ORIGINAL ARTICLE

Relationship of cumulative dust exposure dose and cumulative abnormal rate of pulmonary function in coal mixture workers

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Abstract To investigate the dose-response relationship between cumulative dust exposure (CDE) and cumulative abnormal rate of pulmonary function in coal mixture workers. Three hundred and twenty eight coal mixture workers (exposed group) and 169 nondust-exposed workers (control group) were recruited. Basic information data were collected and pulmonary function tests were performed. Pulmonary function was compared between the two groups after comparing smoking behaviors. Pulmonary function indices [forced vital capacity in 1 second after full inspiration (FVC)%, forced expiratory volume (FEV)1%, and FEV1/FVC%] were compared among groups stratified by service length (exposure duration). The relationship between CDE dose and cumulative abnormal rate of pulmonary function in coal mixture workers was analyzed. Abnormal rate of pulmonary function in the exposed group (35.1%) was significantly higher than the control group (10.1%; $p < 0.001$); FVC%, FEV1%, and FEV1/FVC% in the exposed group decreased significantly compared with the control group (all $p < 0.05$). Differences in FVC%, FEV1%, and FEV1/FVC% among coal mixture workers stratified by exposure duration in the exposed group were statistically significant (all $p < 0.05$). The discernible increase in the cumulative abnormal rate was observed, from $\geq$ 1000 mg/m^3·years group to $\geq$ 1700 mg/m^3·years group. Correlation analysis revealed a positive correlation between the CDE dose and the cumulative abnormal rate of pulmonary function. Higher abnormal

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pulmonary function rate was found among coal mixture workers, characterized by decreased pulmonary function indices. Our results suggested a positive relationship between CDE dose and cumulative abnormal pulmonary function rate, and a rapid increase in cumulative abnormal rate within a certain range of CDE dose. A lower limit value of 1000 mg/m^3·years has reference significance.

Introduction

Cumulatively exposed to respirable coal mine dust, coal miners are at risk of developing chronic occupational lung diseases and suffer from irreversible lung damage, including coal workers' pneumoconiosis (CWP), progressive massive fibrosis, and chronic obstructive pulmonary disease (COPD) [1,2]. Previous studies have well documented the association between long-term exposure to coal mine dust and mortality, even after adjustment for smoking [3,4]. Further, the association of emphysema and COPD with coal dust exposure has been reported, and increased cumulative dust exposure (CDE) may also increase the death rate of these diseases [1,5]. With enforcement of occupational exposure limits for coal mine dust, declined CWP prevalence from 11.2% to 2.0% is found among underground coal miners [6,7]. However, miners working entirely according to the contemporary standard still continue to develop lung diseases, implying that further restrictions and regulations in occupational dust exposure are needed [6,8].

In 2013, a total of 23,152 occupational disease cases in China were reported, among which coal mining activities accounted for $>$ 50% of them [9]. Occupational dust and gas/fume exposure is associated with the increased prevalence of COPD in the Chinese population, independent of smoking, sharing a similar attributable fraction in Western populations [10]. Pulmonary ventilation function serves to evaluate the damaged pulmonary function and compensatory function in early stage of CWP patients who exhibit impaired pulmonary ventilation and diffusion function [11]. Forced expiratory volume in 1 second after full inspiration (FEV1) and FEV1/forced vital capacity (FVC) are widely used in pulmonary function examination [12,13]. Generally, an accelerated decline in FEV1 over time may result in COPD; while low FEV1 in early adulthood has been suggested to play important roles in causing COPD [14,15]. Pulmonary function tests (FVC, FEV1, and FEV1/FVC) have important implications for the labor ability appraisal of CWP patients. However, regulations for limiting coal mine dust exposure, and efforts to reduce the prevalence and severity of lung diseases still need to be further evaluated [1,6]. Therefore, the current study was performed to examine the relationship between CDE and cumulative abnormal rate of pulmonary function, and to propose a lower limit value for CDE in coal miners in China.

Methods

Study participants

A total of 328 coal mixture workers (exposed group) were recruited from a coal mine in Tangshan, and 169 nondust-exposed workers (control group) were selected from an instrument, electrical, and mechanical factory in the same area. Participants in the exposed group were enrolled if they met the following inclusion criteria: (1) dust-exposed time $>$ 1 year; (2) dust-exposed length of service in the coal mine accounted for more than half of one's dust exposure career; (3) complete physical examination results within 2 years; and (4) clear and complete records of occupational history. All enrolled individuals were men. The mean age of the 328 coal mixture workers was 46.8 $\pm$ 9.5 years (range, 21—60 years) and the mean body weight was 58.7 $\pm$ 11.3 kg (range, 42—86 kg). The mean age of the nondust-exposed workers was 46.5 $\pm$ 7.8 years (range, 21—59 years) and the mean body weight was 58.1 $\pm$ 8.5 kg (range, 43—85 kg). There were no significant differences in age or body weight between the exposed group and the control group (all $p > 0.05$). The study was approved by the Ethics Committee of our university. All participants provided written, informed consents. Study protocols followed the ethical principles for medical research involving human participants of the Helsinki Declaration [16].

Data collection

Information on baseline characteristics were collected using questionnaires including the following contents: (1) dust exposure history and demographic characteristics (date of birth, sex, initial working time, occupational history, current occupation, retirement age, etc.); and (2) pulmonary disease history (time of initial diagnosis, grades, complications, onset time of complications, etc.). Occupational data of all the participants were mainly extracted from the Capital and Labor Staff Database, and supplemented by Occupational Health Examination Records. Any contradictories or difficulties in obtaining complete information were solved by face-to-face interviews with employed workers or telephone interviews with retired workers. The pulmonary function data were obtained by a periodic check in the Occupational Disease Prevention and Treatment Institute of the coal miner, and supplemented