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Geographical distribution of Typhoid using Geographic Information System (GIS) during 2009-2014 in Iran

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Abstract

Background: Salmonella induced infections remain one of the most important health problems worldwide. The purpose of this study is to investigate the incidence and geographical distribution of typhoid using GIS and to predict its incidence in Iran in 2021.

Methods: This study is a descriptive analytical study. Information on pertussis was obtained from the Center for Communicable Diseases Control during 2009-2015. In the next step, ArcGIS 9.3 was used to prepare geographic maps of the disease incidence and frequency Therefore, using the Raster Calculator tool, the disease prediction map was drawn.

Results: The results showed that the highest incidence of typhoid during 2009-2014 was in Kermanshah, Lorestan, Hamadan, Kurdistan, and Ilam provinces. The incidence of typhoid in Iran increased during 2009-2010. The annual incidence of typhoid decreased from 0.85 per 100,000 in 2010 to 0.5 in 2014. Based on the modeling results for Iran, Kermanshah, Lorestan, Kurdistan, Ilam and Hamadan provinces with 92.17%, 46.56%, 31.74%, 25.62% and 22.96% of their areas (Km2) are at high risk for typhoid in the coming years, respectively.

Conclusion: Considering that the provinces of Kermanshah, Lorestan, Kurdistan, Ilam, and Hamadan are at risk of typhoid incidence in the coming years in Iran, and given that salmonella infections have a direct relationship with the individual's health status and individual's environmental health and socioeconomic status, improving the health status and disease control in carriers as well as improving the socio-economic status of the population living in these areas can prevent the disease in the years to come.

Keywords: Incidence, Typhoid, GIS, Iran

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Introduction

Salmonella, a gram-negative bacillus, is non-spore-forming motile bacteria. Based on a new DNA-based classification, only two species of Salmonella have been identified:

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↑What is "already known" in this topic:
Typhoid is one of the oldest endemic diseases in our country. In spite of efforts that have been made to reduce the disease in the country, its prevalence is still considerable in various climatic regions.

→What this article adds:
Health status and disease control in carriers and improving the socio-economic status of the population living in provinces high risk to can prevent the disease in the years to come.

Salmonella enterica and Salmonella bongari (1, 2). Intestinal fever caused by Salmonella enterica Paratyphi A, B, C is known as parathyroid fever. In many cases, it is not clinically distin guishable from typhoid fever (3) . Intestinal perforation and gastrointestinal bleeding are the most important complications of Salmonella typhi (4) . Before the advent of antibiotics, the illness length was long (several weeks), and the fatality rate was approximately 10-20%. Following the discovery of antibiotics, the fatality rate reduced to less than 1% (5, 6).

This disease is widespread throughout the world. In local areas, the disease incidence follows a specific age pattern. The incidence of the disease in less than one year and 2-4 years children is lower due to less exposure to the disease. Most cases are reported in school-age (5-19). However, the incidence of the disease in individuals over 35 years is not common (7).

The most important ways of transmission are through drinking water in developing countries and through food by chronic disease carriers in developed countries with good health status (6). Due to the similarity of the clinical symptoms to many febrile infectious diseases, as well as the low bacteriological capacity to identify the disease specially in less developed countries, it is difficult to determine the true rate of disease worldwide(8). In trials conducted in African and American countries, most cases in the non-immunized groups were estimated to be 810 per 100000 people in Indonesia(9), 643 in Nepal (10), 442 in South Africa (11), and 227 in Chile (12). It is endemic in Africa, Asia, and Central and South African countries, the Middle East, and Eastern and Southern Europe (3).

It is also an endemic disease in Iran; its frequency in 2004 was 541 cases with a national incidence rate of 0.8 per 100000. The disease is more or less present in all provinces of Iran, but the highest incidence was in Kerman, Baluchistan, and Hamedan provinces with a rate of 4 per 100000 (13).

Since the incidence of the disease varies in different Iranian provinces, understanding the geographical pattern of its incidence and prevalence can be very important for interventions and disease management. Disease mapping using GIS has been carried out around the world for many years. It is now considered as a first step in the development of disease warning systems, and its importance is increasing day by day (14-16) .

GIS is a powerful and useful application that can investigate the causes by presenting the geographical distribution pattern of the disease and quantitatively and qualitatively illustrate the spatial distribution of the illness. In this way, it can help health and treatment decisions to prevent and control the disease (17, 18). Therefore, the purpose of this study is to investigate the geographical distribution of Typhoid using the Geographic Information System (GIS) during 2009-2014 in Iran and to predict its incidence in Iran in 2021.

