Spatio-temporal analysis of Deaths from carbon monoxide poisoning in Iran between 2011 and 2018- An ecological study

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Research article

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Abstract

Background

Carbon monoxide (CO) poisoning, as one of the lethal poisoning, is responsible for a large percentage of poisonings and accidental deaths. Since the investigation of the mortality and the distribution of CO poisoning deaths in Iranian provinces is still unknown and no study has investigated so far, this study was conducted to determine the trend of mortality rate changes due to CO poisoning by Spatio-temporal analysis in Iran from 2011 to 2018.

Methods

An ecological study was conducted based on data from the reports of at the National Center for Statistics of Iran for eight years from 21 March 2011 to 21 March 2018. The number of deaths due to CO poisoning and the annual mortality rates of CO poisoning per 100,000 population were calculated. The Spatio-temporal analysis used to determine the spatial and temporal distribution of deaths.

Results

A total of 6078 deaths were reported due to CO poisoning that 4497 death were male (74%) and 1596 were female (26%) from 2011 to 2018. In both sexes, the mortality rate due to CO poisoning was 1.26 from 2011 to 0.91 in 2018. According to the results, the overall male-to-female ratio was 2.8. The mortality rate due to CO Poisoning had a decreasing trend. However, this trend did not have a linear trend (p=0.37). Our results showed that most of the deaths due to CO poisoning are higher in the northern and western provinces of Iran.

Conclusion

This study is one of the first studies to compare the spatial and temporal mortality rates due to CO poisoning in Iran. Paying attention to general education about the principles of safety in the installation of heaters and the use of the gas networks, continuous and accurate monitoring of the installation and operation of CO-producing, and the use of sensitive alarms can reduce mortality and morbidity due to CO poisoning.

Background

Poisoning is one of the major concerns of the health system in every country. In Iran, poisoning is one of the leading causes of hospitalization and death(1), and about 20% of hospital admissions are due to poisoning (2). Carbon monoxide (CO) poisoning, as one of the lethal poisoning, is responsible for a large percentage of poisonings and accidental deaths (3). It is colorless and odorless and is the result of incomplete combustion produced by motor vehicles, coal stoves, stoves, and heaters(4, 5).

CO poisoning accounts for about 50,000 deaths annually in the US emergency department, with 38% of deaths due to CO poisoning between the ages of 10 and 19 years(6, 7). Some studies in Iran have shown that about 10% of poisonings in Iran are due to CO and reported mortality rate 3.1 per 100,000 population in 2016 (8). Another study showed that the mortality ratio of this poisoning was 11.6 per 1000 deaths in 2016(9).

Iran, as one of the main producers of natural gas, has extensive use of natural gas domestically. Despite the widespread use of gas-fired devices and their possible risks, especially the sudden death of CO poisoning in Iran, the investigation of the mortality and the distribution of CO poisoning deaths in Iranian provinces is still unknown and no study has investigated so far. The purpose of this study was to determine the trend of mortality rate changes due to CO poisoning by Spatio-temporal analysis in Iran from 2011 to 2018.

Methods

Study area:

Iran is a country in the Middle East with a total area of 1 648 195 km^2. According to the last National Census in 2016, the total population of Iran is approximately 80 million. Iran has a common border with Armenia, Turkmenistan, and Azerbaijan in the North; Afghanistan and Pakistan in the East; the Persian Gulf and Gulf of Oman in the South; and Iraq and Turkey in the West.

Study design and used dataset:

An ecology analysis was conducted based on the data obtained from the Iran official reports on population. Deaths from CO poisoning data were obtained based on the reports of at the National Center for Statistics of Iran for eight years from 21 March 2011 to 21 March 2018. These cases were classified based on the International Classification of Diseases, Tenth Revision (ICD-10) code T58, and verified by Iranian legal medicine organization (LMO). The number of deaths due to CO poisoning and the annual mortality rates of CO poisoning per 100,000 population were calculated. Calculation of rates per 100,000 inhabitants in Iran was performed using census data from 2011 to 2018.

