Original Article

Modeling the time series of scorpion stings in Southwestern Iran

Rostampour, F[1], Heidari, M[2], Rashidi, H[3], Faramarzi, A[4], Shojaei, S[5], Barati, B[6], Mousavi, SA[6*]

1. *Department of Biostatistics and Epidemiology, Faculty of Medicine, Urmia University of Medical Sciences, Urmia, Iran*
2. *Social Determinants of Health Research Center, Clinical Research Institute, Urmia University of Medical Science, Urmia, Iran*
3. *Department of Epidemiology & Biostatics, Arnold School of Public Health, University of South Carolina, Colombia.*
4. *Department of Health Management and Economics, School of Public Health, Urmia, university of medical sciences, Urmia, Iran*
5. *Department of Epidemiology, School of Public Health and safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran.*
6. *Department of Public Health, Shoushtar Faculty of Medical Sciences, Shoushtar, Iran*

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ABSTRACT

Scorpion stings pose a significant public health concern in Iran, resulting in approximately 45,000-50,000 cases and 19 deaths annually. The Khuzestan and Hormozgan provinces have the highest reported incidence rates, with an estimated 36,000 cases each year. This study focused on modeling the time series data of scorpion stings, specifically in Shoushtar City, from 2017 to 2022. Our objective was to investigate the presence of seasonality and long-term trends in the incidence of scorpion stings by utilizing advanced analytical techniques, such as the Autoregressive Integrated Moving Average (ARIMA) model. We applied the seasonal ARIMA model to fit a univariate time series of scorpion sting incidence. This study revealed a significant seasonal trend and an overall increase and decrease in scorpion sting cases during the study period. The best-fitting model for the available data was a seasonal ARIMA model in the form of ARIMA(0,0,1)(1,1,1)12. This model can forecast the frequency of scorpion sting cases in Southwestern Iran over the next two years. As a result, time series analysis can provide valuable insights into the patterns and trends of scorpion sting incidents, allowing for better planning and allocation of healthcare resources. By understanding the seasonal variations, proactive measures can be implemented to address the growing issue of scorpion stings in Iran effectively.

Keywords: Scorpion stings; Time series analysis; ARIMA modeling; Box Jenkins model; Southwestern Iran

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Corresponding Author's E-Mail:
Mousaviseyedali2021@gmail.com

1. Introduction

Scorpion stings pose a significant public health challenge not only in Iran but also in neighboring countries, such as Iraq, Pakistan, Saudi Arabia, Oman, Yemen, and the United Arab Emirates (1). Iran, in particular, has one of the highest rates of scorpion stings globally, with more than 42,500 reported cases and approximately 19 annual deaths (2). Many individuals affected by scorpion stings require admission to critical care units due to irreversible cardiovascular and kidney complications (3). A total of 64 species of scorpions have been identified in Iran (distributed in 17 genera) and classified into three families: Buthidae, Hemiscorpiidae, and Scorpionidae. Androctonus, Hottentotta, Mesobuthus, Odontobuthus, and Hemiscorpius genera are dangerous scorpions to humans found in the southern part of Iran (4). Scorpions, belonging to the Arachnida class, are venomous arthropods found in all continents except Antarctica. They are of particular concern in tropical and subtropical regions (4). The stinger located at the tail's tip contains venomous substances stored in two glands, serving as a defense mechanism for scorpions (5). When a scorpion feels surprised or threatened, it may employ its stinger to inject venom into its target. There exist approximately 1,500 scorpion species worldwide; however, only around 30 of them possess stings that pose a danger to humans (1). Regions with a high likelihood of scorpion bites are inhabited by roughly two billion individuals, resulting in an estimated one million cases of scorpion envenoming globally each year (6). Research suggests that at least one million scorpion stings occur annually worldwide, leading to over 3,250 deaths (7). Studies published in the field indicate that children exhibit a higher prevalence and mortality rate (8). Scorpions, being nocturnal arthropods, present a threat to humans due to their venomous and potentially lethal stings. Scorpion-related fatalities have the highest mortality rate among poisonous arthropods worldwide (9, 10). The clinical effects of scorpion stings vary in severity and depend on factors such as the scorpion's genus and species, the timing of the sting, the frequency of stings, the amount of venom injected, and the age and health condition of the affected individual (11). The venom of a scorpion contains a complex mixture of neurotoxic proteins, salts, acidic proteins, and organic substances, which can exert various effects on the nervous system, heart, blood, and kidneys, as well as local effects, such as inflammation, discomfort, burning, and swelling (12). Fatality can occur not only due to the venom's toxic properties but also as a consequence of an allergic reaction called anaphylaxis (13). Scorpion stings have a significant impact on individuals living in underprivileged communities where access to medical resources is often limited (14). Studies conducted on scorpionism in Iran have produced several significant findings: most scorpion stings occur in rural areas during the summer season (15). The age groups most susceptible to these stings are individuals between 10-24 and 25-44 years old (16, 17). Furthermore, scorpions tend to bite the feet and hands more frequently (18). The application of time series analysis provides an alternative approach to evaluating disease management programs. By examining a time series where each observed variable depends on its preceding period, a dependable sequence is generated. This aspect assists researchers in identifying, explaining, and predicting the impacts of management programs implemented over time (19). The Middle Eastern region harbors approximately 52 species of poisonous scorpions, with a significant presence found in Iran due to its favorable geographical and climatic conditions (20). Scorpion stings and fatalities resulting from them are observed throughout the country, with approximately 75% of cases occurring in the provinces of Khuzestan, Sistan and Baluchestan, Kerman, and Hormozgan. These provinces have reported several deaths annually due to scorpion stings (21, 22). Shushtar County, located in the southwestern region of Iran, is known for its hazardous climate conditions. This study was conducted to implement preventive and targeted measures, obtain information about scorpion sting patterns, and predict its occurrence in the future.