Methods

This research is a descriptive analytical study with applied results. The research uses spatial and climatic information and the incidence rate of typhoid in Iran. Initially, the information on typhoid was obtained from the Center for Communicable Diseases Control during 2009-2014. The incidence and frequency table for typhoid was prepared for each year and the incidence rate was calculated for 100000 people in Iran. In the next step, GIS was used to prepare geographic maps of the disease incidence and frequency. To prepare the spatial database for the disease, the vector map of Iran's administrative divisions for 2017 used by the National Mapping Organization was used to link descriptive information about the disease to the spatial data in the GIS environment. The geographical locations were verified through Google Earth. When the geographic database of the disease was developed, descriptive information such as incidence and frequency of the disease was added to the GIS descriptive table using Excel. Next, a spatial analysis was prepared to map the incidence and frequency distribution of disease during 2009-2014 in the GIS environment through Symbology functions. With the information of each province, the incidence and frequency map of the disease was prepared for the whole country. In order to plot the disease prediction map, it was assumed that the probability of disease occurrence was higher in regions with the highest incidence and the highest recurrence of disease in a statistical period. Therefore, using the Raster Calculator tool, the fuzzy map of the disease over a given period was multiplied by the disease recurrence map and the disease prediction map was eventually drawn (19). The map shows the most likely areas for disease incidence in red.

With the information of each province available, the incidence and frequency of disease were developed for the whole country. In order to plot the map of interpolation, the inverse distance interpolation (IDW) method was used (20).

High-risk points analysis

The Getis-Ord-Gi* statistic was used for the appropriate spatial distribution of hot and cold spots. A disease is recognized as a hot spot when its figures and those of its surrounding conditions are fairly high. When the Getis-Ord-Gi* statistic is calculated to be 1, 2, 3, the confidence interval is estimated at 99%, 95%, 90%, respectively (21).

Since the incidence data are obtained based on the findings of the routine healthcare system, the difference in incidence that was observed in different provinces can be largely dependent on the sensitivity of the healthcare system to record and report cases in these provinces.

Results

The results of our study showed that during 2008-2014 more than half (57.4%) of typhoid patients were women. 52.8% of patients were in urban areas, and 62.7% were self-employed. Also, 17.7% of all patients diagnosed during this period had travel experience. Fever was reported in 54.9% of the cases, 12.8% of patients had a cutaneous rash, 7.1% had a large spleen, and 12.8% had headache and consciousness disorder (Table 1).

The results of the study showed that most typhoid cases reported between 2008 and 2014 were in 2010 with 628 cases (Fig. 1).

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Table 1. Demographic information of typhoid patients in Iran during 2009-2014

Variable		Frequency (%)
Sex	Female	1982 (57.4)
	Male	1473 (42.6)
Place of residence	City	1825 (52.8)
	Village	1630 (47.2)
	Housewife	1247 (36.1)
Occupation	Government employee	41 (1.2)
	Self-employed	2167 (62.7)
Travel history	Yes	611 (17.70
	No	2844 (82.3)
History of fever	Yes	1898 (54.9)
	No	1557 (45.1)
Cutaneous rash	Yes	443 (12.8)
	No	3012 (87.2)
Large spleen	Yes	264 (7.1)
	No	3209 (92.9)
Headache and consciousness disorder	Yes	376 (10.9)
	No	3079 (89.1)

