Time series analysis of the admission to the emergency department due to respiratory and cardiovascular diseases between 2010 and 2014 in Kırklareli, Turkey

Yeliz Mercan, Seniha Bilge Hapcioğlu, Halim Issever

1Department of Health Management School of Health, Kırklareli University, Kırklareli,
2Department of Public Health, Faculty of Medicine, Istanbul University, Istanbul, Turkey

Abstract

Aim: The aim of this study was to estimate the admissions to the emergency department due to cardiovascular and/or respiratory diseases for the next twelve months. Material and Method: This research was characterized as an ecological study. The data were obtained from the hospital database between years 2010 and 2014. Emergency department admissions (N=148,169) from ≥15 years due to cardiovascular and/or respiratory diseases were evaluated according to the monthly average. Multiplicative Seasonal Auto-Regressive Integrated Moving Average (SARIMA) modeling method was used for the research. Results: It is observed that the emergency department admissions display seasonal changes. ARIMA(1,1,2)(1,0,1)12 model (MAPE=98,039) was ascertained to be the most suitable model with the success of 99.6% in the predictions. It was predicted that the admissions would be higher in the winter period. Model success for admissions according to disease groups vary between 75.2% and 89.2% and was estimated the highest level of admissions in January and February. The most suitable models used to estimate the number of admissions were the ARIMA(2,1,3)(1,0,0)12 for respiratory diseases, the ARIMA(2,1,2)(1,0,0)12 for cardiovascular diseases and the ARIMA(1,1,1)(1,0,0)12 for both for cardiovascular and respiratory diseases. It was estimated that the admissions due to cardiovascular diseases which had a conjuncture structure would increase mostly in April and the admissions due to respiratory diseases and both of the diseases would be higher mostly in the winter period. Discussion: SARIMA models are a good prediction model that can be used to estimate emergency department admissions due to cardiovascular and/or respiratory diseases. The estimations derived comprise a good evidence-based source for policymakers and health service providers.

Keywords

Emergency Department Admissions; Cardiovascular Diseases Admissions; Respiratory Diseases Admissions; Time Series; SARIMA Models

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Corresponding Author: Yeliz Mercan, Department of Health Management, Kırklareli University, School of Health, 39000, Kırklareli, Turkey.
GSM: +905072392995 F.: +90 2882145547 E-Mail: mercan.yeliz@gmail.com
ORCID ID: 0000-0002-7099-4536
Introduction
Epidemiological studies have shown the association between air pollution and climate change and health effects over the past decade. Many of these studies examined the effects of air pollution and climate change on daily mortality, emergency department visits, and hospital admissions for particularly cardiovascular and respiratory diseases in many parts of the world [1-6]. These studies provide evidence for the negative effects of urban air pollution on health and a better understanding of biological mechanisms; and in addition to creating an important field of research, they have allowed decision-makers to understand the effects of pollutants and the benefits that can be achieved by control measures [6-8]. In the studies conducted in America, Canada, and Europe, it was determined that there would be a possible rise in emergency admissions due to cardiovascular and respiratory reasons, and related hospitalization cases and health expenses [7, 9-11]. In studies conducted in Turkey, it has been shown an increase in emergency room visits and hospitalizations due to changes in air pollution and meteorological parameters. The majority of these admissions was from the elderly and was mostly seen in winter period [12-14]. Because of these diseases which intimidate the sustainability of health care service, it is needed to carry out accurate strategic planning and prepare proper infrastructure taking into consideration all the dynamics [10, 15, 16]. Depending on these reasons, it is aimed to predict emergency admissions for the next twelve months due to cardiovascular and/or respiratory diseases at the Kırklareli State Hospital between January 2010 and December 2014.

Material and Method
Study design and settings
The study is characterized as ecological research conducted in the center of a north-western Turkish city - Kırklareli between January 2010 and December 2014.

Study population
Among 602,792 admissions to Kırklareli State Hospital Emergency Department, a total of 148,169 individuals aged 15 years and older who have cardiovascular diseases and/or respiratory diseases were included in the research between the pre-mentioned dates. Admissions more than once for each person were recorded separately to the database and each admission was considered to be a new case. Daily obtained emergency department admission numbers were organized as monthly mean values and time series of 60 months were created.

Definition
WHO International Statistical Classification of Diseases and Related Health Problems 10th Revision was utilized in the research as the diagnostic tool. According to the related classification, the total number of emergency department admissions (EDA) was constituted by the sum of all individuals who have received at least one of the I00-I99 and/or J00-J99 diagnosis codes. Among them, individuals with I00-I99 were diagnosed for cardiovascular diseases (CVD) admissions, J00-J99 diagnosed were for respiratory diseases (RD) admissions and the ones who received minimum one diagnosis from both codes at the same time were treated for CVD and RD (CVD&RD) admissions.