Temporal trend analysis

To assess the trend of reported mortality rates was used the presence of a linear or non-linear trend, the Cochran–Armitage. The α = 0.05 was considered a significant level.
Spatial analysis

A Choropleth map was used to describe the distribution of mortality rate of CO poisoning cases (per 100,000 people) each year by the population of the province. This index calculated for each province as this formula:

$$\text{Mortality rate in year of x: } \frac{\text{number of new cases in year of X}}{\textit{total population in year of } x} * 100{,}000$$

Hotspot identification

To identify clusters of fatal cases due to CO poisoning in different years, the Hotspot analysis was used. Hot spots present the clusters of under study event. This analysis performed using the Getis-Ord Gi statistics. A high score on this index combined with a lower p-value indicates the clustering of understudy event. The Gi statistics formula is as follows:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2}{n-1}}}$$

Where Xj is the mortality rate of under study event for province j, w i.j is the spatial weight between provinces i and j, and n is the total number of provinces. X and S, are calculated as follows:

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{X})^2}$$

In terms of hot spot analysis, the α: 0.01 and 0.05 were considered as significant level. All analyses were performed using ArcGIS 10.5 and Excel 2010.

Results

Descriptive analysis:

As showed in Table 1, A total of 6078 deaths were reported due to CO poisoning that 4497 death were male (74%) and 1596 were female (26%) from 2011 to 2018. In both sexes, the mortality rate of CO poisoning was 1.26 from 2011 to 0.91 in 2018. According to the results, the overall male-to-female ratio was 2.8. As Fig. 1 demonstrated, the average mortality rate due to CO poisoning in Semnan, North Khorasan, and Qazvin, Zanjan, Alborz, and Tehran was higher than in other provinces of Iran.

Table 1
Number of death and mortality rates due to CO poisoning by gender in Iran between 2011 and 2018

Christian Year	Persian year	Population (million)			Death (n)			Mortality raty per 100,000 population			
		female	male	Both sex	Male	Female	Both sexes	Male	Female	Both sexes	Male/female
2011	1390	37244	37906	75,150	712	253	950	1.88	0.68	1.26	2.76
2012	1391	37672	38403	76,075	490	207	697	1.28	0.55	0.92	2.33
2013	1392	38101	38915	77,016	588	240	828	1.51	0.63	1.08	2.40
2014	1393	38536	39434	77,970	468	158	626	1.19	0.41	0.80	2.90
2015	1394	38979	39961	78,940	482	144	626	1.21	0.37	0.79	3.27
2016	1395	39428	40498	79,926	620	216	836	1.53	0.55	1.05	2.78
2017	1396	40021	41049	81070	564	202	766	1.37	0.50	0.94	2.74
2018	1397	40546	41538	82084	573	176	749	1.38	0.43	0.91	3.21

Temporal analysis:

As Fig. 2, in both sexes, the time trend in mortality rate due to CO Poisoning had a fluctuation over time. The lowest and highest mortality rate was reported in 2014 and 2011, respectively, in both sexes. In addition to this visual inspection, by Cochran–Armitage analysis, the mortality rate due to CO Poisoning had a decreasing trend. However, this trend did not have a linear trend ($p = 0.37$).

Spatial distribution:

Figure 3 shows that some provinces have had higher mortality rates than others in different years. Among all provinces of Iran, North Khorasan, Semnan, Qom, Qazvin, Zanjan, Chaharmahal Bakhtiari, and Tehran had the highest mortality rates between 2011 and 2018. The lowest mortality rates also found in southern provinces of Iran, such as Kerman, Sistan and Baluchestan, Hormozgan, Bushehr, and Khuzestan.

