Research Paper

Spatial-temporal cluster analysis of mortality from road traffic injuries using geographic information systems in West of Iran during 2009–2014

Alireza Zangeneh¹, Farid Najafi², Saeed Karimi³, Shahram Saeidi⁴, Neda Izadi⁴,∗

¹ Social Development and Health Promotion Research Center, Kermanshah University of Medical Sciences, Kermanshah, Iran
² Department of Epidemiology, Research Center for Environmental Determinants of Health (RCEDH), Kermanshah University of Medical Sciences, Kermanshah, Iran
³ Faculty of Environment, University of Tehran, Tehran, Iran
⁴ Department of Epidemiology, Student Research Committee, School of Public Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran

ARTICLE INFO

Keywords:
Spatial-temporal clustering
Mortality
Road traffic injuries
Geographic information systems

ABSTRACT

Introduction: Road traffic injuries (RTIs) are considered as one of the most important health problems endangering people's life. The examination of the geographical distribution of RTIs could help policymakers in better planning to reduce RTIs. This study, therefore, aimed to determine the spatial-temporal clustering of mortality from RTIs in West of Iran.

Methods: Deaths from RTIs, registered in Forensic Medicine Organization of Kermanshah province over a period of six years (2009–2014), were used. Using negative binomial regression, the mortality trend was investigated. In order to investigate the spatial distribution of RTIs, we used ArcGIS. (Version 10.3).

Results: The median age of the 3231 people died in RTIs was 37 (IQR = 31) year, 78.4% were male. The 6-year average mortality rate from RTIs was 27.8/100,000 deaths, and the average rate had a declining trend. The dispersion of RTIs showed that most deaths occurred in Kermanshah, Islamabad, Bisotun, and Harsin road axes, respectively. The mean center of all deaths from RTIs occurred in Kermanshah province, the central area of Kermanshah district. The spatial trend of such deaths has moved to the northeast-southwest, and such deaths were geographically centralized. Results of Moran's I with respect to cluster analysis also indicated positive spatial autocorrelations.

Conclusion: The results showed that the mortality rate from RTIs, despite the decline in recent years, is still high when compared with other countries. The clustering of accidents raises the concern that road infrastructure in certain locations may also be a factor. Regarding the results related to the temporal analysis, it is suggested that the enforcement of traffic rules be stricter at rush hours.

1. Introduction

Approximately two million people annually die from road traffic injuries (RTIs) worldwide, and 50 million are left with injuries.¹ According to the World Health Organization (WHO), RTIs would be the second leading cause of years of life lost in the world by 2020.² The mortality rate from RTIs varies according to the region, but, overall, the regional average for low-and-middle-income countries is much higher than that for industrialized countries.³ The results of studies carried out in Iran show that the mortality rate from RTIs is 30/100,000 people, while the rate in the world is 22.6.⁴ Given that most deaths from RTIs occur for middle-aged and younger people, the subsequent negative impacts on life expectancy at birth and, accordingly, on the economy and society are inevitable.⁵,⁶ Overall, 2.5% of the world RTIs occur in Iran, meaning that the rate in Iran is twenty times higher than those elsewhere.⁷ Moreover, a study of the mortality rate from RTIs in Kermanshah province, Iran, indicated that the rate was 51.3/100,000 people, which is relatively high when compared with those reported in other regions (in Swaziland 48, in Iraq 44.5, and in Afghanistan 25 deaths per hundred thousand people).⁸–¹⁰

The pattern of RTIs and the subsequent mortality and injuries could vary in different geographical regions and environmental conditions according to individual and demographic variables, vehicle types, roads, and population density.¹¹ Even the prevalence and pattern of injury could vary across different urban and rural communities and different parts of a country.¹² Recent advances in Geographic Information Systems (GISs) provide a powerful tool that could improve our description and understanding of geographical distributions of diseases and other health events.¹³ For several reasons, GISs are potentially powerful sources for the health of communities due to their

∗ Corresponding author.
E-mail address: neda.izady@yahoo.com (N. Izadi).
ability to integrate data from different sources to produce new information as well as their applications in inherent visualization (mapping a vector); consequently, by providing creative solutions to problems, they could bring about lasting effects on people's health and lives.\textsuperscript{14,15} Related findings using GISs could guide efficient use of limited resources in health care.

The deaths and disabilities due to RTIs as well as its rising incidence should receive authorities' special attention as one of the most important health priorities in terms of prevention and control. Examining the geographical distributions as well as factors influencing mortality from RTIs could not only help authorities in identifying high-risk groups, but it also could pave the way for policymakers in better planning to reduce the rate of such accidents. Therefore, this study aimed to determine the spatial-temporal cluster analysis of mortality from RTIs in West of Iran.

