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Smoking and air pollution exposure and lung cancer mortality in Zhaoyuan County

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ABSTRACT

Background: Simultaneous exposure to high levels of air pollution and high tobacco consumption at the same place is rare. The aim of the present study was to evaluate the impact of the two factors on the risk of developing lung cancer.
Methods: Data on the number of deaths due to lung cancer and on population from 1970 to 2009 were obtained from Zhaoyuan County. Data on the smoking populations were obtained at random sampling survey during the time in Zhaoyuan. Data on the components of atmospheric surveillance were obtained from the local environmental protection offices. Logarithmic linear regression and general log-linear Poisson age-period-cohort (APC) models were used to estimate age, period, cohort, gender, smoking, and air pollution effects on the risk of lung cancer mortality.
Results: The standardized mortality rates of lung cancer drastically increased from 8.43 in per 100 000 individuals in the 1970–1974 to 25.67 in per 100 000 individuals in the 2005–2009 death survey. The annual change of lung cancer mortality was 3.20%. In the log linear regression model, the age, proportion of smokers, gender, period, and air pollution are significantly associated with lung cancer mortality. The APC analysis shows that the relative risks (RRs) of gender, smoking, and air pollution are 2.29 (95% confidence interval (CI): 2.16–2.43), 3.05 (95% CI = 2.76–3.36), and 1.42 (95% CI = 1.19–1.69), respectively. Compared with the period 1970–1974, high RRs were found during 1995–2009. Compared with the birth cohort 1950–1954, the RRs increased in the birth cohorts of 1910 to the 1940. Compared the aged 35–59 and 60–84 in the1980–1984 death survey (not exposed to air pollution) with that in the 2005–2009 death survey (exposed to air pollution), The two age groups exposed to air pollution, 25 years later, had an increased mortality rates for lung cancer by 2.27 and 3.55 times for males and by 1.47 and 3.35 times for females.
Conclusion: The mortality rates of lung cancer drastically increased in the past 35 years. The trend of lung cancer mortality may be in a great extent possibly due to the effects of combined smoking and air pollution exposure.

Introduction

Lung cancer mortality of Chinese population increased most remarkably from 5.47 per 100 000 during 1973–1975 to 30.83 per 100 000 during 2004–2005. It has become the leading cause of cancer-related deaths in China (National Office for Cancer Prevention and Control, 1980, 1995; The Ministry of Health of the People's Republic of China, 2008).

In Shandong Province of China, the standard mortality rates of lung cancer had increased from 13.46 per 100 000 men, and 6.59 per 100 000 women in the death survey of 1970–1974 to 47.78 per 100 000 men and 23.31 per 100 000 women in the death survey of 2004–2005 (Cui et al., 2010).

Smoking and atmospheric pollution play a dominant role in the development of lung cancer. Many studies in western countries have shown that many of the deaths, including those from lung cancer, cardiovascular disease, and chronic obstructive pulmonary disease are caused by cigarette smoking (Doll et al., 1994; Pope et al., 2002; International Agency for Research on Cancer, 2004; Avino et al., 2004; Wakai et al., 2006). Since 1981, China has

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been the world's largest actual and potential national market for cigarettes. As the world's largest producer and consumer of tobacco, about 1.7 trillion cigarettes are produced in China. Therefore, China bears a substantial proportion of the global burden of smoking-related diseases (Millaman et al., 2008).

Along with the great economic benefits, China's rapid development has brought severe environmental degradation, notably due to air pollution from coal burning and motor vehicle emissions. Components of ambient air pollution include total suspended particulates (TSP), polycyclic aromatic hydrocarbons, nitrogen dioxide (NO_2), heavy metals, and carbon dioxide. Combustion of coal produces sulfur dioxide (SO_2). The main source of outdoor air pollution in China is the vast industrial network; the power plant system relies on coal to meet 70–75% of its energy requirement (Millaman et al., 2008). Indoor air pollution also leads to major environmental exposure (Agnihotram et al., 2007).

In summary above studies, as far as we know, there are few reports of simultaneous exposure of cigarette smoking and air pollution to be associated with risk of lung cancer mortality. The data on long-term studies on lung cancer cases and on the change of these factors have been gathered in the past 35 years in Zhaoyuan County, China. Therefore, they may be assessed for their association with the risk of developing lung cancer.

The aim of the current study was to examine the time trends of lung cancer mortality during 1970–2009 in Zhaoyuan by considering the effects of smoking and atmospheric pollution.

