Journal of Biostatistics and Epidemiology

J Biostat Epidemiol. 2023;9(3):298-311

Original Article

The Pattern of Motorcyclists' Death Due to Accidents and a Three-year Forecast in East Azerbaijan Province, Iran: A Time Series Study

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ARTICLE INFO

Received 05.02.2023
Revised 23.02.2023
Accepted 27.03.2023
Published 15.09.2023

Key words:
Accident;
Traffic accident;
Injury;
Motorcycle;
Epidemiology;
Time series.

ABSTRACT

Introduction: In low- and middle-income countries, a large proportion of road users include pedestrians, cyclists, and motorcyclists, and nearly half of road traffic fatalities occur among motorcyclists. This study aimed to examine the pattern of motorcyclists' death due to accidents in East Azerbaijan, Iran between 2006 and 2021 and present a forecast.

Methods: We used death data due to motorcycle accidents of Legal Medicine Department between 2006 and 2021. For time series analysis, the Box-Jenkins model was used and three stages of identification, estimation, and diagnosis were successively performed and repeated several times to achieve the best prediction model. The Box-cox transformation method was used to stabilize the variance, and the first-order seasonal differential method with a period of 12 was used to control the seasonality. Due to seasonal variations, the Seasonality Auto-Regressive Integrated Moving Average model: SARIMA (p, d, q) (P, D, Q)s was employed and the death trend was predicted for 36 months. The candidate models were compared based on Log-likelihood, AIC, and BIC indices. STATA 17 was used for data analysis.

Results: About 18.6% of all accident deaths are attributed to motorcycle accidents. The death rate for all causes of accidents and motorcycle accidents were 23.13 and 4.30 per 100,000 population, respectively. Seven models were considered as candidates. The SARIMA (0, 0, 0) (1, 1, 1)12 model was selected as the best model due to better fit and used to predict the number and trend of motorcycle accident deaths. Motorcycle accident deaths are predicted to decrease gradually in the next 36 months, from June 2021 to May 2024, affected by seasonal changes.

Conclusion: The trend of death due to motorcycle accidents from 2006 to 2021 in East Azerbaijan was declining, and it is predicted to decrease slightly in the next three years as well. As this reduction may be attributed to many factors, it is recommended to investigate effective factors in future studies.

Introduction

Traffic accidents are a major cause of fatalities across the globe. Currently, traffic accidents rank as the eighth leading cause of death for all age groups, but experts predict that by 2030,

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they will become the seventh cause of death. Traffic accidents are especially prevalent among young people globally, with those aged 15 to 29 years being the most affected. The number of fatalities due to road accidents keeps increasing, from 1.15 million in 2000 to 1.35 million in 2016.[1] Daily, over 3,700 people lose their lives to road accidents while tens of millions are left injured or disabled annually, with long-term effects. These accidents also result in high costs for emergency response and healthcare, not to mention human suffering. Families and communities bear a significant economic burden due to these injuries.[2]

Compared to high-income countries, in low- and middle-income countries, a much larger proportion of road users, include pedestrians, cyclists, and motorcyclists, and nearly half of road traffic fatalities occur among motorcyclists.[3] Injuries caused by motorcycle accidents are a major public health problem in the Eastern Mediterranean region (EMRO), including Iran; according to the World Health Organization (WHO) report, 24% of deaths due to road traffic accidents in Iran are due to motorcycle accidents, while this figure is 15% in the entire EMRO.[2] As a result, Iran's share of deaths due to motorcycle accidents is much higher than the average of the EMRO. Although the death rate due to road traffic accidents in Iran has decreased in recent years, it is still very high.[2] It is, therefore, recommended that traffic injuries be considered a serious public health priority in Iran.[4]

Considering the widespread use of motorcycles in Iran,[2] the high mortality and disability caused by motorcycle accidents in this country, and the risk of mortality when traveling by motorcycle is 20 times higher than other vehicles,[5] planning and quick intervention are required in Iran. Considering that motorcycle accidents and related injuries in the northwest of Iran also account for a significant share of all accidents and are one of the major public health problems in the region, and considering that the Integrated Road Traffic Injuries Registry (IRTIR) is active in East Azerbaijan and high-quality data about traffic accidents and injuries are recorded in the best way and are available for different years, it is necessary and applicable to investigate related accidents in the region.[4] To carry out precise planning and administer effective interventions, it is necessary to study the trend of mortality from motorcycle accidents and estimate the future trend. Therefore, this study was conducted to examine the pattern of motorcyclists' death due to accidents in East Azerbaijan Province between 2006 and 2021 and present a forecast.