2. Materials and Methods

This study was a descriptive cross-sectional investigation that examined a total of 3,054 documented cases of scorpion bites in Shushtar city between April 2017 and March 2022. The collected data were analyzed using statistical analysis using R Studio and Minitab software. The Box-Jenkins SARIMA model constrained the analytical approach of the study. The monthly data on scorpion sting cases were utilized for the analysis. The SARIMA model incorporates both non-seasonal and seasonal components and can be defined as SARIMA (p, d, q) (P, D, Q) s, where p, d, and q represent the orders of the non-seasonal components (23). The model includes autoregressive (AR) components, non-seasonal differencing, and non-seasonal moving average (MA) components. The orders of the AR, differencing, and MA components are denoted by P, D, and Q, respectively. Additionally, the model incorporates seasonal AR, seasonal differencing, and seasonal MA components, with the orders represented by P, D, and Q. The variable s indicates the length of the seasonal period (24). In the initial stage of this analysis, the focus is on identifying any unusual or anomalous data points in the series. The aim is to work with stationary data over time, examining both the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF). When the time diagram displays data points scattered around a constant mean, and the ACF and PACF values decrease rapidly close to zero, it indicates stationarity. However, if this rapid decrease is not observed, the nonstationary stage can be potentially resolved through differentiation (25, 26). The ACF is a widely used tool for analyzing time series data in academic research. It enables researchers to identify patterns, such as seasonality, cycles, and other recurring features in a dataset. Moreover, the ACF offers valuable information regarding the relationship between current observations and previous periods, which helps researchers gain a better understanding of the sequential nature of the data (26). Using the available data, a model was developed and constructed. The selection of the best-fit model was determined by considering criteria such as the smallest Akaike information criterion (AIC) and satisfying the conditions for residuals (27). Subsequently, this model was utilized to forecast the number of scorpion sting cases for the period between April 2023 and March 2024.