2. Methods

In this cross-sectional study, the deaths from RTIs, registered in Forensic Medicine Organization (as the gold standard source for RTIs mortality) of Kermanshah province in western Iran over a period of six years (2009–2014), were used. The required information including variables such as age, gender, year of death, city and place of death, and ultimate cause of death was collected. By definition, an RTI is an incident involving a moving motor vehicle alone or between a moving motor vehicle and another element such as one or more vehicles, pedestrians, and/or fixed objects, resulting in damage to life and property; the deaths occurring within 30 days after the injury are considered as deaths from RTIs.\textsuperscript{7,10} Therefore, according to this definition, the deaths occurring within more than 30 days following the RTIs, non-traffic deaths, the deaths occurring in neighboring provinces, and the cases under study to determine the cause of death were excluded from the current study.

For the deaths from RTIs, the codes V01-V98 have been regarded as the underlying cause of death. Therefore, individuals were classified on the basis of the external causes of death using the code ICD-10 (International Classification of Diseases).\textsuperscript{17} The information about the size of the population of Kermanshah province was collected from Statistical Center of Iran. Data analysis was completed using Stata (version 11). To investigate the trend of mortality rate and its significance, negative binomial regression was employed.

Moreover, given the spatial and geographical nature of the research, GISs were used, and all the data were entered and analyzed using the software ArcGIS (version 10.3). Considering the fact that the pattern type which the data sets followed was unknown, autocorrelation coefficients are appropriate for examining the spatial pattern of the data sets.\textsuperscript{18,19} In this study, Moran's I statistical parameter was used to evaluate the spatial pattern of mortality from RTIs in Kermanshah province. Moran's I compares the variable values at each location with those at other locations\textsuperscript{20,21} and is displayed as follows:

\[
I = \frac{N \sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij} (X_i - \overline{X})(X_j - \overline{X})}{\sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij} (X_i - \overline{X})^2}
\]

where \(N\) is the number of cases, \(X_i\) is the variable value for a specific location, \(\overline{X}\) is the variable mean, and \(w_{ij}\) is a weight for the comparison of the locations \(i\) and \(j\). \(w_{ij}\) is a matrix of spatial weights and the inverse distance between the locations \(i\) and \(j\).

To identify the geographical pattern of mortality from RTIs, the following tests were used:

1. Mean Center: This is, in fact, the average of the \(x, y\) coordinates of all events under study. It is calculated to examine and compare the changes in the spatial dispersion and distribution of events. Mean center is computed as follows:

\[
X = \frac{\sum_{i=1}^{N} X_i}{N}, \quad Y = \frac{\sum_{i=1}^{N} Y_i}{N}
\]

where \(X_i\) and \(Y_i\) are the coordinates of the event \(i\), and \(N\) is the total number of features and events.

2. Standard Deviational Ellipse: This is an appropriate tool for displaying the spatial stretch of a set of points and is calculated as follows:

\[
SDE_x = \sqrt{\frac{\sum_{i=1}^{N} (X_i - \overline{X})^2}{n}}
\]

\[
SDE_y = \sqrt{\frac{\sum_{i=1}^{N} (Y_i - \overline{Y})^2}{n}}
\]

where \(X_i\) and \(Y_i\) are the coordinates of the event, \(\overline{X}\) and \(\overline{Y}\) are the centers, and \(n\) is the total number of features and events.

The rotation angle is calculated as follows:

\[
\tan \theta = \frac{A + B}{C} \quad A = (\sum_{i=1}^{N} X_i^2) - (\sum_{i=1}^{N} Y_i^2) \\
B = (\sum_{i=1}^{N} Y_i^2) - (\sum_{i=1}^{N} X_i^2) + 4(\sum_{i=1}^{N} X_i Y_i) \\
C = 2 \sum_{i=1}^{N} X_i Y_i
\]

\[
\sigma_x = \sqrt{\frac{\sum_{i=1}^{N} (X_i - \overline{X})^2}{n}} \quad \sigma_y = \sqrt{\frac{\sum_{i=1}^{N} (Y_i - \overline{Y})^2}{n}}
\]

3. Results

The median age of the 3231 people died in RTI was 37 (IQR\textsuperscript{1} = 31) year; the age ranged from under one to 99 years (36 (IQR = 29) in men and 43 (IQR = 36) in women). From the total, 78.4% (2534 people) were male (M/F ratio = 3.6). The most frequency of death by age group was in youth (Table 1). The final cause of death in most cases was head injury (71.6%). Most external causes of death were related to motor vehicle accidents. Moreover, 66.5% of deaths occurred in suburban areas. In deaths occurred in urban areas, pedestrians had the highest percentage and number (62.1%, 566 deaths), and in suburban areas, motor vehicles had the largest percentage (56.5%, 1207 deaths). The highest rate of mortality in terms of the external causes of death was also related to motor vehicles (72.7 per hundred thousand people) (Table 2).

