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Original Article

Evaluating trends and influencing factors of cardiovascular disease mortality over time: a time series analysis in West Azerbaijan province

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Abstract

***Background & Aims*:** Cardiovascular diseases are among the most important causes of death worldwide. The present study aimed to evaluate the trend of changes in the death rate due to cardiovascular diseases, with an emphasis on short- and long-term effective variables.

***Materials & Methods*:** In this descriptive-analytical (time series) study, all deaths due to cardiovascular diseases registered in the health registration system of death cases by the Health Vice-Chancellor of Urmia University of Medical Sciences from 2018 to 2021 were analyzed. A total of 27,146 cases of death due to cardiovascular causes were recorded and included in our study. SPSS, Minitab, and SAS software were utilized for data analysis.

***Results*:** The rate of death due to cardiovascular causes in this study was 30.51% during the investigated period. The univariate time series model (ARMA 1, 2) was deemed the most suitable fit model for cardiovascular death data. Also, age and education were identified as effective factors in the rate of cardiovascular deaths.

***Conclusion*:** The trend of cardiovascular deaths has not been rising. It has increased with age and lower education levels over time. This rate has been further exacerbated during the COVID-19 pandemic.

***Keywords*:** Cardiovascular, Death rate, Time series

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Introduction

Cardiovascular diseases are the most significant causes of mortality and disability worldwide (1). According to the report of the Center for Statistics of Heart Diseases and Strokes of the American Heart Association, as one of the reliable sources, only in 2022, about 19 million people died due to cardiovascular diseases worldwide, which is about 18.7% higher compared to the rate in 2010 (2). It is predicted that by 2030, more than 23 million deaths will occur annually due to cardiovascular diseases worldwide (3). Cardiovascular diseases themselves

pose a serious challenge for the world's health system, with many people dying annually from these diseases (4). With the emergence of the COVID-19 disease in December 2019 (5) and the resulting anxiety, a level of excitability has been created among different people, which can have adverse effects on people's health (4). Cardiovascular complications caused by COVID-19 infection, which occur in 8 to 12% of COVID-19 patients, have raised significant concern (6). Studies conducted in China indicated that cardiovascular diseases and their risk factors such as high blood pressure and diabetes have been among the common diseases associated with COVID-19 (7). It was been shown that in patients with severe COVID-19, the prevalence of high blood pressure is about two times higher, cardiovascular diseases are about three times higher, and diabetes is about twice as high than in patients with mild involvement (8). Old age and sex are among the factors that affect cardiovascular mortalities and require further attention (9).

Since pandemics such as COVID-19 can have various effects on the mortality rate in society, the present study has aimed to evaluate the trend of the mortality rate due to cardiovascular diseases pre- and post- COVID-19 pandemic in West Azerbaijan province, with an emphasis on effective factors in the mortality of cardiovascular patients. This will be done using the time series statistical models, so that the trend of deaths due to cardiovascular diseases in West Azerbaijan province can be forecasted, and needed interventions to prevent such premature deaths due to cardiovascular diseases can be implemented.

Materials & Methods

The present descriptive-analytical study was conducted through the analysis of secondary data to evaluate the trend of mortality due to cardiovascular diseases pre- and post-COVID-19 in West Azerbaijan Province from 2018 to 2021. All registered death cases due to cardiovascular diseases in the statistics section were included in the study. Subsequently, the desired statistics, including the number of deaths and the total characteristics of individuals were recorded and entered into the software, divided by each month. To identify the trend of mortalities due to cardiovascular diseases, time series model was utilized after determining the best model. Meanwhile, to increase the forecasting power of the model in determining the trend, the month was employed as the time variable. Additionally, the Box-Jenkins Method was used to ascertain this trend. Following the modeling of univariate and multivariate time series, ARDL models were used to demonstrate short- and long-term relationships, and the Chi-square test was used to describe the relationship between variables pre- and post-COVID-19. The stages of the time series model in the present study included: removal of the nonstationary component, identification of the fitted model, estimation of parameters, analysis of residuals, and finally, evaluation of the model's forecasting power. Ultimately, the trend of the forecast for mortality due to cardiovascular diseases was compared to the real statistics in 2022. In the present study, all deaths due to cardiovascular diseases registered in the system of health registration of death cases by the Health Vice-Chancellor of Urmia University of Medical Sciences from 2018 to 2021 were analyzed. The SPSS, MiniTab, and SAS software employed for this purpose.