Ethical consideration
The Research was conducted according to the ethical principles and was approved by The Ethics Committee of the Istanbul University Faculty of Medicine - Clinical Researches Ethical Committee in 2015, reference number: 2015/863-09.

Statistical analysis
Total EDA, CVD, RD, and CVD&RD time series which are obtained from the monthly averages between January 2010 and December 2014 together with the Seasonal Auto-Regression Integrated Moving Average (SARIMA) models were used to predict the next twelve months data. Multiplicative SARIMA model was used to capture the seasonal and non-seasonal scene that arise synchronously in time series and was represented as ARIMA(p,d,q)(PD,Q). In this formula, “d” indicates the non-seasonal difference as “D” stands for the seasonal difference, “p” for non-seasonal autoregressive process (AR), “q” for moving average (MA), “P” seasonal autoregressive process (SAR), “Q” seasonal moving average (SMA) and finally “s” for periodic (s=12) seasonality [17]. The stability control and autocorrelation structure of time series were visually examined using autocorrelation function (ACF) and partial autocorrelation function (PACF) graphs. Trend effect in time series was controlled by using Hodrick-Prescott Filters Method (lambda=14400). For the formation of models and predictions, Least Squares Method was used. For the determination of the most suitable SARIMA model, Akaike Information Criterion (AIC) was utilized. In the evaluation of prediction results depending on the static prevision, Mean Absolute Percentage Error (MAPE) and Theil’s Inequality Coefficient (Theil’s UC) were used. For the analysis of the data, EViews 7.0 statistic package program was used and statistically significant value was considered to be p<0.05.

Results
In the study, between January 2010 and December 2014, 148,169 admissions were received to the emergency department, 52.7% of whom were males and 52.0% were aged between 15-39 years. Among the total admissions, 75.1% were due to RD, 23.9% were CVD and 1.0% was both due to RD and CVD. The majority of the admissions were collected from females (52.7%). For RD, CVD, and RD&CVD the admission rates of females were respectively found to be 50.3%, 60.0%, and 53.7%. RD admissions aged between 15-39 years were 65.0%, CVD aged between 40-64 years were 45.1% and CVD&RD admissions aged between 65-84 years were 47.7% (Table 1). EDA and RD admissions which are observed to be increased in the pre-mentioned period were also presenting a seasonal characteristic. CVD, together with CVD&RD admissions were observed to have a conjuncture structure. The amount of EDA, RD, and CVD&RD admissions was highest in February 2011, CVD in November 2010 among all other months. It is observed that the time series comprise no-trend (Figures 1).
For the time series which primary differences are taken and the stability is verified, the most suitable SARIMA models are iden-
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tified according to the AIC criteria. EDA, RD, CVD, CVD&RD admissions, and AIC were found to be 8.162, 8.357, 4.663, -0.131 respectively. The models chosen were found to affirm all the assumptions (Table 2).

According to the prediction results which are performed via the static foresight of the time series, the most suitable model for EDA time series was found to be ARIMA(1,1,2)(1,0,1)12 (MAPE=98.039, Theil’s UC=0.996). For RD admissions time series, ARIMA(2,1,3)(1,0,0)12 (MAPE=106.209, Theil’s UC=0.892); for CVD, ARIMA(2,1,2)(1,0,0)12 (MAPE=247.525, Theil’s UC=0.752); for CVD&RD, ARIMA(1,1,1)(1,0,0)12 (MAPE=128.541, Theil’s UC=0.803) models were found to be the most suitable models for the prediction (Table 3).

According to the models obtained, it is determined that the real and predicted values of the time series were compatible (Figures 2).

Depending on the next twelve-months prediction of time series which are converted into real values, the mean EDA and RD admission mean values were predicted to be the highest in January, while CVD to be the highest in April and both CVD&RD in February (Table 4).

Table 1. Descriptive characteristics of emergency department admissions, 2010-2014.

<table>
<thead>
<tr>
<th>Subseries</th>
<th>Gender</th>
<th>EDA</th>
<th>RD</th>
<th>CVD</th>
<th>CVD&amp;RD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>70 146 (47.3%)</td>
<td>55 283 (49.7%)</td>
<td>14 148 (40.0%)</td>
<td>715 (46.3%)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>78 023 (52.7%)</td>
<td>55 981 (50.3%)</td>
<td>21 212 (60.0%)</td>
<td>830 (53.7%)</td>
</tr>
</tbody>
</table>

*Percentage of row. EDA: Emergency Department Admissions, RD: Respiratory Diseases admissions, CVD: Cardiovascular Diseases admissions, CVD&RD: At least one diagnosis was made at the same time from RD and CVD admissions.