3. Results

Time series analysis was performed using the monthly distribution of scorpion sting cases throughout the study period. The lowest and highest numbers of recorded scorpion sting cases were 7 (in January 2021) and 128 (in August 2022), respectively. The cases of scorpion stings exhibited an increase from March to August, coinciding with the onset of the hot season in the southern region of Iran, followed by a decrease from September to January. The observed data is presented in figure 2. The trend of scorpion sting occurrences showed an upward trajectory from 2017 to 2018, followed by a decline until 2021. However, it started rising again as of the year 2022. The incidence rate per 100,000 population showed a similar trend, and the study's average incidence rate was determined to be 366.85 cases. Figure 3 illustrates the decomposition of the data, indicating the presence of a discernible trend. This trend is further evident in figure 3-B. Additionally, figure 3-C depicts the occurrence of seasonal fluctuations within the data series. In figure 3-D, the residuals of the time series are displayed after eliminating both the trends and seasonal changes. Notably, this section of the graph does not exhibit any distinct patterns in the data. Initially, the variability in variance was examined utilizing the Box-Cox test. The findings suggested a lack of indications regarding instability in the variance of the series. Notably, both the lower confidence limit (CL) and upper CL encompass a value of one. This observation implies that the dispersion of data remains consistent over time, thereby substantiating the assertion that the series exhibits stationarity concerning variance. Several methods were used to evaluate whether the data exhibited stationarity in its mean. Initially, a time series chart was utilized to visualize any upward or downward trends in the data. Additionally, the ACF and PACF plots were analyzed (Figure 5). The ACF plot indicated that the correlation did not tend to approach zero over time. It also revealed that the correlation became insignificant after the third lag. These observations suggest that there is instability in the mean of the data. This notion was further supported by the results of the KPSS test (P=0.02). To address this issue, the differentiation method was applied. It was discovered that applying seasonal differentiation had a more significant impact in reducing the observed mean instability in the series. To establish initial parameters for constructing the Box-Jenkins model, autocorrelation and partial autocorrelation plots were examined after applying seasonal differencing. The ARIMA(0,0,1)(1,1,1)12 model, determined as the most appropriate fit using auto ARIMA, was implemented. Notably, all parameters in table 1 were found to be statistically significant.

