RESEARCH ARTICLE

# Time Trends of Esophageal Cancer Mortality in Linzhou City During the Period 1988-2010 and a Bayesian Approach Projection for 2020

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## Abstract

**In recent decades, decreasing trends in esophageal cancer mortality have been observed across China. We here describe esophageal cancer mortality trends in Linzhou city, a high-incidence region of esophageal cancer in China, during 1988–2010 and make a esophageal cancer mortality projection in the period 2011–2020 using a Bayesian approach. Age standardized mortality rates were estimated by direct standardization to the World population structure in 1985. A Bayesian age–period–cohort (BAPC) analysis was carried out in order to investigate the effect of the age, period and birth cohort on esophageal cancer mortality in Linzhou during 1988–2010 and to estimate future trends for the period 2011–2020. Age-adjusted rates for men and women decreased from 1988 to 2005 and changed little thereafter. Risk increased from 30 years of age until the very elderly. Period effects showed little variation in risk throughout 1988-2010. In contrast, a cohort effect showed risk decreased greatly in later cohorts. Forecasting, based on BAPC modeling, resulted in a increasing burden of mortality and a decreasing age standardized mortality rate of esophageal cancer in Linzhou city. The decrease of esophageal cancer mortality risk since the 1930 cohort could be attributable to the improvements of social-economic environment and lifestyle. The standardized mortality rates of esophageal cancer should decrease continually. The effect of aging on the population could explain the increase in esophageal mortality projected for 2020.**

**Keywords:** Esophageal cancer - mortality - Linzhou - Bayesian APC model - projection

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## Introduction

Esophageal cancer is one of the most common cancers worldwide. Global esophageal cancer mortality ranks fifth in mortality frequency in men and eighth in women (6.5% of males and 3.9% of females) (Ferlay et al., 2010). It is even more prominent in Linzhou city (formerly LinXian County) where it ranks second in cancer mortality in men and first in women (35.50% of males and 38.41% of females) in year 2008 (Jie et al., 2012). Linzhou City is situated in the northwest of Henan province the Taihang Mountain area which includes the southwest of Shanxi province and the south of Hebei province. Previous research has shown that some factors, such as dietary, inhabiting environment and living habits, associated with the occurrence of esophageal cancer in this region (Sun et al., 2010).

After undergoing great changes in the economy and lifestyle in China since the late 1970s, recent reports showed downward trends on the incidence rates of esophageal cancer (Jin et al., 1993; He et al., 2003; Tse et al., 2007; Song et al., 2008; Wei et al., 2011). Similar, People inhibiting Linzhou also have shown a progressive decrease both in the incidence and mortality (Sun et al., 2007; Sun et al., 2007).

In this study, we presented the mortality rate for esophageal cancer from 1988-2010. Then we used a Bayesian age-period-cohort model to estimate age, period and cohort effects and projected the burden of esophageal cancer in the next 10 years.

## Materials and Methods

The Linzhou Cancer Registry has provided mortality and population data for the period 1988–2010. Population for the period 2011–2020 was projected by the life table method. In Linzhou, throughout the period 1988–2002, the code for esophageal cancer was 150 according to the ninth revision of the International Classification of Diseases (ICD-9), and since 2003, the code was C15 according to the tenth revision of the ICD (ICD-10).

The population size and the number of deaths from esophageal cancers were stratified by age and gender form each year between 1988 and 2010. Age was grouped into

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5-year age-groups between 30 and 80 years of age with 80 years of age and older being the oldest group, which makes a total of 11 age groups. Rates were calculated by sex for each age-group as the number of esophageal cancer per 100,000-person years.

Age standardized mortality rates were using the direct method with world standard population structure in 1985. For calculate the age standardized mortality rates, the 23 years of data (1988-2010) were grouped into 5-year periods, with the first 3 years forming one period.

Bayesian APC models were fitted separately for males and females with using specialized software (BAMP) (Schmid et al., 2007). Bayesian formulations assume some sort of smoothness of age, period and cohort effects in order to improve estimation and facilitate projection. For fitted and projected age standardized rates samples of 1010000 were drawn from the posterior distribution. These samples were summarized by their median, and 80% credible intervals were calculated from 10th and 90th percentiles, after excluding the initial 10000 iterations as "burn-in". The estimated age, period and cohort effects were presented as rate ratios with log scale. In contrast to non-Bayesian approaches, the forecasts do not rely on strong parametric assumptions for future values of cohort and period and therefore seem to be particularly well suited for projection.

In order to quantify the goodness of fit of our models, the posterior deviance, the effective number of parameters and the deviance information criterion (DIC) were computed (Spiegelhalter et al., 2002). A low deviance indicates a good fit of estimated mortality rates to the data. However, as the deviance decreases with the number of parameter, we used the DIC to compare the different models.