Table 2. Subseries optimal models and parameter estimates for emergency department admissions

<table>
<thead>
<tr>
<th>Subseries</th>
<th>EDA</th>
<th>RD</th>
<th>CVD</th>
<th>CVD&amp;RD</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR(1)</td>
<td>-0.644 (0.092)</td>
<td>1.455 (0.147)</td>
<td>-0.460 (0.068)</td>
<td>0.581 (0.108)</td>
</tr>
<tr>
<td>AR(2)</td>
<td>-0.726 (0.125)</td>
<td>-0.773 (0.060)</td>
<td>-0.274 (0.131)</td>
<td>-0.373 (0.104)</td>
</tr>
<tr>
<td>SAR(12)</td>
<td>0.965 (0.086)</td>
<td>0.417 (0.048)</td>
<td>0.274 (0.131)</td>
<td>0.373 (0.104)</td>
</tr>
<tr>
<td>MA(1)</td>
<td>0.217 (0.076)</td>
<td>-2.277 (0.155)</td>
<td>0.374 (0.061)</td>
<td>-0.981 (0.009)</td>
</tr>
<tr>
<td>MA(2)</td>
<td>-0.262 (0.080)</td>
<td>2.029 (0.262)</td>
<td>0.957 (0.030)</td>
<td>0.374 (0.104)</td>
</tr>
<tr>
<td>MA(3)</td>
<td>-0.751 (0.152)</td>
<td>-0.946 (0.066)</td>
<td>-0.274 (0.131)</td>
<td>-0.373 (0.104)</td>
</tr>
</tbody>
</table>

Parameter estimates are displayed with standard error in parentheses.*p<0.01. EDA: Emergency Department Admissions, RD: Respiratory Diseases admissions, CVD: Cardiovascular Diseases admissions, CVD&RD: At least one diagnosis was made at the same time from RD and CVD admissions.

Table 3. Estimation levels of models derived from time series for emergency department admissions

<table>
<thead>
<tr>
<th>Subseries</th>
<th>EDA</th>
<th>RD</th>
<th>CVD</th>
<th>CVD&amp;RD</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARIMA(1,1,2)(1,0,1)_{12}</td>
<td>98.039</td>
<td>0.305</td>
<td>0.996</td>
<td></td>
</tr>
<tr>
<td>ARIMA(2,1,3)(1,0,0)_{12}</td>
<td>106.209</td>
<td>0.398</td>
<td>0.892</td>
<td></td>
</tr>
<tr>
<td>ARIMA(2,1,2)(1,0,0)_{12}</td>
<td>247.525</td>
<td>0.498</td>
<td>0.752</td>
<td></td>
</tr>
<tr>
<td>ARIMA(1,1,1)(1,0,0)_{12}</td>
<td>128.541</td>
<td>0.460</td>
<td>0.803</td>
<td></td>
</tr>
</tbody>
</table>

EDF: Emergency Department Admissions, RD: Respiratory Diseases admissions, CVD: Cardiovascular Diseases admissions, CVD&RD: CVD at least one diagnosis was made at the same time from RD and CVD admissions.

Figure 1. Change of emergency department admissions by monthly average, 2010-2014.