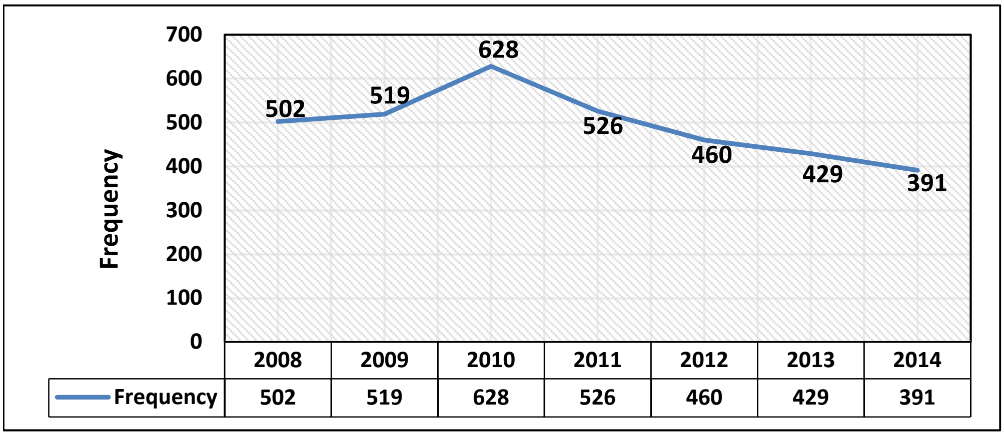

Fig. 1. Frequency of reported cases of typhoid during 2008-2014

According to the results of the present study, most typhoid cases during 2008-2014 were reported in June and May, with 409 and 403 reported cases, respectively (Fig. 2).

The results showed that the highest incidence of typhoid during 2009-2014 was in Kermanshah, Lorestan, Hamadan, Kurdistan, and Ilam provinces (Table 2).

The results indicated that the incidence of typhoid in Iran increased during 2009-2010. The annual incidence of typhoid decreased from 0.85 per 100,000 in 2010 to 0.5 in 2014 (Fig. 3).

The prepared GIS maps show the incidence of typhoid in different provinces during 2009-2014 (Fig. 4).

According to GIS maps of the whole country, 6.13% of the total area of Iran (101054.77 km^2) comprising parts of Ilam, Chaharmahal & Bakhtiari, South Khorasan, Khora-

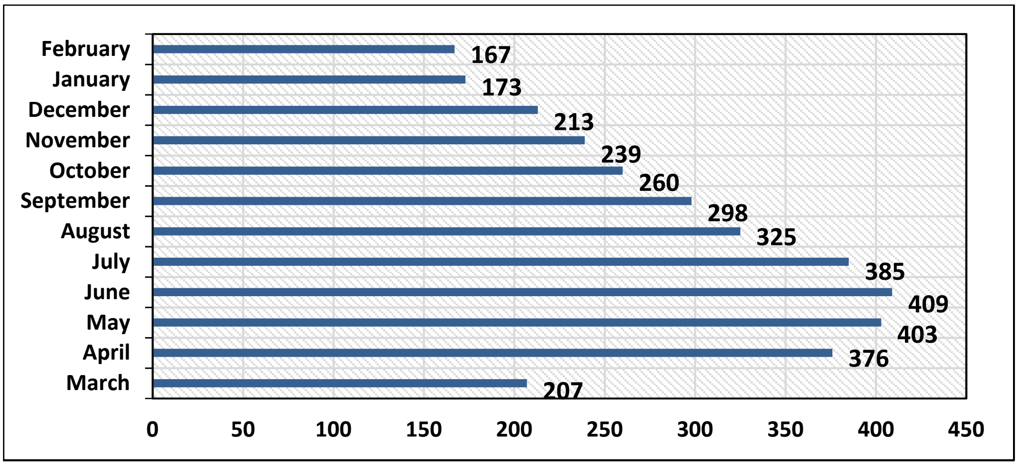

Fig. 2. Typhoid frequency according to the months reported

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Table 2. Incidence of typhoid per 100,000 population in Iran during 2009-2014