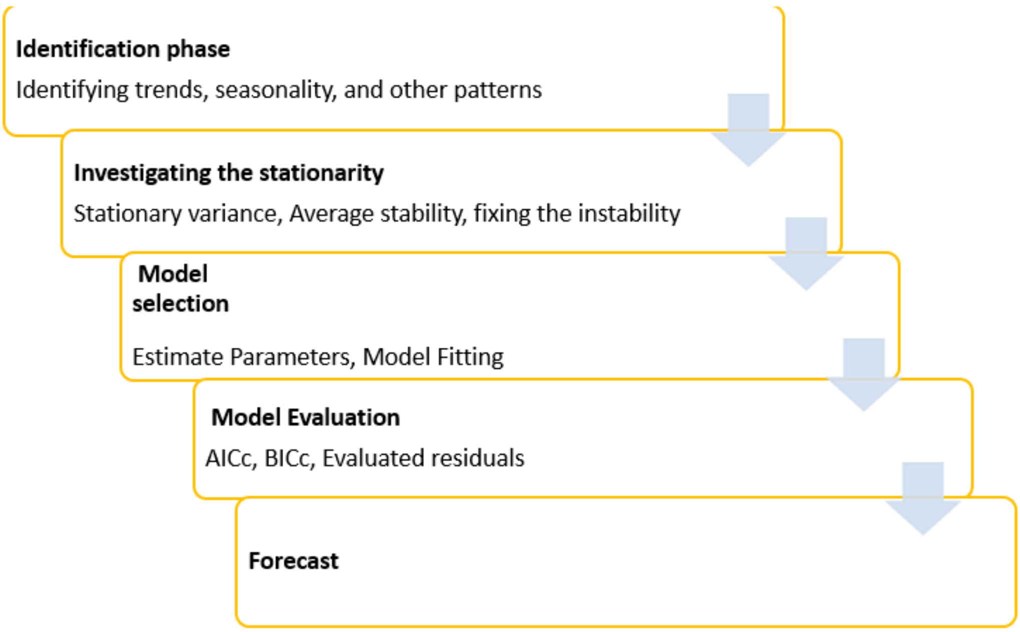

Figure 1: Steps of time series analysis

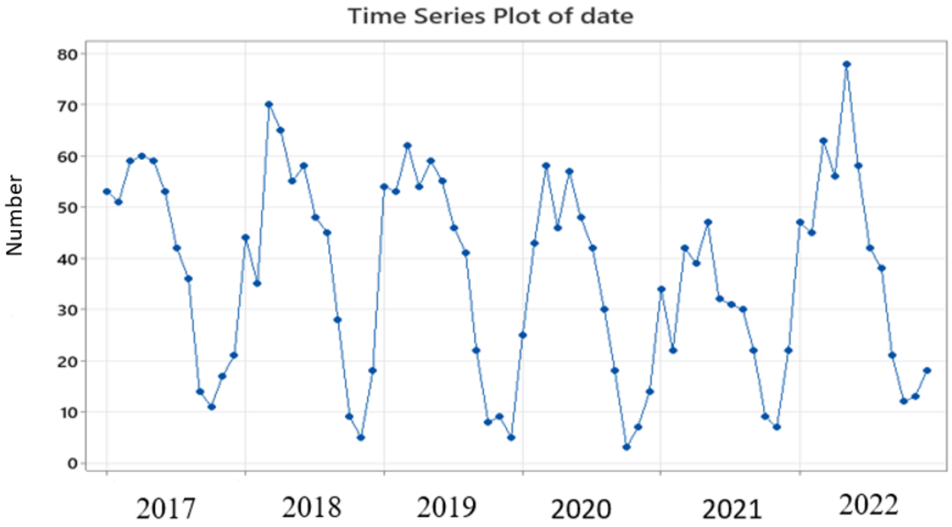

Figure 2. Time series curve of scorpion sting cases

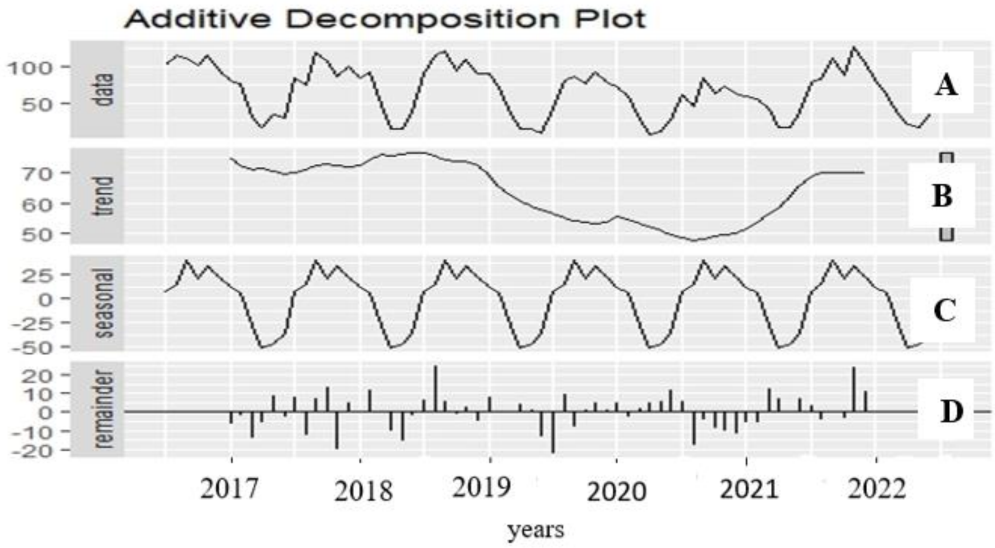

Figure 3. Decomposition of scorpion sting cases time series components: trend, seasonality, and residuals