Results

Overall, during the period under study, 32,690 deaths due to cardiovascular diseases were recorded in West Azerbaijan province. The average number of recorded deaths during the pre- COVID-19 years was nearly 499 cases, while it was 615 cases for the post-COVID-19 period, which shows a 23% increase compared to three years before the pandemic (Figure 1). In terms of sex distribution, 51.28% of the mortalities were recorded for men, while 48.71% were recorded for women.

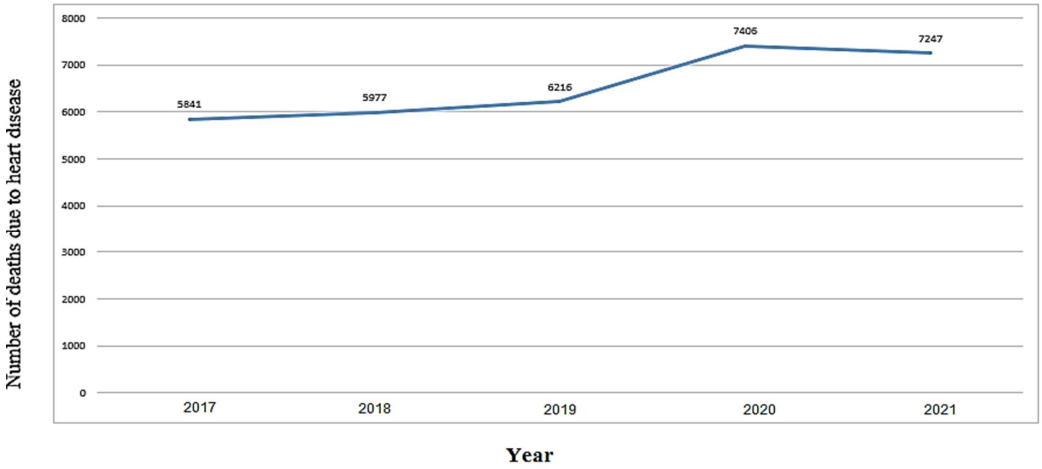

Fig. 1. Trend of mortalities due to cardiovascular diseases in West Azerbaijan province

Table 1. Frequency distribution of mortalities due to cardiovascular diseases pre- and post-COVID-19 pandemic

Variable		Period				Significance level
		Pre- COVID-19		Post-COVID-19		
		Frequency	Percentage	Frequency	Percentage	
Deaths due to cardiovascular diseases	Cardiovascular	12493	40.5	14653	33.9	$X^2 = 344.831$ $P = 0.001$
	Non-cardiovascular	18337	59.5	28629	66.1	

Based on the results in Table 1, the increase in the death rate due to cardiovascular diseases post- COVID-19 has been statistically significant compared to pre-COVID-19 ($p = 0.001$).

The time series shown in Figure 2 indicates the mortalities due to cardiovascular diseases per month. As shown in the figure, it is static. The data in this series have been collected and divided by month.