Hot Spots:

In 2011, Qazvin and Qom were considered as Hot spot. It means that the mortality rate due to CO poisoning (per 100,000) in these provinces was significantly higher than the overall average of the country, so these provinces were considered as hot-spots ($p < 0.05$). In 2012, the Qom was considered as hot-spot area ($p < 0.05$). Mazandaran, Qazvin, Tehran, Qom, and Lorestan provinces were considered as Hot spot in 2013($p < 0.05$). Among provinces, Alborz had the Most mortality rate in comparison to the country average, so were considered as hot-spots ($p < 0.01$) in 2014. although there were not any Hot spot areas in 2015, there were Hot-spots in Qazvin, Tehran, Qom, and Lorestan provinces in 2013($p < 0.01$). Also, among provinces, Mazandaran, Tehran, and Qom were considered as Hot spot in 2017 ($p < 0.05$), and finally, in 2018, Alborz and Qom were considered as hot-spots ($p < 0.05$). (Fig. 4)

Discussion

CO poisoning is considered as one of the health emergencies for its lethal nature as well as its subsequent complications if survived. This study aimed to investigate the trend of deaths due to CO poisoning among provinces of Iran. The results showed that the mortality rate due to CO poisoning was from 1.26 from 2011 to 0.91 per 100,000 population in 2018, and the mortality trend did not change in these eight years. Although there are not studies in the same period to compare these findings with others, some studies indicate that the trend of changes has not been significant before 2011. In a study carried out in Iran in 2010(10), the mortality rate due to CO poisoning was between 1.1 and 2.2 per 100,000, which was not statistically significant between 2002 and 2006. In another study by Nazari et al.(11), the mortality rate due to CO poisoning was less than 1 per 1,000 people, with no statistical difference between 2003 and 2008. Since the LMO approves the data in this study and there is no underreporting in the data collection, it seems that overall, there has not been little change in the mortality rate of CO poisoning in Iran over the years.

Our results demonstrated both the number of deaths and the mortality rate due to CO poisoning were higher in men than women each year. Consistent with our study, in studies of Mirahmadizadeh et al. in 2016(12), Nazari et al. (11), and Shokrzadeh et al. in 2017(13) have shown mortality rate due to CO poisoning was higher in men than women. Previous studies in other countries have also indicated these differences (14–17). Although these differences are unclear, it seems men have more risky activities, such as working indoors or in garages with combustible tools than women that increase the exposure duration (18, 19). It may also be hypothesized that men may have a deeper sleep than women due to hard-working, and emissions of CO will lead to more deaths for men than for women during sleeping at night. Studies to compare occupational among men and women who died, the mechanism of the effect of CO on Dying, and its differences between women and men, may help to understand this difference better.

Spatial analysis in this study showed that most of the deaths due to CO poisoning are higher in the northern and western provinces of Iran. As the northern and western provinces of Iran have a colder climate and many fatality cases accrued in the cold season (8, 20, 21), the use of gas heaters in these areas is higher than elsewhere, which could increase the exposure of the population to CO. To confirm this, a study conducted in the northern and western parts of Iran has shown that most deaths due to CO poisoning and have been in cold seasons (11, 22). On the other hand, increasing the number of villages and cities with the urban gas distribution network in the north and west of Iran can also increase the number of poisoning cases and deaths due to CO. In support of this, our study showed that the mortality rate due to CO poisoning is lower in southern provinces of the country with warmer climates and provinces with less gas distribution network than in other regions of Iran.

There were some limitations to our study. First, we did not have additional data on seasonal distribution, occupational distribution, demographic characteristics, and the number of poisoned cases, which could better explain the epidemiological characteristics. Second, there were no further studies using data other than LMO to compare these findings with the theme.

Conclusion

This study is one of the first studies to compare the spatial and temporal mortality rates due to CO poisoning in Iran. As our findings showed, mortality changes over time were not significant, and the mortality rate was higher in the northern and western provinces than in the south of Iran. Paying attention to general education about the principles of safety in the installation of heaters and the use of the gas networks, continuous and accurate monitoring of the installation and operation of CO-producing, and the use of sensitive alarms can reduce mortality and morbidity due to CO.

Declarations

Ethics approval and consent to participate:

All data in this study are freely available by the Forensic Medicine Organization and the National Center for Statistics of Iran, and there are no specific ethical aspects to publishing the results. All data was accessed as part of ongoing public health

surveillance activities, and all data were obtained as part of ongoing public health surveillance activities and therefore considered exempt from consent to participate.

Consent for publication:

Not applicable.