Methods

Data on the number of deaths due to lung cancer and on population from 1970 to 2009 were obtained. The reporting system of all cause death registration in the Zhaoyuan Center for Disease Control and Prevention, which has been established since the first death survey in 1970–1974 in Shandong Province. The code corresponding to lung cancer in the International Classification of Diseases was 162 in the 9th revision (1979–1994), and C33 and C34 in the 10th revision (1995–2009). Based on these data, the age-specific mortality by gender was calculated for thirteen 5-year age groups (20–24 to 80–84) and eight 5-year calendar periods (1970–1974 to 2005–2009). Using the age and calendar period classification, 20 overlapping 5-year birth cohorts were identified and defined according to the central year of a birth cohort. The age-standardized death rates from lung cancer were calculated using the world standard population (National Office for Cancer Prevention and Control, 1980).

Data on smokers during 1970–2009 was obtained from a random sampling survey in Zhaoyuan. The data on the concentration of TSP, SO_2, and NO_x during these periods were obtained from the Bureau of Zhaoyuan Environment Detection and Prevention (Li et al., 1994; Dong and Zhang, 1990; Cao, 1985).

Statistics

To evaluate the independent variables (age, period, birth cohort, smoking, and air pollution) to be associated with the risk of lung cancer, we first used the log-linear regression model in order to determine the risk factors linking to the lung cancer mortality (dependent variable) and to estimate the determination coefficient of the regression model, and to make out whether there was a serious collinearity these variables.

For the age-period-cohort (PAC) analysis the general log-linear Poisson models (GLPM) were fitted by the maximum likelihood method. The number of lung cancer death was assumed to follow a Poisson distribution. Each factor in the models had an additive effect on the log ratamonge as follows:

$$\log \lambda_{ijk} = \mu + \alpha_i + \pi_j + \gamma_k + x + y_j + z_j + \varepsilon_{ijk}$$

where the age effect is represented by $\alpha_i (i = 1, 2, \ldots, 13)$, the period effect is $\pi_j (j = 1, \ldots, 8)$, the birth cohort effect is $\gamma_k (\kappa = 1, 20)$, the gender effect is x, the smoking effect is $y_j (j = 1, \ldots, 8)$, and the air pollution effect is $z_j (j = 1, \ldots, 8)$. ε_{ijk} represents the random error.

The linear relationship (collinearity) between the age and birth cohort effect prevents the sorting of the linear effects of all these terms (a non-identifiable problem). Finally, three GLPM were fitted. In these models the dependent variable was the number of lung cancer death, with person-year at risk as the offset variable. In one model the independent variables included the factor of period as well as covariates of gender, age, smoking and air pollution. The second model included the factor of age as well as covariates of gender, period, smoking and air pollution. The third model included the factor of birth cohort as well as covariates of gender, period, smoking and air pollution. WHO (2000) limited that the criteria of SO_2 emission was less than 50 μg/L of average concentration of 24 h. Because the absence of details regarding the estimation of the measurement of air pollution, the variable of air pollution was an indicator variable coded "1" for exposure to the air pollution (after 1980 year) and "0" for non-exposure (before 1980 year).

The effects of each parameter were estimated as relative risks (RRs), using data on age 80–84 years, the 1970–1974 period, and the 1950–1954 birth cohorts as the reference values in above three models respectively. The RRs for the parameters were adjusted for the respective other parameters as derived from the best-fit model. On the one hand, in logged dependent variable model if there is heteroscedasticity present, then the relative risk of sublevel A compared to sublevel B (for category variable) is corrected by the formula as following:

$$\mathrm{CRR} = e^{(\mu_A - \mu_B) + 0.5(o_A^2 - o_B^2)}$$

where CRR represents corrected relative risk (Manning, 1998).

The annual percent change was calculated using the Joinpoint regression model. The software enabled the user to test that an apparent change in trend is statistically significant (Kim et al., 2000). Statistical analysis was conducted using SPSS version 17.0 and Joinpoint version 3.0.

Results

Table 1 shows the lung cancer mortality per 100 000 individuals by age group for years of deaths for males and females. The survey shows that lung cancer mortality markedly increased in the past 35 years. The crude and standardized mortality rates of lung cancer were 17.43 and 8.43 per 100 000 in the 1970–1974 death survey, and 44.17 and 25.67 per 100 000 in the 2005–2009 death survey. For males, the two rates of lung cancer were 21.51 and 10.38 per 100 000 in the 1970–1974, and 57.86 and 37.03 per 100 000 in the 2005–2009. For females, the two rates were 13.34 and 6.70 per 100 000, and 30.59 and 15.98 per 100 000 during the two periods of death survey, respectively. Based on the standardized mortality rates, the latter period is much higher than the former, and the ratios of the latter over the former were 3.57 for males and 2.39 for females. The annual changes were 3.82% and 2.52% for males and females, respectively, in the period of 1970–2009. The annual change was 5.90% for males during 1970–1995 and 3.47% for females in the period of 1970–2000.