Methods

This is a cross-sectional study with time-series analysis. The data on death due to motorcycle accidents for 15 years, from March 2006 to May 2021, were retrieved from the Legal Medicine Department of East Azerbaijan Province. First, the quality of the data was checked. Due to the existence of many gaps in daily time, monthly time was used.

The Box-Jenkins model was used for time series analysis and three stages of identification, estimation, and diagnosis consecutively passed. To achieve the best prediction model, these steps were repeated several times.

Linear graphs, autocorrelation function (ACF), and partial autocorrelation function (PACF) were used to check data stationarity. Considering the changes of variance over time and the existence of seasonality, the

Box-cox transformation method was used to stabilize the variance, and the first-order seasonal differential method with a period of 12 was used to control the seasonality. The ACF diagram was used to identify q and Q parameters, and the PACF diagram was used to identify p and P parameters. Due to seasonal variations, the Seasonality Auto-Regressive Integrated Moving Average model: SARIMA (p, d, q) (P, D, Q)s was employed, where p, d, and q represent auto-regressive, integration, and moving average in the non-seasonal part, respectively, and P, D, and Q denote auto-regressive, integration, and moving average in the seasonal part; s also indicates period of seasonality. By using the above parameters, several models were considered as candidates, and by using the goodness of fit indices of Log-likelihood, Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Sigma coefficient, and the significance of Auto-Regressive (AR), Moving Average (MA), and Constant, the best model was selected and run. By checking the conditions of the residuals being white noise using the graph of the residuals and portmanteau test, stability of AR parameters, and invertibility of MA parameters, the final model was selected and forecasts were made.

Finally, the number of deaths from motorcycle accidents and its trend from June 2021 to May 2024 was predicted for 36 months.

All the calculations were performed in STATA 17.

Results

From March 2006 to May 2021 (15 years and two months), 13,715 deaths due to accidents occurred in East Azerbaijan Province, of which 2,553 cases (18.6%) were deaths due to motorcycle accidents. The death rate for all causes of death from accidents during the 15 years was 23.13 per 100,000 person-years for East Azerbaijan Province, which decreased to 19.49 per 100,000 person-years with a downward trend in the last year of the study (2021). The death rate for motorcycle accidents was 4.30 per 100,000 person-years, which also decreased to 3.22 per 100,000 person-years in 2021. The highest number of deaths occurred in 2006 with 254 people (9.9%), 2007 with 249 people (9.8%), and 2008 with 244 people (9.6%), respectively, while the lowest mortality rate occurred in 2016 with 110 people (4.3 %), 2014 with 121 people (4.7%), and 2020 with 126 people (4.9%), showing a downward trend with a slight slope. The most deaths occurred in September with 350 people (13.7%), July with 342 people (13.4%), and August with 328 people (12.8%), and the lowest was in January with 67 people (2.6%), February with 70 people (2.7%), and December with 84 people (3.0%).

According to the findings, in the study period from March 2006 to May 2021 in East Azerbaijan province, the average age of death resulting from motorcycle accidents was 33.38 years with a standard deviation of 16.18. Men accounted for the majority of the deaths (96.4%) during the study period. Most of the fatalities (70.9%) were people with education levels below the 7th grade, while only 1.3% of deaths occurred among individuals with university education. Head injury was the leading cause of death (70.8%), and motorcycle riders accounted for most of the deaths (82.3%). The Baseline characteristics of participants are demonstrated in Table 1.