Availability of data and materials: The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: Danial Rahimi interpreted the data. Yousef Alimohamadi contributed to the statistical analysis, and Ahmad Mehri participated in the planning, writing, and was the lead editor of the project and contributed to the writing. All authors read and approved the final manuscript.

Acknowledgment

This study conducted by using data from Iranian legal medicine organization and National Center for Statistics of Iran from 2011 to 2018.

Abbreviations

CO
carbon monoxide
LMO
Iranian legal medicine organization

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Figures

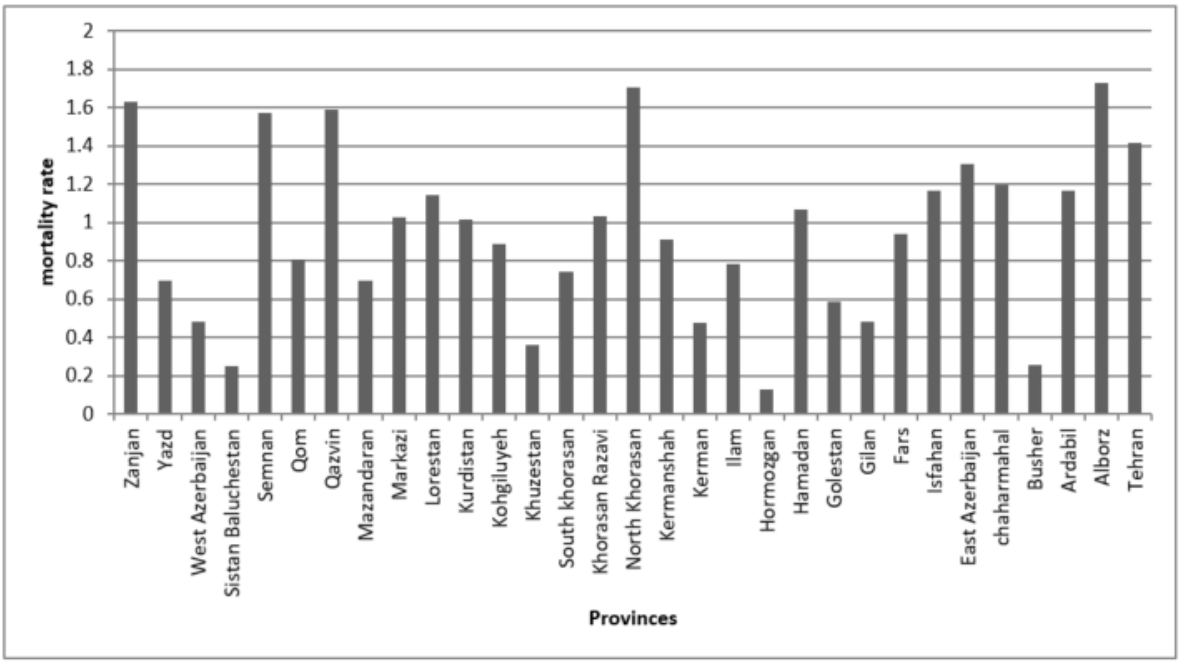

Figure 1

The average mortality rate of CO poisoning among provinces of Iran from 2011 to 2018 (per 100,000)