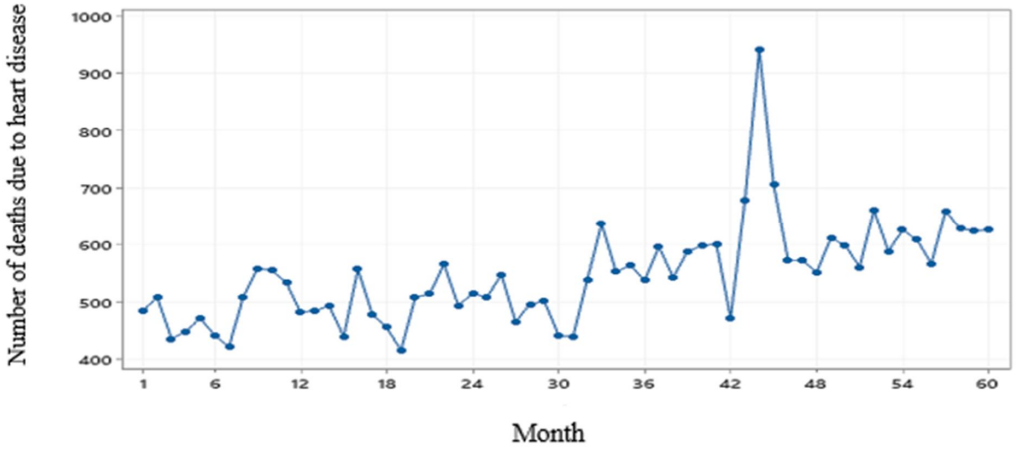

Fig. 2. Evaluation of time series of mortalities due to cardiovascular diseases

Furthermore, Figure 3 depicts the values of autocorrelation and partial autocorrelation to demonstrate that the previous data are static.

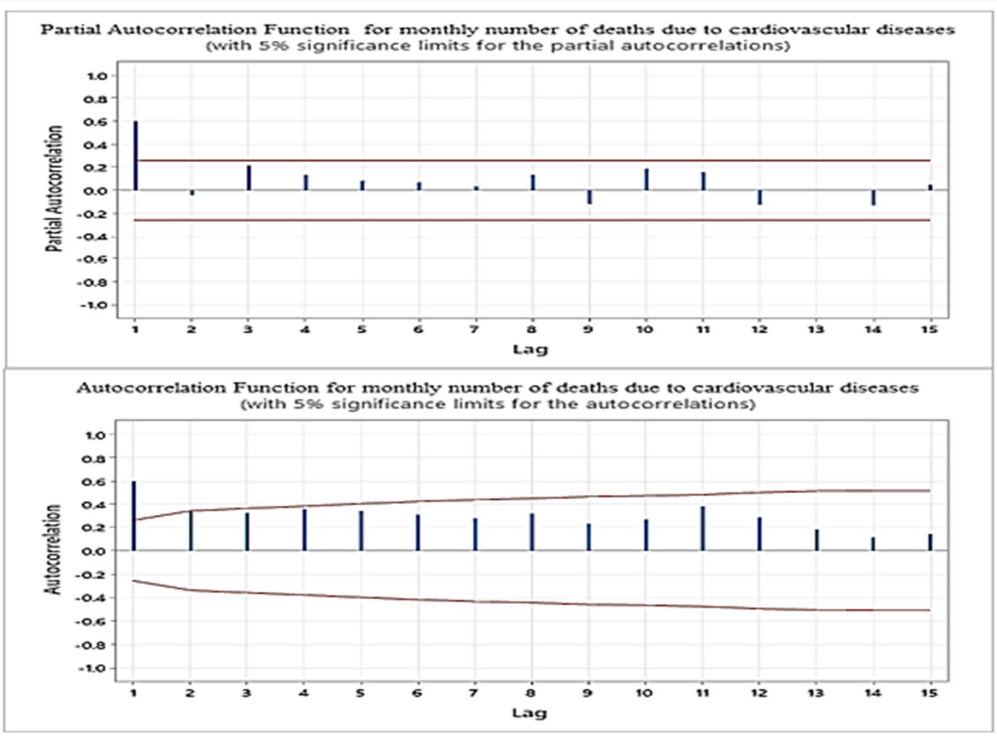

Fig. 3. ACF and PACF of time series for the number of deaths due to cardiovascular diseases

An ARMA (1, 2) model with a y-intercept of μ was chosen as the best model for the behavior of the time series of monthly deaths due to cardiovascular diseases. The summary of results obtained by this model alongside the estimates of parameters using the Maximum Likelihood method as well as the significance levels mentioned for these parameters are presented in Table 2.

Table 2. Estimate of Maximum Likelihood for parameters of ARMA (1, 2) with a y-intercept of μ

Parameter	Estimate	Standard Error	t Value	*P* Value	Lag
AR	0.99943	0.00526	190.13	0.000	1
MA	0.340	0.131	2.59	0.012	1
MA	0.411	0.130	3.16	0.003	2

Based on Table 2, the ARMA (1, 2) (μ≠0) model is presented as below using the backward operator:

$_t = \mu + Z_t (1- \beta_1 B- \beta_2 B^2)$ y $(1-\Phi_1 B- \Phi_2 B^2) (1-B)^2$

The Ljung-Box test for the ARMA (1, 2) model with a y-intercept of μ for deaths due to cardiovascular diseases during the 2017-2021 period in West Azerbaijan province is indicative of the independence of the residuals. After identifying the best model of fit for the series and estimating the relevant parameters,

the third stage of fit of the Box-Jenkins model, which forecasts the series using the identified model, was addressed. Using the ARMA (1, 2) model, the series forecast for 2022 predicts approximately 735 death cases due to cardiovascular diseases (with a significance level of 95%: 2372-9097), while the actual cases were 6,447.