Row	Province	2009	2010	2011	2012	2013	2014
1	East Azerbaijan	0.00	0.14	0.54	0.51	0.63	0.05
2	West Azerbaijan	0.13	0.13	0.06	0.19	0.09	0.12
3	Ardebil	1.62	0.48	0.32	0.40	0.24	0.16
4	Isfahan	0.36	0.25	0.25	0.12	0.20	0.04
5	Alborz	0.48	0.04	0.25	0.28	1.04	0.55
6	Ilam	1.27	3.96	2.69	0.71	0.88	1.39
7	Bushehr	0.00	0.00	0.19	0.28	0.37	0.64
8	Tehran	0.19	0.17	0.13	0.11	0.10	0.07
9	Chaharmahal va Bakhtiari	0.34	0.56	1.56	1.44	0.44	0.11
10	Southern Khorasan	1.08	0.61	1.66	1.48	1.87	0.92
11	Khorasan Razavi	0.41	0.19	0.05	0.21	0.13	0.14
12	Northern Khorasan	0.71	0.35	0.00	0.00	0.00	0.00
13	Khuzestan	1.04	0.94	0.73	0.41	0.47	0.28
14	Zanjan	0.10	0.20	1.08	2.34	0.68	0.19
15	Semnan	0.65	0.00	0.32	0.16	0.46	0.60
16	Sistan and Baluchestan	1.13	2.43	1.89	0.77	1.02	0.70
17	Fars	0.56	0.64	1.09	1.31	0.87	0.95
18	Qazvin	0.26	0.17	0.42	1.15	0.98	1.70
19	Qom	0.00	0.00	0.00	0.00	0.00	0.00
20	Kurdistan	1.97	3.44	2.74	1.73	1.32	1.25
21	Kerman	1.24	0.90	0.41	1.17	0.56	1.24
22	Kermanshah	5.94	6.21	3.50	1.59	1.12	1.42
23	Kohgiloyeh and Boyerahmad	2.31	1.84	1.52	0.75	0.00	0.00
24	Golestan	0.00	0.17	0.06	0.28	0.00	0.00
25	Gilan	0.20	0.61	0.28	0.24	0.24	0.20
26	Lorestan	3.57	5.27	3.02	1.86	1.90	2.00
27	Mazandaran	0.30	0.26	0.36	0.19	1.34	1.84
28	Markazi	0.22	0.93	0.85	0.70	0.62	0.00
29	Hormozgan	0.00	0.52	0.13	0.19	0.00	0.00
30	Hamedan	0.92	1.77	2.16	2.60	2.25	1.18
31	Yazd	0.29	1.89	1.58	1.37	1.24	1.59
	Whole country	0.71	0.85	0.70	0.60	0.56	0.50

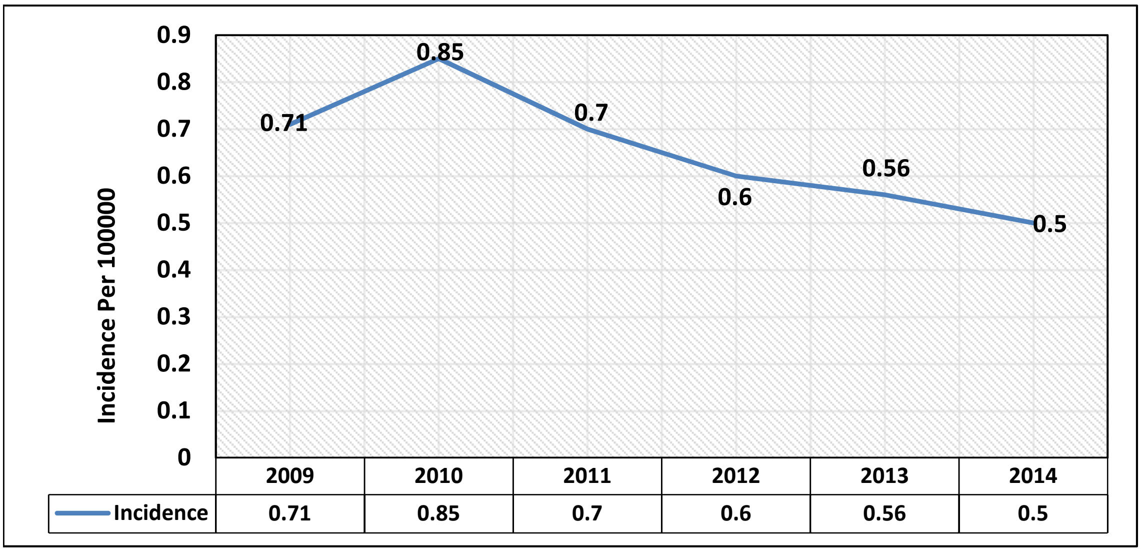

Fig. 3. Trend of typhoid incidence in Iran during 2009-2014

san Razavi, Khuzestan, Sistan And Baluchistan, Fars, Kurdistan, Kerman, Kermanshah, Lorestan, Mazandaran, Markazi, Hamadan and Yazd provinces are at high risk for typhoid in the coming years (2021). Based on the modeling results in Iran, Kermanshah, Lorestan, Kurdistan, Ilam, and Hamedan provinces with 92.17%, 46.56%, 31.74%, 25.62% and 22.96% of their areas(Km^2), respectively, are at high risk for typhoid in the coming years. (Fig. 5).

Discussion

Infectious diseases remain the leading cause of mortality in developing countries (22, 23) . Typhoid fever is very important among the diseases caused by Salmonella infection. Increased antimicrobial resistance among typhoid and non-typhoid species of Salmonella is increasing, which adds to the importance of the Issue (24-26). Typhoid fever is associated with debilitating complications and high mortality if not timely diagnosed and appropriately treated (27).