Mortality rate: The 6-year average mortality rate from RTIs in Kermanshah province was 27.8/100,000 people. The mortality rate from RTIs in Kermanshah province experienced a decrease from 32.7/100,000 people in 2009 to 21.9 in 2014, and the 6-year data showed a declining trend on the basis of negative binomial regression in such a way that for each one unit increase in years, the mortality rate reduced by an average of 5% (\(\beta = -0.05, CI = -0.002, -0.11\)) (Fig. 1).

Temporal analysis: The temporal analysis of mortality from RTIs in Kermanshah province, based on months and hours of the day, showed the highest mortality rate with the frequency of 15–20 deaths in April from 16:30 until 17:30; June from 10:30 until 12:00 and from 16:30 until 17:30; July from 9:00 until 12:30 and from 16:00 until 19:30; August exactly at 11:00 as well as from 13:30 until 14:30 and from 16:30 until 17:30; October from 15:30 until 17:30; and March from 13:30 until 15:30. In general, the incidence of deaths was higher in the spring, summer, early fall, and in March, and most deaths occurred in the hours before the noon and in the evenings (Fig. 2).

\textsuperscript{1} Interquartile of Range.
Spatial distribution of RTIs axes in Kermanshah province: Fig. 3 displays the point distribution of RTIs. The high volume of points on the map represents the concentration of RTIs. The distribution pattern of RTIs indicates that most RTIs have occurred in the axes of Kermanshah, Islamabad, Bisotun, Harsin, Kangavar, Sarpol-e Zahab, Songhor, Sahneh, Kerend-e Gharb, Javanroud, Rawansar, Gilan-e Gharb, Qasre-Shirin, Paveh, and Salas-e Babajani, respectively.

Examining the pattern of accidents also showed that most accidents have occurred along the routes to Kermanshah metropolis. The routes Bisotun-Kermanshah, Harsin-Bisotun, Kangavar-Sahneh-Bisotun, Kangavar-Hamadan, Songhor-Bisotun, Kermanshah-Kamyaran-Rawansar, Rawansar-Paveh-Javanroud, Kermanshah-Sarab-Niloufar-Kouzaran, Kermanshah-Halashy, Kermanshah-Mahidasht-Islamabad, Islamabad-Homeyli, and Islamabad-Dalahoo-Sarpol-e Zahab-Qasr-e Shirin experienced most injuries, respectively. Overall, Kermanshah-Bisotun, Islamabad-Homeyli, Kermanshah-Sarab-Niloufar, Kermanshah-Kamyaran, Bisotun-Sahneh-Kangavar, Kermanshah-Islamabad, province has moved to the northeast-southwest. The pattern of injuries in 2014 also showed a greater stretch and dispersion in comparison with the period of 2009–2013. The stretch of the standard deviational ellipse of RTIs occurred in the entire province indicates that their centralization is just around some particular points, and, overall, the spatial pattern of mortality from accidents was geographically centralized (Fig. 4).

Results of cluster analysis of mortality from RTIs using Moran’s I: Results of Moran’s I with respect to the spatial cluster analysis of mortality from RTIs indicated positive spatial autocorrelations. The Z value also showed that the test was significant (Figs. 5–10). Obviously, there are spatial mechanisms for cluster of fatalities from RTIs in Kermanshah province.

4. Discussion

The results obtained in the current study showed a decrease in the
mortality rate from RTIs over the last five years; this was consistent with Bahadorimonfared et al. (2013) reporting a decrease in the mortality rate from RTIs in Iran from 38.2 to 31.1 in recent years.22 Similar findings have been reported in China from 2004 to 2010.23 It seems that different factors contributed to such decrease: new legislation on increasing fines related to driving, possible improvements in vehicle and road quality and effective strategies for reducing the speed over recent years. In Iran, a combination of such factors decreased the death over the recent years. Restrict supervision and control by police, wide-country use of speed camera especially for highways, compulsory use of safety belt for car passengers and helmet for motorcyclist, retraining program for those drivers who did not follow the regulations and an

---

**Fig. 2.** Temporal analysis of months of the year and hours of the day RTI's occurrence in Kermanshah Province (2009–2014).