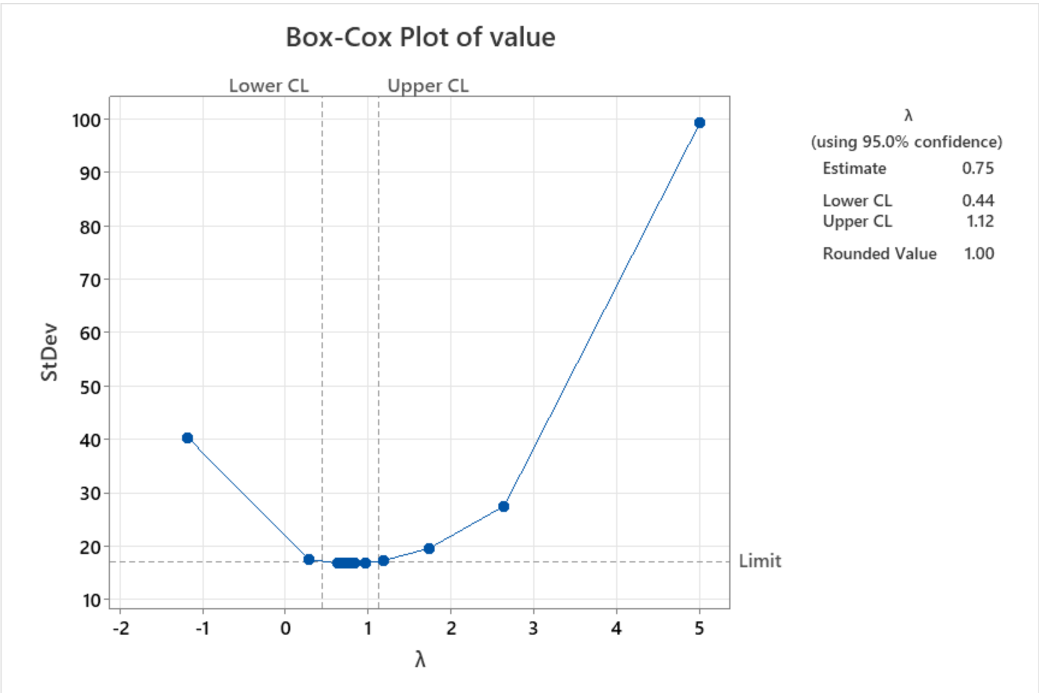

Figure 4. Box-Cox test of scorpion sting cases

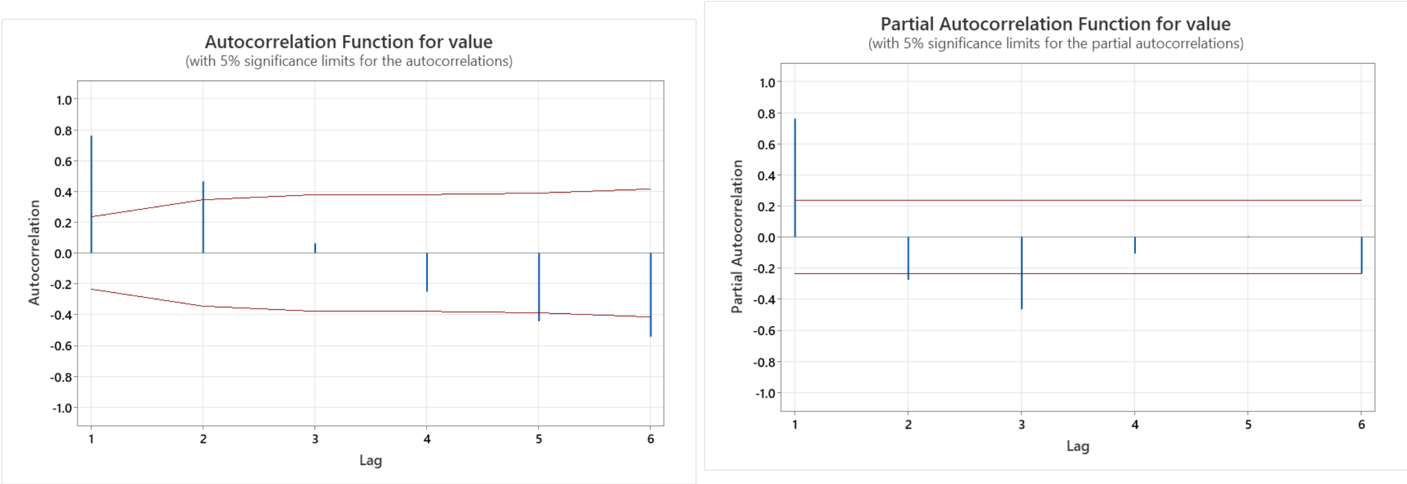

Figure 5. Plot of autocorrelation (ACF) and partial autocorrelation functions (PACF) for scorpion sting cases

Table 1. Final Estimates of Parameters

Type	Coef	SE Coef	T-Value	P-Value
SAR 12	-0.708	0.144	-4.93	0.000
MA 1	-0.482	0.134	-3.59	0.001
SMA 12	0.830	0.152	5.46	0.000
Constant	5.654	0.821	6.89	0.000