After adjusting the data for time series analysis, first, the data graph was plotted to check the

Table 1. Baseline characteristics of participants

Qualitative Variable		Frequency	Percent
Gender	Male	2462	96.4
	Female	91	3.6
Education (years)	<7	1791	70.9
	7-12	615	24.3
	university student	89	3.5
	12<	32	1.3
Cause of death	Head trauma	1807	70.8
	Multiple fractures	234	9.2
	Hemorrhage	146	5.7
	combination of different causes	303	11.9
Place of death	Hospital	1355	53.1
	Accident scene	939	36.8
	Hospital way	235	9.2
Role	Rider	2101	82.3
	Pillion passenger	434	17.0
	Pedestrian	5	0.2
Quantitative Variable		Mean	SD
Age		33.38	16.18

stationarity of the data (Figure 1a). Due to the non-stationary nature of the data, the Box-cox method was used to stabilize the variance (Figure 1b). To control the seasonality, the first-order seasonal differential method with a period of 12 was employed (Figure 1c). Due to the stabilization of the data after fixing the variance and seasonality, there was no need to modify the average. Therefore, parameter d was 0, and parameter D was 1 (Figure 1).

After the data being stationary, the ACF diagram was used to obtain q and Q parameters (Figure 2a) and the PACF diagram was used to obtain p and P parameters (Figure 2b). Based on the ACF diagram, for the initial model, q was 0 and Q was 1. Moreover, based on the PACF diagram, p was 0 and P was 1 for the initial model. Therefore, model A: SARIMA (0, 0, 0) (1, 1, 1)12 was selected as the initial model (Figure 2).

Models B to G were also considered as candidates. All the models were run and compared based on Log-likelihood, AIC, and BIC indices, and the best model was selected (Table 2). Based on these indices, any model that has a higher Log likelihood or lower AIC, BIC, and Sigma is the best.[6] After comparing the models based on the mentioned indicators, model F was selected as the best model, and models A and B were selected as the next models (Table 2).

Then, model F was run and the necessary conditions for forecast in this model were checked. To this end, the graph of the residuals of this model was plotted to check whether the residuals were white noise (Figure 3a). The portmanteau test was also used to complete this step. The results of the residuals' graph and the Portmanteau test (P=0.125) showed that the residuals of the model F were white noise, and the first condition for this model was satisfied.

Then, the second and third conditions for this model were checked. The second condition, which is the stability of the estimated process of