**Fig. 3.** Point distribution of RTIs in Kermanshah Province (2009–2014).
increase in driving fine are of most important factors (Bahador-imonfared A et al., 2013). Countries such as Switzerland and Denmark have experienced a decrease of 12% and 24% in the mortality rate from RTIs by reducing the speed limit from 130 to 120 km/h and from 60 to 50 km/h, respectively.24 Despite the decline in the mortality related to RTIs, the overall mortality in Kermanshah is 27.8/100,000 people, while the rate in the world is 32.6, in America 16.1, in Europe 17.4, in Eastern Mediterranean 26.4, and in Africa 28.3/100,000 people.4,25,26 These finding indicate that health policy makers need to make a strategic, long acting decision in order to reduce the number of RTIs and related fatalities. Such decisions might include continuous improvement in the quality of cars (especially mini-bus and bus) produced in Iran and better design of roads and highways. In addition, improvement in public education and training can effectively create a better public
driving culture in a way that the burden of RTI could be reduced by people themselves.

In this study, most of the deaths in suburbs involved motor vehicles and those in urban areas involved pedestrians. In Gilan (one of the provinces in the north part of Iran), the greatest frequency of injuries occurred in both urban and suburban areas was related to motor vehicles. In Tanzania, the highest rate was related to motorcyclists. In fact, the intensity of RTIs could be reduced, in urban areas, by following strategies: creating separate traffic spaces for vehicles and motorcycles, increase in compliance of traffic safety by drivers and pedestrians, and providing pedestrian traffic facilities. In suburban areas, RTIs may decrease by enhancing the safety of intercity roads, administering higher fines and punishment for drivers not following the rules, requiring people to drive when they are in complete alertness and not talking to the mobile phone, limiting the hours of driving during days, and banning drowsy driving. In fact, Kermanshah in the western part of Iran is not different from other provinces in terms death from RTIs and therefore all such strategies can be implemented in Kermanshah.

The results of the present study indicated several spatial and temporal differences in the occurrence of deaths from RTIs in Kermanshah province. This finding was in line with that obtained in Jonesa et al. (2008) and Erdogan (2009) reporting large geographical differences in the number of deaths and injuries from RTIs among local areas in England and Wales and among provinces of Turkey, respectively.

According to the results, mortality from RTIs in Kermanshah province was in the form of clusters, and its formation was not based on chance. Obviously, clusters in Kermanshah, Islamabad, Biston and Harisn are related to their heaviest traffic in Kermanshah province. There are special mechanisms for the formation of mortality from RTIs as clusters in Kermanshah province. This finding was in line with the results reported by Eckley et al. (2013) and Yang et al. (2013) that examined the spatial and temporal clustering of RTIs in eastern Fairfax, Virginia and Franklin, Ohio and St. Louis, Missouri and neighboring cities, respectively. Additionally, the mean center of all RTIs occurred in Kermanshah province was located in the central area of the Kermanshah district. As also stated in other studies, this is probably due to the concentration of population in such areas.

In the current study, the standard deviation ellipse of mortality from RTIs has moved over the period of study and covered a wider stretch which is in line with studies from elsewhere. Among possible reasons are the accumulation of RTIs at specific locations (indicating a centralized spatial pattern), increased traffic and as result the traffic accident in even less accident-prone spots. The results of the temporal analysis of mortality from RTIs also showed that most accidents had occurred during 10–12 a.m. and late afternoon/early evening; this was consistent with the findings reported by Levine et al. and Blazquez et al.
5. Conclusion

The results showed that the mortality rate from RTIs, despite the decline in recent years, is still high when compared with other countries. The clustering of accidents raises the concern that road infrastructure in certain locations may also be a factor. In fact, Islamabad, Harisn, Biston and Kermanshah have the heaviest traffic and therefore any improvement in highways, and road design with more control by police enforcement and camera monitoring will decrease the number of death related to road traffic accidents. In addition, time
clustering of deaths confirms that police control on speed, texting, use of safety belt and other preventive factors need to be enforced during the rush hours with highest deaths. The highest number of deaths among pedestrians also revealed that public training about crossing the pedestrian line and use of the pedestrian bridge is important. Although not confirmed by the result of this study, in fact, providing retraining of those drivers who does not follow the regulations as well as timely health and treatment care, could be effective in reducing road accidents and casualties.

Conflicts of interest

All authors declare that they have no conflict of interest.

Ethical approval

All procedures performed in studies involving data extracted from existing information were in accordance with the ethical standards of the forensic medicine organization and Kermanshah University of Medical Sciences grant number 94237. The funding agency did not play any role in the planning, conduct, and reporting or in the decision to submit the paper for publication.

Acknowledgments

We would like to express our thanks to all the staff of Forensic Medicine Organization of Kermanshah province, Iran as well as to all individuals helping us in completing this research project.

References