The results showed that the highest incidence of typhoid during 2009-2014 was in Kermanshah, Lorestan, Hamadan, Kurdistan, and Ilam provinces. The incidence of ty-

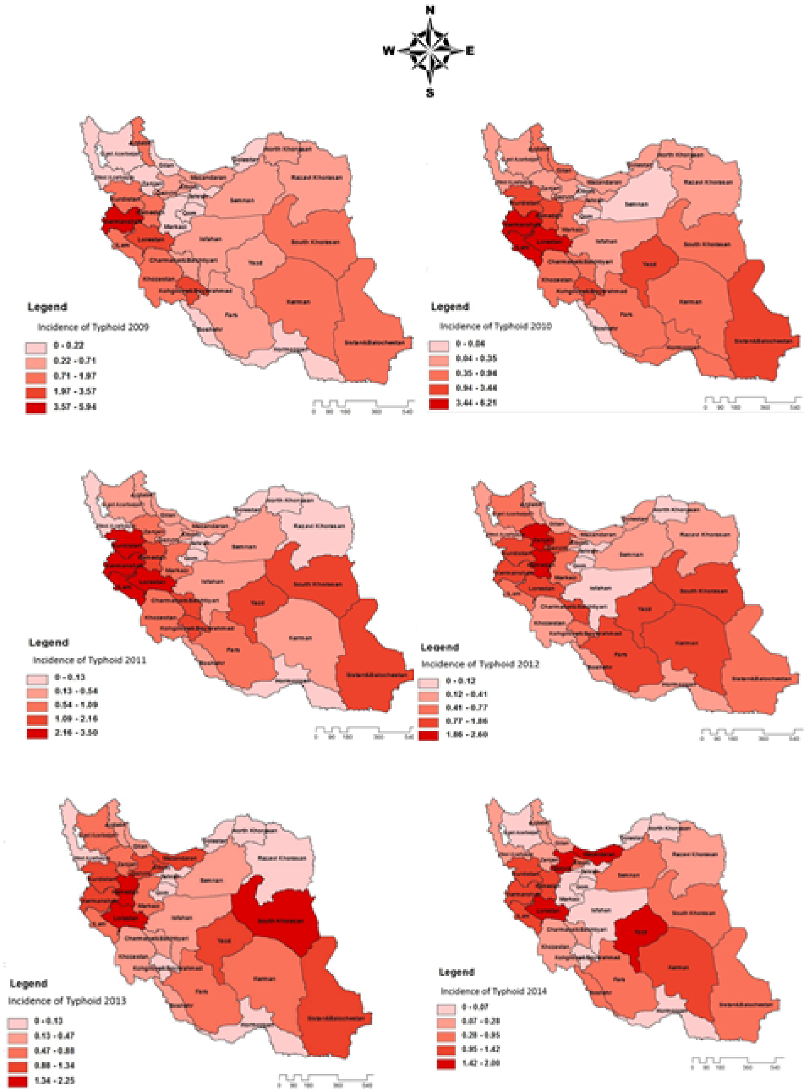

Fig. 4. Typhoid incidence in Iran during 2009-2014

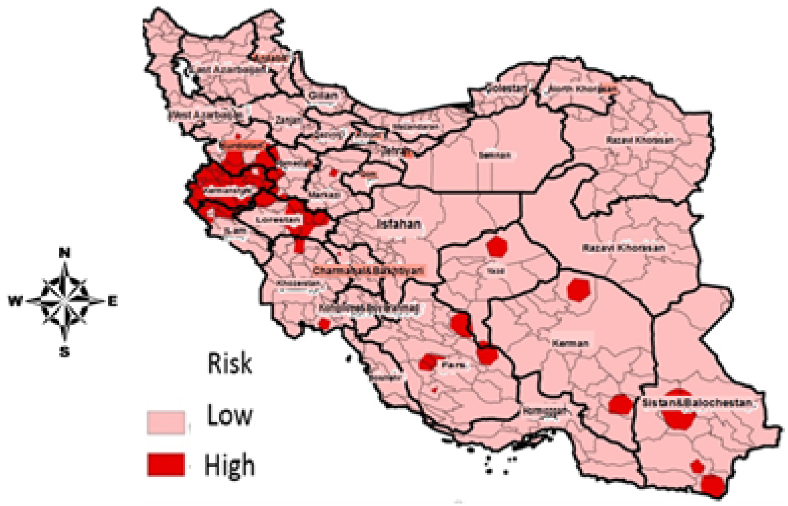

Fig. 5. Prediction of high-risk areas for typhoid in Iran in 2021

phoid in Iran increased during 2009-2010. The annual incidence of typhoid decreased from 0.85 per 100,000 in 2010 to 0.5 in 2014. Based on the modeling results for Iran, Kermanshah, Lorestan, Kurdistan, Ilam and Hamadan provinces with 92.17%, 46.56%, 31.74%, 25.62% and 22.96% of their areas are at high risk for typhoid in the coming years, respectively.