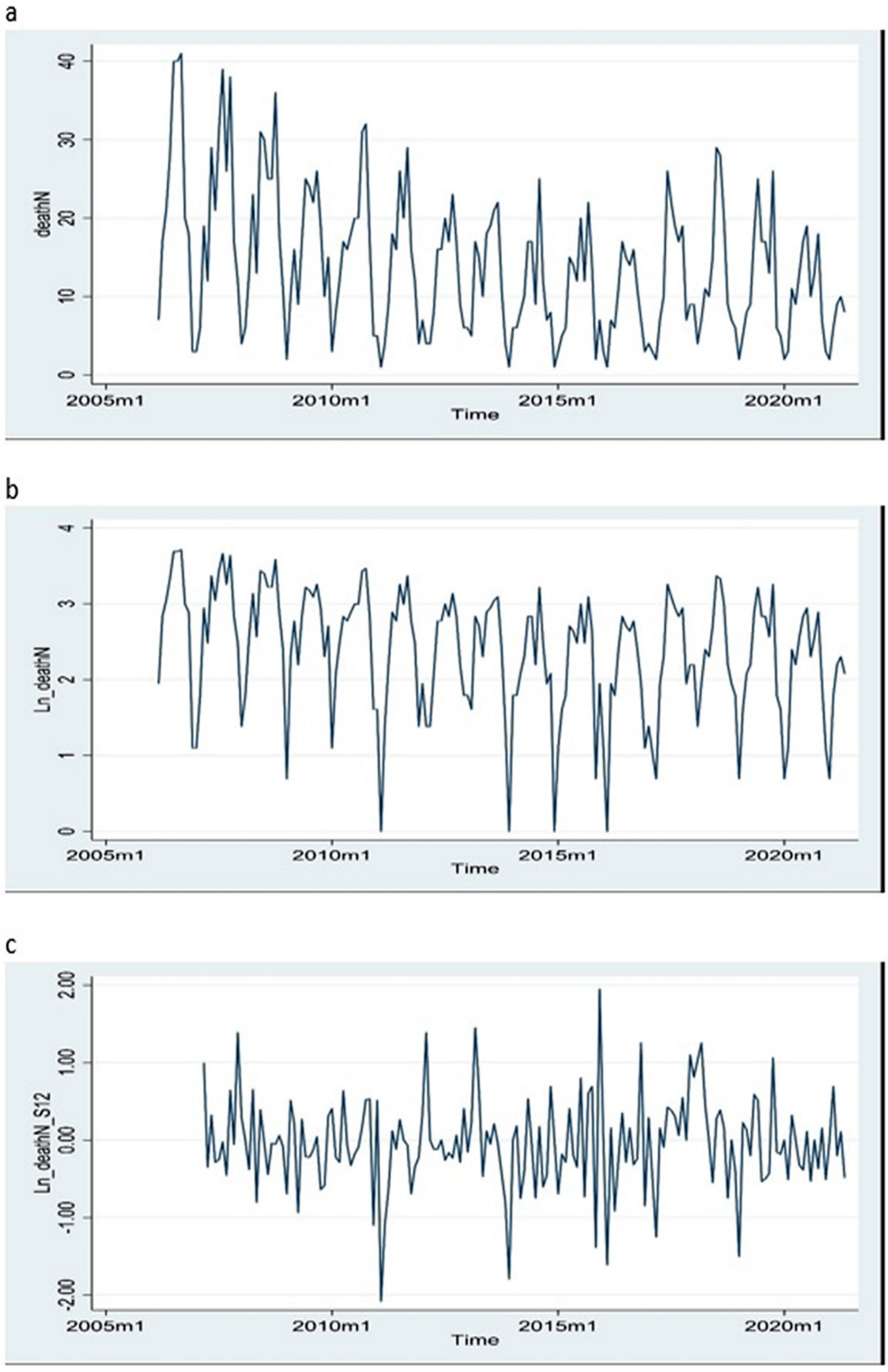

Figure 1. a) Trend of death due to motorcycle accidents in East Azerbaijan; b) Ln-deathN for making variance stationary: c) First order seasonal difference for Ln_deathN in order to omit seasonal effect

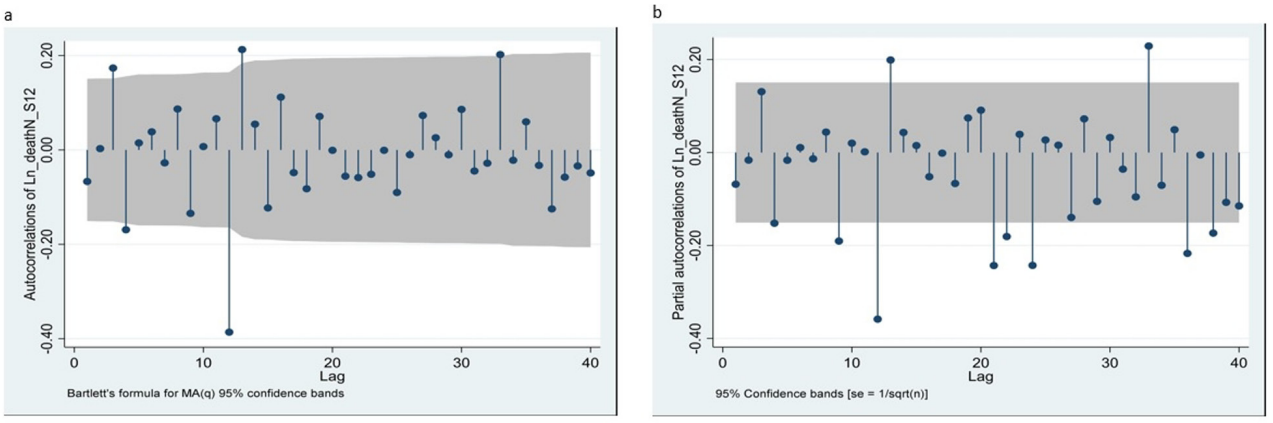

Figure 2. a) ACF for first order seasonal difference (S12) for Ln_deathN; b) PACF for first order seasonal difference (S12) for Ln_deathN