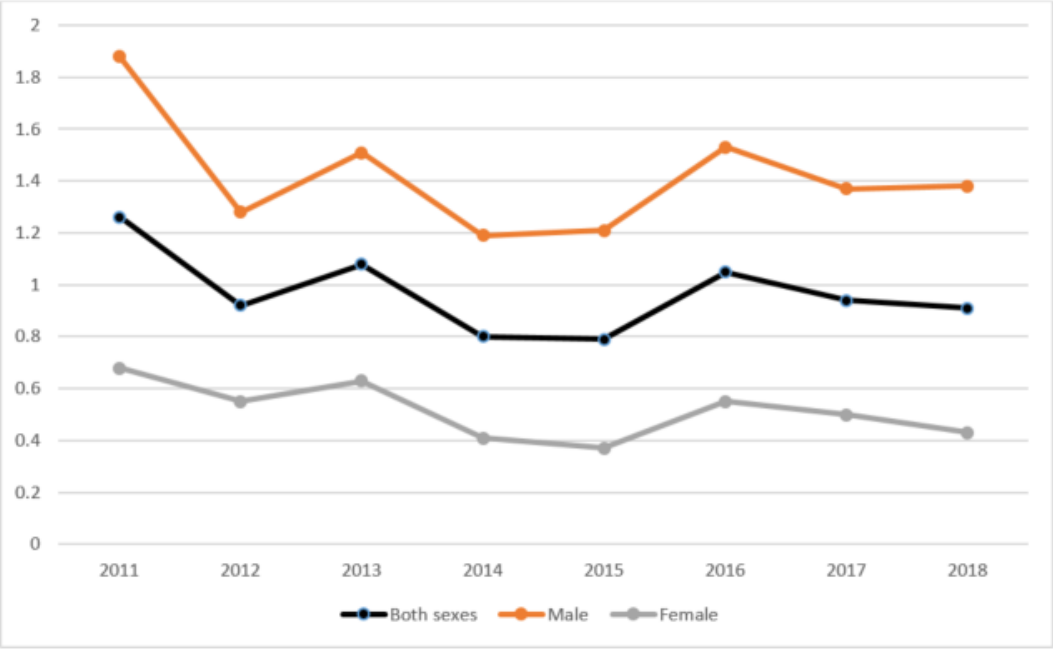

Figure 2

The time trend of mortality rate due to CO Poisoning from 2011 to 2018 in Iran by gender.