The absolute value of the Dickey-Fuller statistic, generalized to each variable, is lower than the absolute value of the critical statistics. Therefore, the H0 hypothesis or presence of a common root cannot be rejected. Thus, all variables are reliable at the model level (intercept, without trend) or in the first-order difference (with intercept, without trend) for the average response of death rate due to cardiovascular diseases.

The results of the estimate of the function of the death rate due to cardiovascular diseases are presented in the following table:

$$NY=AP+\sum_{i=1}^{n}\gamma_i Age_{i-t}+\sum_{i=0}^{n}\gamma_i Job_{i-t}+\sum_{i=0}^{n}\gamma_i residence_{i-t}+\sum_{i=0}^{n}\gamma_i Sex_{i-t}+\sum_{i=0}^{n}\gamma_i education_{i-t}$$

Table 3. Results of estimates of death rates due to cardiovascular diseases using the ARDL (1,0,0,0,0,0) model

Variable	Coefficient	Standard deviation	*p* Value
NY(-1)	0.51373	0.17174	0.004
Age	3.4811	1.8124	0.06
Job	-2.8446	3.0478	0.355
Residence	-7.8714	8.814	0.376
Sex	4.9037	90.3917	0.957
Education	138.5298	77.3872	1.7901
$R^2 = 0.44546$		F = 8.5149	

Regarding the *p* value for the autocorrelation test, which is equal to 0.382, the H0 on lack of autocorrelation is confirmed, and based on the *p* value for the correct functional form test, which is equal to 0.053, the H0 hypothesis on the correct functional form is confirmed. Also, regarding the *p* value for the normality of the date which is equal to 0.159, the H0 hypothesis on the normality of data is confirmed. Moreover, considering the *p* value of the Heterogeneity of Variance Test, which is equal to 0.243, the H0 hypothesis on the heterogeneity of variance is confirmed. Based on the above values, the fit of the model is approved.

Table 4. Results of long-term estimate of the function of deaths due to cardiovascular diseases using the ARDL (1,0,0,0,0,0) model

Variable	Coefficient	Standard deviation	*P* value
Age	7.1588	2.6096	0.008
Job	-5.8499	5.9672	0.331
Residence	-16-1873	22.2907	0.471
Sex	10.0843	186.6062	0.957
Education	284.8827	134.6207	0.039

Since the model used in the present study is logarithmic, the coefficients of the variables are indicative of the correlation between age and education and the rate of deaths due to cardiovascular diseases. According to Table 4, the average age effect on the long-term coefficient of deaths due to cardiovascular diseases is significant, with a 1% increase (decrease) in the average weight (7.1588), the percentage of deaths due to cardiovascular diseases is increased (decreased) ($p = 0.008$).

The correlation between the long-term coefficient of deaths due to cardiovascular diseases and place of residence is 284.8827, i.e., with a 1% increase (decrease) in the variable of place of residence in the long term, the rate of deaths due to cardiovascular is increased (decreased) by 284.8827%, which is statistically significant ($p = 0.039$). The rest of the variables (job, place of residence, and sex) have not been significantly correlated with the rate of deaths due to cardiovascular diseases ($p > 0.05$).

