



ORIGINAL ARTICLE

Forecasting the Number of Human Immunodeficiency Virus Infections in the Korean Population Using the Autoregressive Integrated Moving Average Model

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Abstract

Objectives: From the introduction of HIV into the Republic of Korea in 1985 through 2012, 9,410 HIV-infected Koreans have been identified. Since 2000, there has been a sharp increase in newly diagnosed HIV-infected Koreans. It is necessary to estimate the changes in HIV infection to plan budgets and to modify HIV/AIDS prevention policy. We constructed autoregressive integrated moving average (ARIMA) models to forecast the number of HIV infections from 2013 to 2017.

Methods: HIV infection data from 1985 to 2012 were used to fit ARIMA models. Akaike Information Criterion and Schwartz Bayesian Criterion statistics were used to evaluate the constructed models. Estimation was via the maximum likelihood method. To assess the validity of the proposed models, the mean absolute percentage error (MAPE) between the number of observed and fitted HIV infections from 1985 to 2012 was calculated. Finally, the fitted ARIMA models were used to forecast the number of HIV infections from 2013 to 2017.

Results: The fitted number of HIV infections was calculated by optimum ARIMA (2,2,1) model from 1985–2012. The fitted number was similar to the observed number of HIV infections, with a MAPE of 13.7%. The forecasted number of new HIV infections in 2013 was 962 (95% confidence interval (CI): 889–1,036) and in 2017 was 1,111 (95% CI: 805–1,418). The forecasted cumulative number of HIV infections in 2013 was 10,372 (95% CI: 10,308–10,437) and in 2017 was 14,724 (95% CI: 13,893–15,555) by ARIMA (1,2,3).

Conclusion: Based on the forecast of the number of newly diagnosed HIV infections and the current cumulative number of HIV infections, the cumulative number of HIV-infected Koreans in 2017 would reach about 15,000.

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1. Introduction

Human immunodeficiency virus (HIV) infection can show nonspecific symptoms in the early stage such as anorexia, weight loss, fever, lymph node enlargement, and fatigue, but has a long asymptomatic period after an acute infection period. Therefore, the real prevalence of HIV infection has been estimated to be more than the reported numbers. Since the first reported case of AIDS, the United Nations Programme on HIV/AIDS (UNAIDS) estimated the global people living with HIV/AIDS (PLWHA) to be 35.3 million in 2012 [1]. The cumulative number of HIV-infected people identified in the Republic of Korea from 1985 to 2012 was 10,453 (9,410 Koreans, 1,043 foreigners), relatively low compared to many other countries [2]. However, since 2000, the number of the HIV infected people in Korea has sharply increased; 800 to 1,000 persons are newly identified each year in the recent 3 years [2], and it is questionable whether this increasing trend will continue.

The United States stated the research on estimation in 1980, and many countries have estimated the HIV-infected persons using the model suggested by UNAIDS for identifying the trend of their own nation. The method to estimate incidence, prevalence, the number of infected persons, and the number of deaths has been improved since its development in late 1980. It includes the back calculation method, ratio method, Delphi survey method, mathematical and computer/simulation models, and Epimodel. No single optimal estimation method exists; each method has its own characteristics. Recent standard methods for estimation and prediction are the workbook method, estimation and projection package (EPP) method, and time series method (autoregressive moving average model).

As for the estimation of HIV-infected Koreans, the back calculation method, Epi-info model, and EPP model cannot be applied because of limitations including: the lack of exact statistics on AIDS cases and no specific information available for commercial sex workers (CWSs), intravenous drug users (IDUs), and the sexually transmitted infection risk group (STI RG). However, the autoregressive integrated moving average (ARIMA) time series method utilizes autocorrelation and can produce an estimation model with information on HIV cases identified yearly or monthly. ARIMA is used for the estimation of influenza mortality [3], malaria incidence [4], and other infectious diseases [5–7].

This study aimed to construct estimation models using the annual number of newly identified HIV-infected Koreans in Korea from 1985 to 2012, and to forecast the number of HIV cases and the trend in epidemiological characteristics.

2. Materials and Methods

2.1. Materials

This study has utilized 9410 identified HIV-infected persons' basic epidemiological data, including diagnosed year, sex, age, screening site, and date of death from 1985 to 2012 in Korea. The local public health centers conduct an epidemiological investigation on the route of infection once the HIV-infected persons are identified and report the results to the Korea Centers for Disease Control and Prevention (KCDC). The epidemiological data are managed by the KCDC HIV database system. The data for this study were collected from the KCDC HIV database system.

2.2. Methods

ARIMA models are the most commonly used time series prediction models. We constructed ARIMA models with data from HIV cases in Korea from 1985–2012, to forecast the annual number of newly diagnosed HIV-infected Koreans and to forecast the cumulative number of HIV cases in the next 5 years (2013–2017). To determine the degree of ARIMA, we have utilized the autocorrelation function (ACF) and partial autocorrelation function (PACF) graphs and constructed an optimal model on the basis of Akaike's information criterion (AIC) statistic and Schwartz's Bayesian criterion (SBC) statistic. Conditional least squares method (CLS) was used for parameter estimation.

This study constructed models by sex, age, and screening site, similar to that of the study by Debanne et al [8]; as a result, the sums of the forecasting numbers by variables are not equal to the forecasting number of newly diagnosed HIV cases. Forecasting numbers were calculated based on a percentage of the forecasting value of each category by each variable. To check the accuracy of each model, mean absolute percentage errors (MAPE) between the number of observed and fitted HIV infections from 1985 to 2012 were calculated. Finally, the number of HIV-infected Koreans in each year from 2013–2017 were forecasted. SAS version 9.3 (SAS Institute, Cary, NC, USA) was used for data analysis.

3. Results

3.1. Status of HIV-infected persons in Korea until 2012

Figure 1 depicts the number of people with HIV in Korea from 1985 to 2012. The cumulative number of HIV-infected Koreans through 2012 is 9,410 (8,668 men, 742 women), and the number of PLWHA is 7,788 (7,165 men, 624 women). The number of HIV case sharply increases from 2000 to 2008. However, the past 5 years have shown a lower increase of newly diagnosed cases.

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