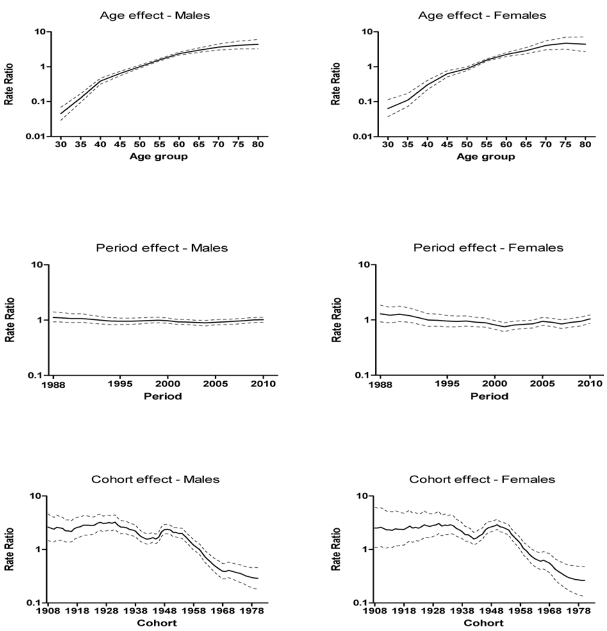


**Figure 1. Age, Period and Cohort Effects by Sex**

## Results

*Male and female mortality rates*

In Linzhou, 14,159 esophageal cancer mortalities were observed during the period 1988–2010. Table1 showed the crude and age standardized rates for men and women. Decline trends in esophageal cancer mortality rates have been observed between periods 1988–1990 and 2001–2005. For men the crude rate and adjusted rate during 2001-2005 were respectively 0.65 times and 0.73 times of the rates observed at 1988-1990 period. Similar to the men, the rates during 2001-2005 were 0.55 times and 0.71 times of the rates during 1988-1990 separately. The rate in the period of 2006-2010 changed little compared with the period of 2001-2005. Both the crude and adjusted rates in women were substantially lower than that in men, at 2006-2010 the crude rate in women was 0.65 times of the rate in men and the age-adjusted rate was 0.81 times of that.

*Age, period and cohort effects*

BAPC analysis was used to further characterize the relative contributions of age, period and birth cohort effects. Figure 1 showed the age, period, and cohort effects by sex from the Bayesian age-period-cohort model. The BAPC model showed risk increased dramatically with age for both men and women. Period effects were similar for men and women showing little variation in risk. The cohort effect were similar for men and women with a consistent decline in the mortality rate in all birth cohorts after those born 1930 except for those born between 1942 and 1950. Table 2 showed the model selection procedure for the BAPC analysis. The full APC model had the lowest DIC for both males and females, indicating that it fitted better than the simpler models.

Figure 2 provided an assessment of model fit by comparing observed esophageal cancer mortality with the mortality projected by the model for each year for 30+

**Table 1. Crude and Age Standardized Rates for Males and Females: 1988-2010**

| Year | Male | | Female | |
|---|---|---|---|---|
| | Crude Rate | Age Adjusted Rate | Crude Rate | Age Adjusted Rate |
| 1988-1990 | 131.6 | 88.7 | 98.1 | 71.1 |
| 1991-1995 | 113.1 | 76.5 | 77.5 | 60.6 |
| 1996-2000 | 105.1 | 69.1 | 65.3 | 50.6 |
| 2001-2005 | 85.1 | 64.3 | 54.3 | 50.5 |
| 2006-2010 | 87.4 | 62.9 | 56.8 | 50.9 |

**Table 2. Comparison of the APC Model with Simpler Models**

| Model | Male | | | Female | | |
|---|---|---|---|---|---|---|
| | Deviance | Effective number | DIC | Deviance | Effective number | DIC |
| Age | 289.1 | 176.5 | 465.5 | 302.4 | 165.8 | 468.3 |
| Age+Period | 284.6 | 163.7 | 448.2 | 294.9 | 144.4 | 439.4 |
| Age+Cohort | 268.5 | 131.9 | 400.5 | 256.7 | 116.5 | 373.2 |
| Age+Period+Cohort | 269.3 | 125.8 | 395.1 | 258.0 | 97.2 | 355.1 |