The short-term analysis of the rate of deaths due to cardiovascular diseases as well as the coefficients of error correction pattern which is indicative of the correlation between the variable of deaths due to cardiovascular diseases and the independent variables in the short term are presented in Table 3:

$$\Delta NY=\Delta AP+\sum_{i=1}^{n}\gamma_i\Delta LAge_{i-t}+\sum_{i=0}^{n}\gamma_i\Delta LJob_{i-t}+\sum_{i=0}^{n}\gamma_i\Delta Lresidence_{i-t}+\sum_{i=0}^{n}\gamma_i\Delta LSex_{i-t}+\sum_{i=0}^{n}\gamma_i\Delta LEducation_{i-t}+\theta esm_{t-1},$$

Table 5. Short-term estimates of function of deaths due to cardiovascular diseases using the ECM method

Variable	Coefficient	Standard deviation	*P* value
Age	3.4811	1.7124	0.046
Job	-2.8446	3.0478	0.355
Residence	-7.8714	8.814	0.376
Sex	4.9037	90.3917	0.957
Education	138.5298	70.3872	0.05
ecm(-1)	-0.48627	0.17174	0.007
R^2= 0.29388		F = 4.4117	

Estimated coefficients show short-term trends in the death rate due to cardiovascular diseases concerning the ratio of residential area (urban to rural), education level ratio (educated to illiterate), job ratio (employed to unemployed), sex ratio (male to female), and the average age of individuals who died due to cardiovascular diseases in the study. For instance, with a 1% increase (decrease) in the ratio of education level (educated to illiterate), the number of people dying due to cardiovascular diseases is increased (decreased) by 138.5298%. Also, with a 1% increase (decrease) in the average age of patients dying from cardiovascular diseases, the rate of deaths due to cardiovascular diseases increased (decreased) by 3.4811%. Finally, the ECM (-1) coefficient in the short term is -0.48627. which is statistically significant and indicates the short-term pace of adjustment towards long-term balance. In fact, this coefficient indicates that in each period, 0.48627% of the imbalance is adjusted (corrected) in the subsequent period. The value of R^2 in the short term is 29.388%, indicating that approximately 29.388% of the changes in the rate of deaths due to cardiovascular diseases are explained by the explanatory variables in the short term. Also, the high values of F and R^2 statistics are indicative of the acceptability of the model.

The AIC value for this model has been lower than other models, which is itself a criterion for choosing it as the best model. This value is equal to -3335.3882.

Discussion

The results obtained in the present study indicate that the average number of deaths due to cardiovascular diseases in West Azerbaijan province has increased by 23% during the COVID-19 pandemic, compared to the years before the pandemic. Additionally, the rate of male deaths has been higher than female deaths both during the COVID-19 pandemic and afterwards. This could be due to differences in life expectancy between women and men, differences in their lifestyles, including riskier behaviors such as smoking among men, and the greater health-related sensitivity and compliance with health matters observed in women compared to men (10).

From 2017 to 2019, the trend of deaths due to cardiovascular diseases has remained constant, without any considerable rise or decline. However, since April 2020, with the onset of the first peak of COVID-19, the number of deaths has increased. During June and July 2020, with the onset of the second peak of COVID-19, the number of deaths increased again. The number of deaths reached its peak in all years under study with the onset of the most severe peak of COVID-19 in Fall 2020. Based on the results, the rate of deaths due to cardiovascular diseases is correlated with average age, education level, and place of residence in the long term, and average age and education level in the short term. In a study conducted on the factors affecting the death rate due to cardiovascular diseases in Yazd, significant associations were found between the death rate and variables such as education, place of residence, type of residence, and age, using the negative binomial regression (11). A study conducted by Kiani in Isfahan also emphasized the effectiveness of age on the mortality rate (12). Furthermore, Mahdavi Shahri et al. indicated that old age significantly increases the rate of deaths due to cardiovascular diseases, which is in line with our results (9).

Regarding the actual results obtained from the data registered in the health registration system of death cases by the Health Vice-Chancellor of Urmia University of Medical Sciences in 2022, there have been 6,447 deaths in West Azerbaijan province due to cardiovascular diseases, compared to the 5,735 death cases forecasted for 2022 by the fit model using time series. Therefore, it can be stated with high confidence that this statistical model can be used to predict deaths due to cardiovascular diseases in the upcoming year and be applied in planning related to the prevention of this non-communicable disease.

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Authors' Contributions

None declared.

Data Availability

The raw data supporting the conclusions of this article are available from the authors upon reasonable request.

Conflict of Interest

The authors have no conflict of interest in this study.

Ethical Statement

This article is extracted from the master's thesis by Ms. Arezoo Hosseini with the code of ethics IR.UMSU.REC.1401.239.

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