Table 2. Candidate models with their goodness of fit criteria

Criteria / Model	Log likelihood	AIC	BIC	Sigma coefficient	C, AR, MA
Model A: SARIMA (0, 0, 0) (1, 1, 1)12	-527.6506	1063.301	1075.821	5.3758	2/3
Model B: SARIMA (0, 0, 0) (2, 1, 1)12	-526.2419	1062.484	1078.133	5.2285	4/4
Model C: SARIMA (0, 0, 0) (3, 1, 1)12	-526.1883	1064.377	1083.156	5.1799	2/5
Model D: SARIMA (1, 0, 0) (1, 1, 1)12	-526.9416	1063.883	1079.533	5.3205	2/4
Model E: SARIMA (1, 0, 0) (2, 1, 1)12	-525.6502	1063.3	1082.08	5.1831	3/5
Model F: SARIMA (1, 0, 1) (2, 1, 1)12	-523.8907	1061.781	1083.691	4.3187	3/6
Model G: SARIMA (1, 0, 1) (1, 1, 1)12	-526.7786	1065.557	1084.337	5.3108	3/5
Best Models due to each criterion	F	F	A	F	B
selected Model	Model F: SARIMA (1, 0, 1) (2, 1, 1)12				

SARIMA, Seasonality auto-regressive integrated moving average; AIC, Akaike information criterion; BIC, Bayesian information criterion; AR, Auto-regressive; MA, Moving average; C, Constant.

AR, i.e., checking the placements of the roots of AR inside the unit circle, was established; however, the third condition, which is the invertibility of the estimated process of MA, i.e., checking the placement of the roots of MAs inside the unit circle, was not established (Figure 3b). Therefore, model F was not used to predict the number and trend of death due to motorcycle accidents. Therefore, the above conditions were checked for model A.

The previous steps were repeated for model A and the necessary conditions for prediction in this model were checked. The graph of the residuals of this model was plotted to check