Based on the examination of ACF and PACF plots, it was determined that none of the lag values were statistically significant. This finding suggested that there was no autocorrelation evident in the residuals (Figure 6). The assessment of the assumptions of the chosen model was based on figure 7. In the A plot, the residuals appear to align closely with the reference line, indicating their normal distribution. This observation was further validated by conducting the Kolmogorov-Smirnov test (*P*=0.150), supporting the normality assumption of the residuals. Additionally, the time plot D demonstrates a random distribution of the residuals without any discernible pattern, providing further evidence for the assumption of random residuals. Finally, figure B illustrates the stability of the residuals' variance, indicating that the assumption of constant variance holds. The selected ARIMA(0,0,1)(1,1,1)model was used to anticipate monthly scorpion sting cases for the next 12 months (the year 2023). Based on the predicted scorpion sting cases, the number of events will increase compared to the past, and the seasonal trend can also be seen in the period (Figure 8).

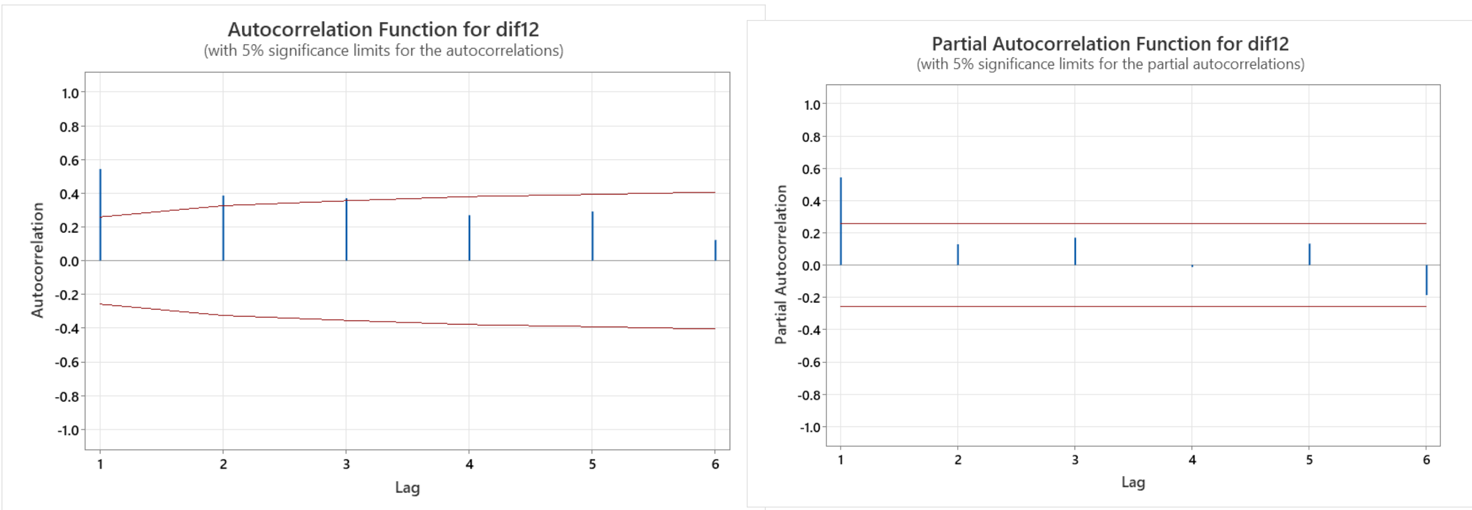

Figure 6. Plot of autocorrelation (ACF) and partial autocorrelation (PACF) of residuals for scorpion sting data set