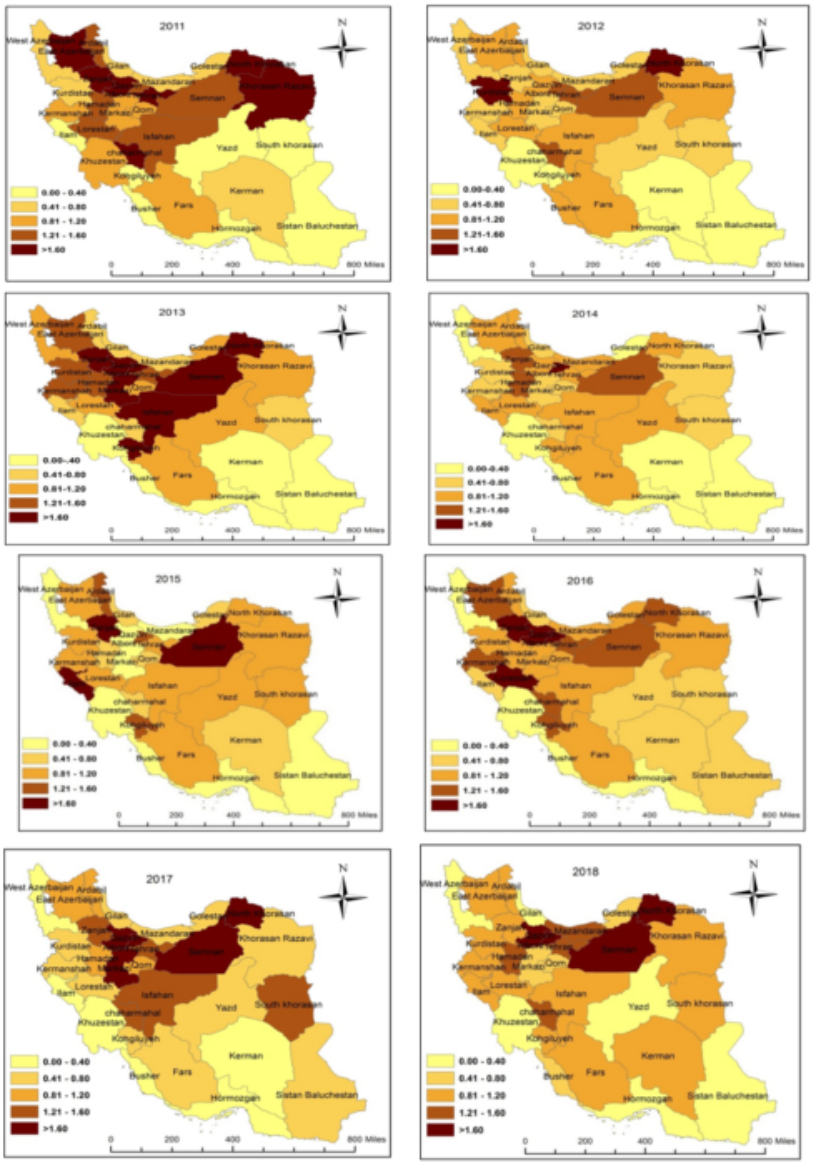

Figure 3

The mortality rate due to CO Poisoning among Iranian population from 2011 to 2018 by provinces (per 100,000)

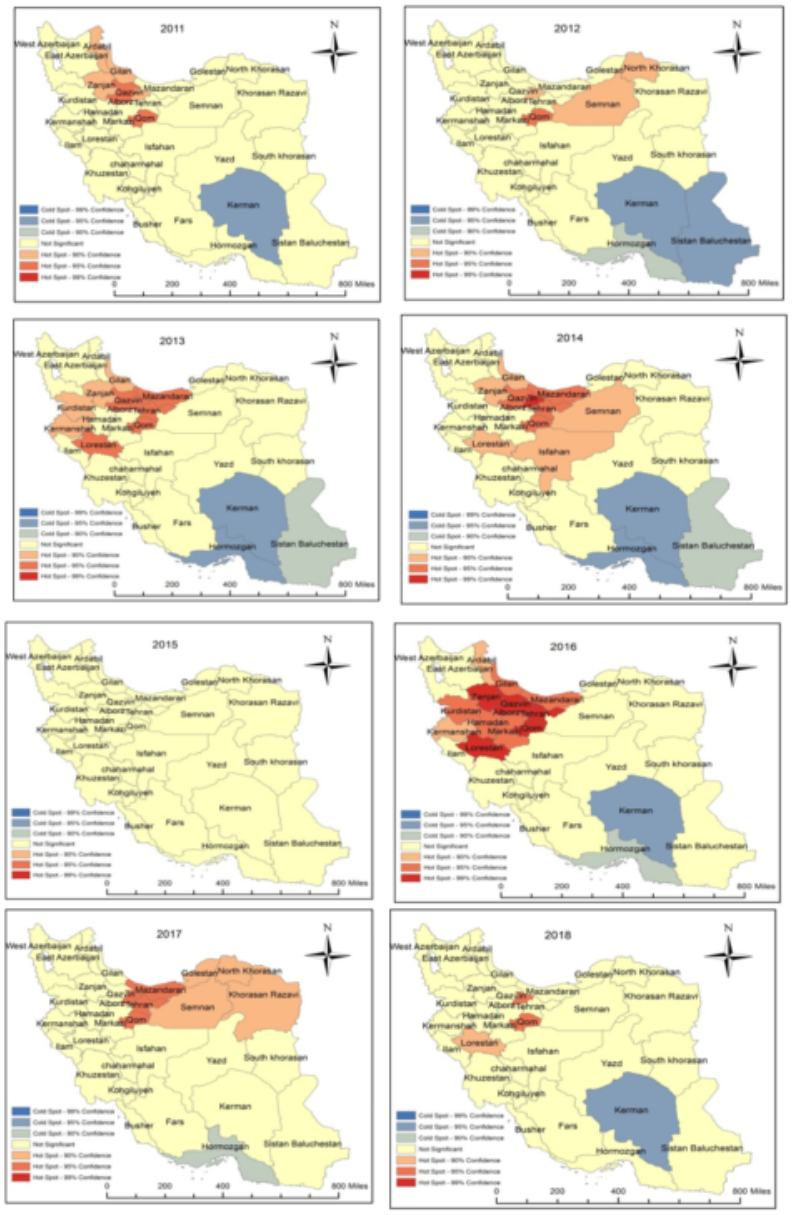

Figure 4

The identified Hot Spot about mortality rate due to CO Poisoning among Iranian population from 2011 to 2018 by provinces (per 100,000)