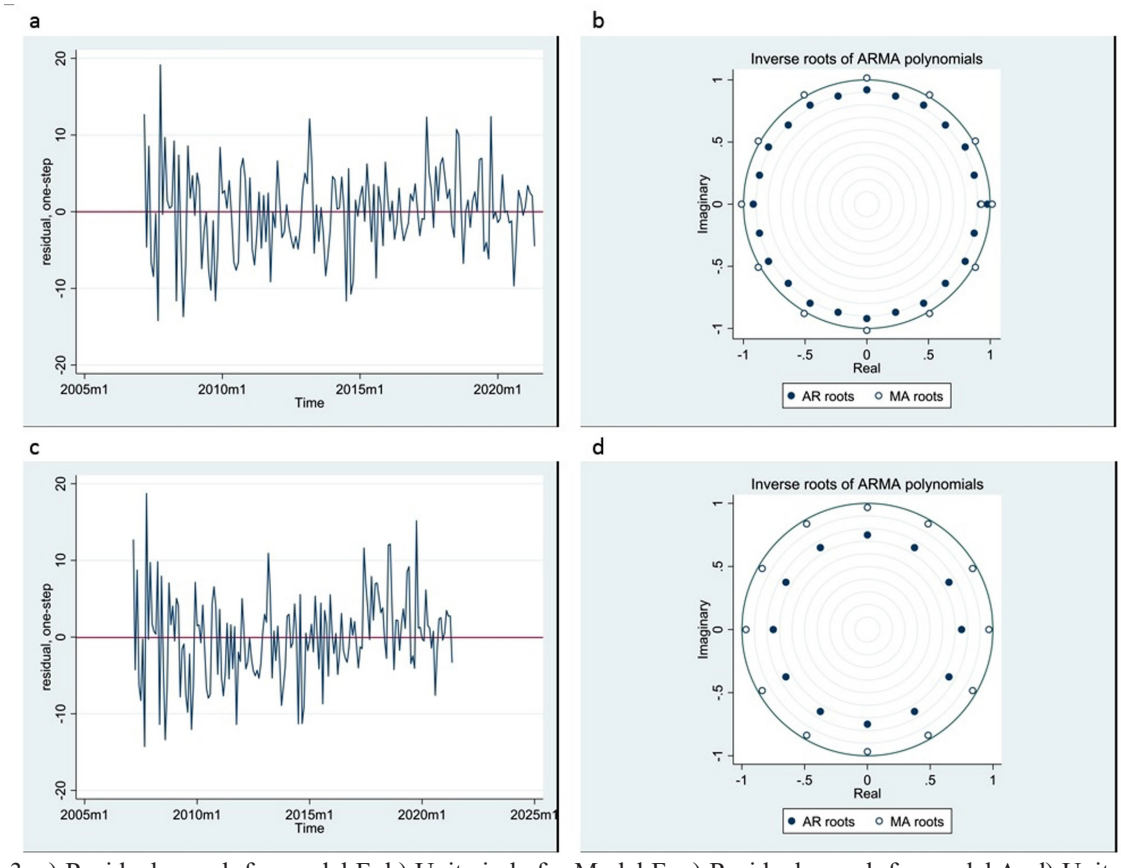

Figure 3. a) Residuals graph for model F; b) Unit circle for Model F; c) Residuals graph for model A; d) Unit circle for Model A

whether the residuals were white noise (Figure 3c), and the Portmanteau test was run to complete this step. The results of the residuals' graph and portmanteau test (P=0.154) showed that the residuals of model A were white noise, and the first condition for this model was fulfilled (Figure 3).

Next, the second and third conditions for this model were checked. Both the second and third conditions were met for model A (Figure 3d); therefore, model A was used to predict the number and trend of death due to motorcycle accidents. The predicted trend of the number of deaths due to motorcycle accidents from June 2021 to May 2024 for 36 months is depicted in Figure 4 which is decreasing with a slight slope, along with seasonal changes. The forecasted numbers of deaths for each month and their associated 95% confidence intervals are shown in Table 3.

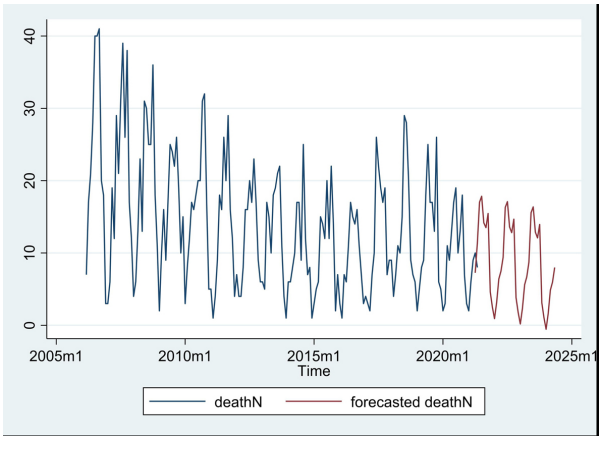

Figure 4. Forecasted Death number and its trend due to motorcycle accidents in East Azerbaijan

Table 3. Forecasted death numbers with 95% confidence intervals for 36 months

Forecasting time		Forecasted death number	95% confidence interval for forecasted death number	
Year	Month		Lower bound	Upper bound
2021	6	17.008	11.118	22.475
2021	7	17.84	12.049	23.406
2021	8	14.171	8.501	19.858
2021	9	13.504	7.951	19.308
2021	10	15.458	9.521	20.878
2021	11	4.627	-1.116	10.241
2021	12	2.501	-3.294	8.064
2022	1	0.924	-4.82	6.537
2022	2	3.174	-2.651	8.985
2022	3	6.392	0.519	11.876
2022	4	7.487	1.72	13.077
2022	5	9.383	3.638	14.995
2022	6	16.302	10.493	21.85
2022	7	17.098	11.337	22.694
2022	8	13.596	8.013	19.37
2022	9	12.814	7.249	18.606
2022	10	14.672	8.785	20.142
2022	11	3.846	-1.901	9.456
2022	12	1.78	-3.972	7.385
2023	1	0.184	-5.542	5.815
2023	2	2.379	-3.403	8.088
2023	3	5.604	-0.239	11.118
2023	4	6.702	0.935	12.292
2023	5	8.721	3.036	14.393
2023	6	15.574	9.808	21.165
2023	7	16.368	10.637	21.994
2023	8	12.872	7.267	18.624
2023	9	12.086	6.492	17.849
2023	10	13.941	8.12	19.477
2023	11	3.115	-2.608	8.749
2023	12	1.051	-4.674	6.683
2024	1	-0.545	-6.253	5.104
2024	2	1.648	-4.085	7.337
2024	3	4.873	-0.917	10.44
2024	4	5.971	0.234	11.591
2024	5	7.994	2.317	13.674