Typhoid is one of the endemic diseases in Iran. Typhoid fever is a widespread disease in deprived areas with poor climatic conditions and health standards. Most of these areas do not have access to laboratory facilities due to economic poverty, resulting in delays in diagnosis and treatment and leading to dangerous complications and high mortality. The disease is more or less reported in all provinces of Iran, but the highest incidence has been in Kermanshah, Lorestan, Markazi and Kurdistan provinces. The incidence of disease was different in Iranian provinces in 1996: most cases were in Kohkiloyeh and Boyer Ahmad, Sistan and Baluchestan, Kerman, Hormozgan, Kermanshah, Kurdistan, Lorestan and Semnan provinces, 57% of which were in urban and 39% were in rural areas (28). The results of our study showed that the highest incidence of typhoid during 2009-2014 was in Kermanshah, Lorestan, Hamadan, Kurdistan and Ilam provinces.

The total number of patients reported in 2004 in Iran was 541, and the incidence rate was 0.8 per 100,000. Kerman, Sistan and Baluchistan and Hamadan provinces had the highest incidence (over 4 per 100,000 population) (13). In a study by Ranjbar et al., out of 161 suspected Salmonella cases in Tehran, 60 were reported as Salmonella typhi(26). In a study conducted in Rasht, 2031 suspected cases were investigated and the prevalence rate was 3.9% (13).

The United States reports 500 cases of the disease annually. In studies conducted in Asia, the incidence of typhoid in Vietnam, China, Indonesia, Pakistan, and India was 24, 29, 180, 413, and 493 per 100000 population, respectively (29). In endemic areas, besides typhoid fever, many other factors are involved in the development of long-term fever. Therefore, timely and accurate diagnosis is difficult and important. Serological tests are available in most laboratories but have low sensitivity and specificity (2, 30).

The Disease Control Center publishes annual reports on a number of diseases, including typhoid and pseudo typhus. According to reports, a decreasing trend of the disease is observed in Iran. According to the 1996 statistics, the number of cases decreased from about 90 per 100,000 in 1981 to about 10 per 100,000 in 1996, a decreasing trend that is evident in all Iranian provinces. According to the Ministry of Health's Center for Infectious Diseases Management, the incidence of the disease in 2011 was less than 0.5 per 100,000 (28) .

The results of our study showed that the incidence of typhoid in Iran increased during 2009-2010 and decreased from 0.85 in 2010 to 0.5 per 100,000 in 2014. This could be due to the expansion of water supply networks and access to safe and healthy water that has been able to control the disease spread. Based on the modeling results for Iran, Kermanshah, Lorestan, Kurdistan, Ilam, and Hamadan provinces with 92.17%, 46.56%, 31.74%, 25.62% and 22.96% of their areas are at high risk for typhoid in the coming years, respectively.

As salmonella infections have a direct relationship with personal and environmental health status, people at lower socioeconomic levels are more susceptible to the disease. Therefore, there is a need for more planning and health interventions in Kermanshah, Lorestan, Kurdistan, Ilam, and Hamadan provinces that are at a higher risk of the disease incidence in the coming years.

The general principle of controlling many diseases, especially infectious diseases, is to adhere to the principles of individual health and education in the community (31). Therefore, personal hygiene, provision of safe water for drinking or washing, proper disposal of human waste and monitoring and treatment of chronic carriers can reduce the incidence of the disease in these areas.

Conclusion

According to the results of the study, the trend of disease incidence has been decreasing in recent years. Based on the modeling maps, the provinces of Kermanshah, Lorestan, Kurdistan, Ilam, and Hamadan are at risk of typhoid incidence in the coming years in Iran. On the other hand, as salmonella infections have a direct relationship with the individual's health status and individual's environmental health and socioeconomic status, improving the health status and disease control in carriers as well as improving the socio-economic status of the population living in these areas can prevent the disease in the years to come.

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Conflict of Interests

The authors declare that they have no competing interests.

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