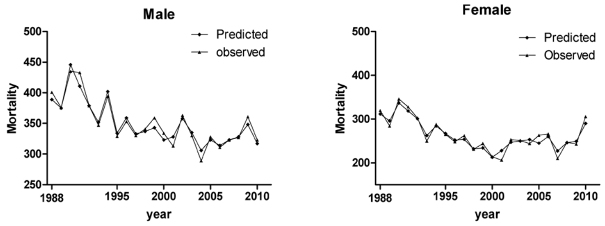


**Figure 2. Comparison of Observed and Projected Mortality of Esophageal Cancer**

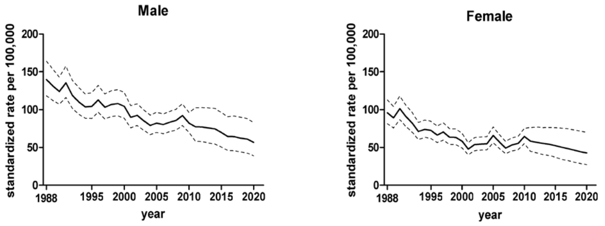


**Figure 3. Fitted and Projected Age Standardized Rate for Males and Females, Age 30+ Years 1988-2020, with 80% Credible Intervals**

aged men and women. The simple linear regression had the same value of $R^2$=0.93 for men and women.

*Estimating future burden*

The age standardized annual mortality rates along with 80% CIs were presented graphically by year and sex (Figure 3). Point estimates of projected rates were decreasing steady for both males and females. For example, the adjusted rates for men and women projected in 2020 were 0.53 times and 0.52 times the respective rates fitted in 2010.

Table 2 compared the mortality of esophageal cancer observed in 2010 with that projected for the year 2020. The estimation of future burden was restricted to those 30 years of age and older. In contrast to the declined age standard mortality rate, the total number of esophageal cancer is projected to be stable for both men and women. For example, the projected mortality for men and women in 2020 is 1.12 times and 1.09 times the respective rates observed in 2010.

## Discussion

Age standardized mortality rates of esophageal cancer for men and women in Linzhou decreased from 1988 to 2005 and were unchanged thereafter. Whether the trend will keep stable or decrease after 2010 has become of concern to government and health agencies.

To project the future burden of this serious health problem, we need to consider three major factors affecting the mortality of esophageal cancer, namely, the age, period, and cohort effects together. These three-time scales are surrogates or proxy measures for other influences. Age covers all factors affecting someone repeatedly as for example nutrition habits. Period effects are factors that impact on all individuals on a particular date such as air pollution or changes in medical treatment. In contrast, cohort effects account for influences that affect the rates in a specified generation equally throughout life.

The fact that there are powerful age effects would come no surprise to most researchers and clinicians.

**Table 3. Projected Esophageal Cancer Mortality for 2020**

| | Observed mortality in 2010 | | Projected mortality for 2020 | | | |
|---|---|---|---|---|---|---|
| Age group | male | female | male | Percent change | Female | Percent change |
| 30-34 | 0 | 0 | 0 | - | 0 | - |
| 35-49 | 1 | 1 | 1 | 0 | 0 | -100 |
| 40-44 | 7 | 1 | 5 | -29 | 2 | 100 |
| 45-49 | 9 | 4 | 9 | 0 | 5 | 25 |
| 50-54 | 33 | 21 | 13 | -61 | 8 | -62 |
| 55-59 | 50 | 36 | 24 | -52 | 19 | -47 |
| 60-64 | 59 | 61 | 67 | 14 | 67 | 10 |
| 65-69 | 42 | 37 | 97 | 131 | 73 | 97 |
| 70-74 | 47 | 49 | 77 | 64 | 79 | 61 |
| 75-79 | 49 | 49 | 43 | -12 | 48 | -2 |
| 80+ | 26 | 47 | 26 | 0 | 31 | -34 |
| Total 30+ | 323 | 306 | 362 | 12 | 332 | 9 |

Of more interest is the fact that result of analysis has revealed that the cohort effect, but not the period effect, played a paramount role in esophageal mortality trends. This observation suggests that some important risk determinants may occur early in life, with their effects only becoming obvious some time later. The decline in esophageal mortality rate in successive cohorts in this study is probably due to the improvements in the social-economic status and lifestyle in recent decades (Taylor et al., 1994; Xibib et al., 2003; Han et al., 2007; Sun et al., 2007; Sun et al., 2010). And the short time variation between 1942 and 1950 possibly attribute to the 1959-1961 famine in China (Chen et al., 2007; Song, 2009). Using mortality data to make an etiological inference has a drawback pertaining to the separation of the effects of the survival rate from true incidence change. However, esophageal cancer survivorship is relatively poor and has shown little change over the last two decades (Sun et al., 2007; Sun et al., 2007; Ma et al., 2009).

We used a Bayesian APC model to project the death number and the trend of the standardized mortality rates. The increased death number and decreased trend reflected the rising aged population and the decreased risks of esophageal cancer in the future.

Estimation and projection of the cancer burden are clearly an essential step in planning an allocation of resources. Our purpose is to shed lights on a major public health issue; public health stakeholders may have a better understanding of the issue of esophageal cancer in the next 10 years.

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The author(s) declare that they have no competing interests.

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