Discussion

This study was conducted to examine the trend of death due to motorcycle accidents in East Azerbaijan Province between 2006 and 2021 using legal medicine data. The study found that the death rate due to all causes of accidents and motorcycle accidents was relatively high. Despite this, there was a decreasing trend in motorcycle accident deaths throughout the study period. This trend is expected to continue over the next three years, with seasonal variations.

Descriptive Findings

This study was conducted to examine the trend of death due to motorcycle accidents in East Azerbaijan Province between 2006 and 2021 using legal medicine data. The death rate from all causes of accidents was 23.13 per 100,000 person-years. This rate was 25.1 per 100,000 person-years in the study by Sadeghi-Bazargani (4) and ranged from 23.15 to 26.28 per 100,000 person-years from 2012 to 2016 in the study by Jafari-Khounigh et al., which was conducted using the data of the health center.[7] In the World Health Organization (WHO) report, this rate is estimated at 20.5 per 100,000 person-years for Iran.[2] Although the death rate from all causes of accidents in the current study was higher than the World Health Organization's estimate, with a decreasing trend, it reached 19.49 per 100,000 person-years in 2021, which was slightly lower than the WHO's estimate for Iran. Contrary to the results of the present study, the death rate from traffic accidents in a study conducted in Ilam (Iran) increased from 22.06 in 2009 to 43.23 in 2013, a rise almost twofold in five years.[8] The death rate from motorcycle accidents in the current study was 4.30 per 100,000 person-years, which was reduced to 3.22 per 100,000 person-years in 2021. This rate was 4.9 per 100,000 person-years in Sadeghi-Bazargani's study, which had a downward trend like the present study.[4]

The share of deaths from motorcycle accidents in East Azerbaijan Province in the present study was 18.6% of the total death due to accidents in the studied period, which was less than the share for Iran in the WHO's report (24%).[2]

In the study by Sadeghi-Bazargani in East Azerbaijan province from 2006 to 2016, the share of deaths caused by motorcycle accidents to the total deaths due to accidents was 19.5%, which was slightly more than that of the present study.[4] In Erenler's study in Turkiye from 2013 to 2017, the share of death due to motorcycle accidents to the total deaths from accidents was 19.6%.[9]

Of those who died due to motorcycle accidents 96.4% were men and only 3.6% were women. In another study conducted in East Azerbaijan, 3.5% of deaths due to motorcycle accidents occurred in women.[4] In studies conducted in the hospitals of Tehran and Mazandaran Provinces (Iran), 6.66% and 6.7% of these deaths occurred in women, respectively.[10, 11] Moreover, in the study of Hefny et al. in the United Arab Emirates, 2.1% of deaths occurred in women[12] and in Alicioglu's study, 3.8% of motorcycle accident victims were women.[13] Although in most studies the share of women in death due to all accidents is significantly lower than that of men, compared to their share in deaths due to motorcycle accidents, this value is much higher; based on most studies, the share of women in deaths due to all accidents varies from about 20% to 30%.[7, 9, 14, 15] This can be attributed to the less usage of motorcycles by

women, especially in Iran, and thus, their fewer motorcycle accidents and deaths than men.

The average age of motorcycle accident victims in the present study was 33.38 years. This average age was 32.3 years in Sadeghi-Bazargani's study and 29.8 years in Hefny's study.[4, 12] The average age of victims of all accidents varied between 39.5 and 41.5 years in different studies.[7, 14, 15] Therefore, the average age of those who died due to motorcycle accidents is about 3-5 years lower than the average for all accidents. This can be ascribed to the greater use of motorcycles in Iran by young people due to reasons such as their greater interest in motorcycles or not affording cars.