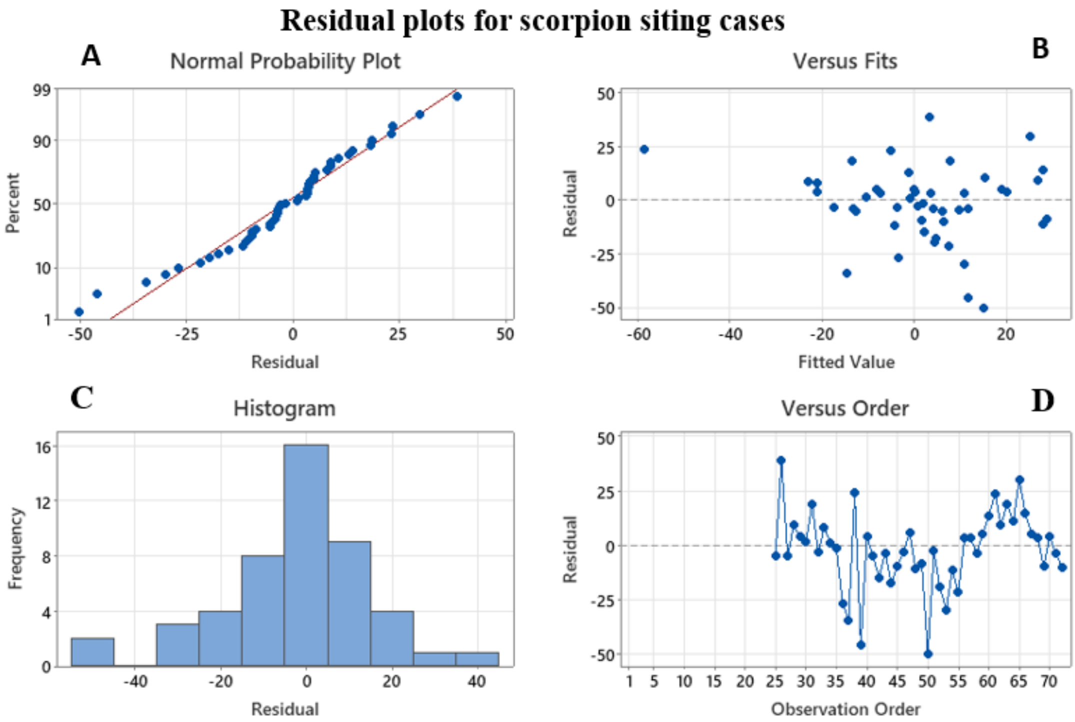

Figure 7. Plot of residual normal probability plot (A), versus fitted values (B), histogram of residuals (C), and plot of residual versus ordered (D) times for scorpion sting cases

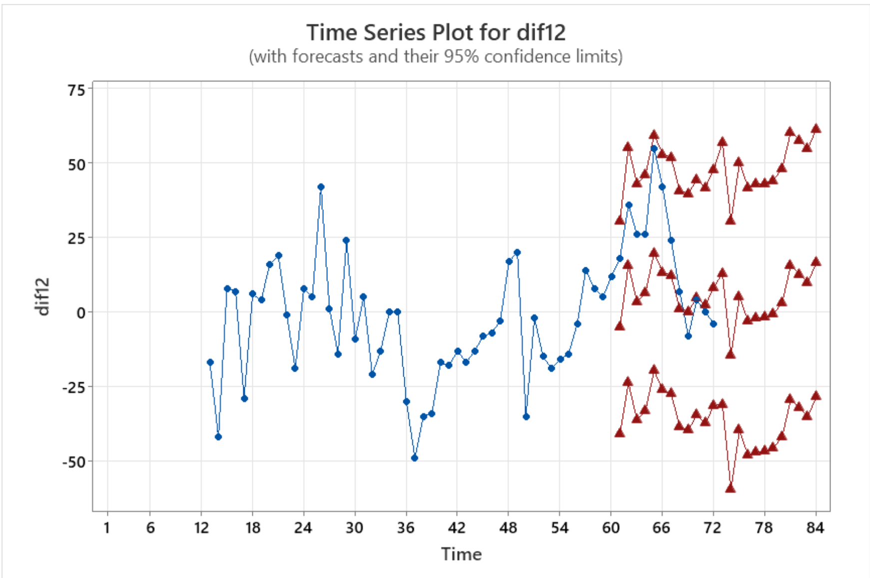

Figure 8. Prediction of scorpion sting cases based on ARIMA (0,0,1) (1,1,1)12 for the next 12 months.