Figure 2. Static estimates of time series according to obtained models for emergency department admissions, 2010M01-2014M12.
COPD burden, cure and strategies in the future [10]. Research a half times and they emphasized to take new precautions for tion would increase in the next 15 years approximately one and autumn period [17]. Khakban et al. found that COPD hospitalizations are expected to increase in spring months [23] and COPD et al. demonstrated that in Canada, the asthma-based admis- sions, often and synchronously ascending amount of pollutants as smoking [22], besides higher vehicle emissions in the cit- ies, often and synchronously ascending amount of pollutants in the atmosphere, meteorological parameters, and exposed allergens were reported to be the reasons of increased emergency department admissions due to asthma and respiratory allergies specifically for the atopic individuals [4, 20]. Rosychuk et al. demonstrated that in Canada, the asthma-based admissions are expected to increase in spring months [23] and COPD admissions are expected to rise much more in winter and au- tumn period [17]. Khakban et al. found that COPD hospitaliza- tion would increase in the next 15 years approximately one and a half times and they emphasized to take new precautions for COPD burden, cure and strategies in the future [10]. Research conducted in Turkey supports the evidence of increased RD-based emergency department admission due to change in air pollution and meteorological parameters [13, 14]. RD emergency department admission mean values were predicted to increase in winter and spring months in Turkey. Simple differenc- es observed in our generally literature-compatible research [17, 23], were expounded by the poor quality fossil fuel consumption as a heating tool, the fluctuations in natural gas prices and in- creased traffic-caused emissions. It is reported that the size and content of particle matter which have an important role in RD emergency department admission may cause systemic inflammation thus, yield to CVD [7, 24]. Related literature indicates that air pollution parameters were associated with increased admissions due to IHD, myocardial infarction (MI) and coronary cases. However, if the exposure is decreased, IHD, arrhythmia and related diseases hospitaliza- tion costs could be diminished [25]. Our research, in which the monthly changes of CVD has a conjuncture structure, similar findings are obtained in the study by Pintaric et al. [5] which was conducted in Croatia. Because there is a difference in higher estimations of admissions during winter and spring, our results may be due to increased air-pollutant concentration in Turkey. The studies conducted in the literature [4, 18, 26], in contrary indicate that emergency department admission and hospital- izations are increasing in summer due to myocardial infarction (MI), heart failure etc. In admissions which are affected by cli- mate change, heatwaves, maximum temperatures and changes in day-time temperatures are found to increase CVD risk in the short-term [4,18, 21, 27]. In the admissions among the elderly population observed due to CVD, the registered excessive morta- lity rates were indicated to have relation with atmospheric conditions [26-29]. In our research, it is estimated that the monthly emergency de- partment admissions mean values of CVD&RD with conjuncture structure would be significantly lower than the other admis- sions. Expected CVD&RD admissions would be higher in winter than in other seasons. Peel et al. found that hypertension, COPD or diabetes diagnosed individuals with CVD were much more sensitive to environmental conditions and this situation was as- sociated with an increase in the number of admissions [30]. Other researches demonstrated that disadvantaged groups and individuals with specific health disorders have a higher risk for CVD and RD-based emergency department admissions [31, 32]. In America, between 2010 and 2030, two of every five individu- als are expected to have CVD and related diseases and thus, the estimated health costs would triple [9]. In literature, there was not found any prevision studies including individuals with CVD&RD. However, the evidences of the current research are valuable to form a basis for future studies. It is determined that the SARIMA model which we used for the future foresight of emergency department admissions has been used in many researches with the similar purposes and successful results were obtained [17, 23, 33, 34]. The time intervals of our time series which are organized according to monthly average values were also suitable for the predictions [35]. In the case of season-dependent admissions, these factors should be considered for the model selections. And prevision studies are proposed to be a fast method for strategic planning, human re- sources, and resource distribution [16, 34, 35]. In our research,

### Discussion

In this research, the monthly mean values of the admissions to the Emergency Department of a hospital which are received from the individuals aged older than 15 years and who had CVD and/or RD in a total period of five years were predicted with SARIMA models for the next twelve months. Studies for the foresight of EDA demonstrated that the request of admissions due to demographical changes would increase in the future [10, 15]. It is also indicated that the global morbidity and mortality cause mostly stems from environmental problems especially the changes of the parameters about climate and air pollution influence CVD and/or RD-based EDA [18, 19]. It is found that the air pollution parameters raise the admission percentage by 0.4-8.0% and changes in temperature by 1.1-3.0% [19, 20]. Due to the complications of related diseases, in which the majority of individuals are composed of a disadvantaged group of children and elderly, it is thought that there would be a decline in the life expectancy due to discretion loss and an increase in mortality. The health expenditures, in general, are expected to be higher [20, 21]. Increased EDA in winter months can be explained by the quantity of elderly population in our time series composed of different characteristics in terms of time, place and person. In the admissions regarding to RD, behavioral risk factor such as smoking [22], besides higher vehicle emissions in the cities, often and synchronously ascending amount of pollutants in the atmosphere, meteorological parameters, and exposed allergens were reported to be the reasons of increased emergency department admissions due to asthma and respiratory allergies specifically for the atopic individuals [4, 20]. 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The time intervals of our time series which are organized according to monthly average values were also suitable for the predictions [35]. In the case of season-dependent admissions, these factors should be considered for the model selections. And prevision studies are proposed to be a fast method for strategic planning, human re- sources, and resource distribution [16, 34, 35]. In our research,
all the predictions with medium and high efficiency were made through SARIMA models that demonstrate the suitability of SARIMA models in this field.

**Conclusion**

It was determined that the mean number of admissions was affected by climate and air pollution parameters. According to 2015 estimates, seasonal features were determined in EDA, RD and CVD&R air pollution and the admissions were estimated to be the highest in January and February, whereas the mean number of admissions to the CVD which have a conjuncture structure was predicted to be the highest in April. In the estimations which yielded successful results, it was determined that the ARIMA(1,1,2)(1,0,1)12 model was the most suitable model for the EDA, and that given the disease groups, the ARIMA(2,3,5) (1,0,0)12 model was the most suitable model for RD, the ARIMA(2,1,2)(1,0,0)12 model for the CVD and the ARIMA(1,1,1) (1,0,0)12 model for the CVD&RD. SARIMA models that we used in our research were successful for the predictions of the CVD and/or RD emergency department admissions and they can be used in other previous studies for similar purposes. Predicting the changes efficiently in emergency department admissions in future gives a good database to both policymakers and health service providers to perform their strategic plans in a better way.

**Scientific Responsibility Statement**

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

**Animal and human rights statement**

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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**Conflict of interest**

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