More than 70% of deaths due to motorcycle accidents occurred in people with less than seven grades of education, and only 1.2% of the deceased had a university education. In the study of Sadeghi-Bazargani et al., 70.3% of deaths due to motorcycle accidents occurred in illiterate people, or people with elementary and junior high education, and 5% in people with university education.[4]

The cause of death in the present study was head trauma in 70.8% of cases. In a study conducted in Mazandaran, the cause of death was head trauma in 50.6% of cases.[10] In other studies, the first cause of death from motorcycle accidents[4, 11] and deaths due to all accidents[14, 16] was also head trauma.

In this study, 2101 (82.3%) of all deaths were the main motorcycle riders and 434 people (17.0%) were pillion passengers. In another study conducted in East Azerbaijan, 82.6%,[4] in Mazandaran 84.2%,[10] and in Tehran 92%[11] were the main motorcycle riders and the rest were pillion passengers. In a study conducted in Thailand, 75.5% of all motorcycle accident deaths occurred in the main riders and 16.3% in the pillion passengers.[17]

The highest number of deaths due to motorcycle accidents occurred in the summer (39.9%), which is consistent with most studies.[7, 9, 16] This can be attributed to the increase in the use of motorcycles in the summer as it is warmer.

Time Series Findings

The results demonstrated a declining trend in deaths due to motorcycle accidents in East Azerbaijan Province from 2006 to 2021, as well as a decreasing trend projected for the next three years. Not surprisingly, there were fluctuations in this overall downward trend; in 2017 and 2018, there was a slight increase in deaths from motorcycle accidents compared to previous years, and then it returned to its downward trend. One reason for the decrease in accidents in the last two years along with prevention programs, may be the decline in travel numbers because of the Covid-19 pandemic and the resulting restrictions.[18] In most of the studies on the trend of deaths from accidents in Iran, a decreasing trend in the number of deaths has been observed in recent years.[19-22] In some countries, the trend of deaths from accidents is decreasing,[23] and in some other countries, increasing;[24, 25] therefore, not all countries have managed to decrease the trend of death due to accidents. It seems that this achievement depends more on the socioeconomic status of countries and the intervention programs administered to reduce the accidents and injuries caused by them.

In the current study, clear seasonal variations were seen in the data in all the years of the study. The number of deaths from motorcycle accidents started to increase in the spring and

peaked in summer and, after a downward trend from the onset of fall, it was minimized mid-winter. This shows that the SARIMA time series model, which was chosen to investigate and predict the trend of death from motorcycle accidents in this study, is suitable for the available data by controlling seasonal changes. The decreasing trend during the 15 years happened in contrast to the increase in the number of motorcycles during this period, suggesting that the interventional and educational programs to raise the awareness of motorcycle riders have been relatively successful in reducing the number of deaths from motorcycle accidents. Considering the cold climate of Azerbaijan, at first glance, it seems that the number of motorcycles is small compared to the total number of vehicles; however, according to official statistics, 35%[26] to 38%[2] of vehicles in the country are motorcycles, and this value (34%) in East Azerbaijan is similar to the national average.[27] In this study, the share of deaths from motorcycle accidents to the total death from accidents is 18.6%; therefore, this figure is low compared to the number of motorcycles. However, if the total number of injuries caused by motorcycle accidents is considered, it will probably account for a larger share of injuries and deaths. Consequently, preventive measures to reduce the number of motorcycle accidents, injuries, and deaths should be included in local and national interventional programs, especially in the hot months of the year when the number of accidents and deaths is higher. These include the creation of designated motorcycle lanes on busy roads, the reconfiguration of dangerous intersections, increased law enforcement efforts to ensure riders follow traffic laws and speed limits, the implementation of strict regulations for regular motorcycle inspections, and the enforcement of helmet usage.

Conclusion

The trend of deaths due to motorcycle accidents in East Azerbaijan is decreasing gradually, and it is predicted to decline slowly in the next three years. This reduction may be attributed to many factors, however, it is not clear which factors had reduced the rate of accidents and deaths. This can be a topic for further studies because, by examining the impact of several factors, more effective measures can be provided to accelerate the reduction in mortality rate.

Acknowledgment

None

Conflict of Interest

The authors report there are no competing interests to declare.

Data availability statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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