4. Discussion

The occurrence of scorpion stings has demonstrated a noticeable trend over the years. From 2017 to 2018, there was a rise in the number of scorpion sting cases, followed by a decline until 2021. However, starting in 2022, there has been a resurgence in the frequency of cases. Unfortunately, limited research has addressed this temporal pattern of scorpion stings and has mainly focused on average incidence rates. In a study by Khatony, the incidence of scorpion stings showed an increase during the years 2008 and 2009 (28). The results of a study by Mousous showed that the average incidence rate of scorpion stings between 2014 and 2018 was high. However, there was a gradual decrease in the incidence rate over this period (29). Ghorban reported that the annual trend of scorpion sting cases in Khuzestan province experienced a decrease from 2010 to 2015. In Aghajari County, southwestern Iran, the average incidence rate of scorpion stings was 7.67 per 1,000 people. From 2012 to 2014, there was a decrease in the number of reported cases. However, starting in 2015, the trend reversed, and the incidence rate of scorpion stings began to increase again (30). In a study conducted by Kassiri in Khorramshahr County, it was observed that the number of cases initially increased during the first year of the study. However, after 2014, there was a significant decrease in the number of cases. Subsequently, from the beginning of 2017, there has been a rise in the number of cases once again (31). In this study, the average incidence rate was determined to be 366.85 per 100,000 population. The average incidence rate of scorpion stinging in a study by Mousavi from 2014 until 2018 was 579.55 per 100,000 (29). In Masjed Soleiman City, the incidence rates were even higher, with 1,850 cases per 100,000 individuals (31). The observed pattern of scorpion sting cases, characterized by an initial increase, followed by a decrease and subsequent rise, implies that various factors influence the population dynamics of scorpions and their interactions with humans. One possibility is that changes in environmental conditions favor scorpion populations, such as an increased abundance of food sources or suitable habitats. Additionally, human activities and urbanization may have encroached upon scorpion habitats, leading to more frequent encounters between scorpions and humans (32). The decline in scorpion sting cases after 2021 can be attributed to a range of factors. One possible reason is the implementation of awareness campaigns and proactive measures to promote scorpion safety during this period. Additionally, environmental conditions like alterations in temperature and rainfall patterns might have played a role in modifying scorpion behavior, resulting in fewer interactions with humans. However, the increase in scorpion sting incidents beginning in 2022 suggests that the earlier preventive measures may not have been maintained or proven effective over the long run. This resurgence could also indicate a shift in the underlying factors influencing scorpion populations and their engagements with humans. Scorpion sting cases in the southern region of Iran tend to increase between March and August, which corresponds to the hot season. Conversely, there is a decrease in cases from September to January. The majority of scorpion stings occur during the spring and summer months, reflecting the natural behavior and life cycle of scorpions, as they are more active and visible during warmer periods. The results of research by Ghorbani confirm these findings, stating that scorpion stings are most prevalent in the spring and summer, while winter sees the lowest occurrence. A separate study conducted in the tropical zone of south Iran discovered that the frequency of scorpion stings was higher during the hot and humid months (33). Similarly, a study examined scorpion sting trends over 51 months from May 2012 to July 2016 in Haji-Abad, south Iran, and revealed an increased incidence of scorpion stings during the hot and humid months (34). In Saudi Arabia, the highest incidence of scorpion stings was observed from May to October, with the peak occurring in June, while the lowest incidence was recorded during winter. Other countries reported the highest incidence of scorpion stings between April and July in Mexico and from July to September in Tunisia (35). It is also important to note that the observed pattern of scorpion sting cases and the factors influencing them may be specific to the region under consideration. Different regions may have unique ecological conditions, scorpion species, and human behaviors that contribute to variations in scorpion sting patterns. Therefore, local studies and context-specific interventions are necessary to effectively address the issue.

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Authors' Contribution
Study concept and design: RP F, M SA.
Acquisition of data: R H.
Analysis and interpretation of data: RP F, H M.
Drafting of the manuscript: M SA, RP F, F A, K M.
Critical revision of the manuscript for important intellectual content: F R, M SA.
Statistical analysis: RP F, H M.
Study supervision: M SA, H M.

Ethics
The present research was supported and approved by the Shoushtar Faculty of Medical Sciences (IR.SHOUSHTAR.REC.1398.006).

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

Data Availability
The data that support the findings of this study are available on request from the corresponding author.

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