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Spatial-temporal Analysis of Brucellosis Using GIS in Ilam Province During 2014-2019

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A B S T R A C T

Introduction: Brucellosis is a highly prevalent disease affecting both humans and animals in Iran. Given the significant role of animal husbandry in Ilam province, it was important to conduct a spatiotemporal analysis of the disease in the region between 2014 and 2019.

Materials & Methods: This study is a descriptive-analytical study. Information about all individuals infected with Brucellosis was collected through a census method. Moran's I was employed to determine the clustering of the disease; Getis-Ord Gi analysis was utilised to identify hotspots; and the Cochran-Armitage test for trend was used for time analysis. Stata and GIS software were applied for data analysis.

Results: In total, 703 cases of Brucellosis were studied. The highest incidence rates were witnessed in Malekshahi (258.97 per 100,000 people) and Dehloran (256.93 per 100,000 people). The highest incidence of the disease by year was in 2014 (26.2 per 100,000 people), by age group was in people aged 41-60 years (213.87 per 100,000 people), and by sex was in men (133.72 per 100,000 people). According to the results of the Getis-Ord Gi analysis, Chardavol city in 2015 and Mehran city in 2016 were identified as hotspots at a 99% confidence level ($p<0.01$). Nevertheless, no clustering pattern was observed along the study years based on Moran's I results ($p > 0.05$ for all years). Further, the time trend of brucellosis from 2014 to 2019 was not significantly associated with $p>0.05$.

Conclusion: The study indicated that Malekshahi and Dehloran had the highest risk of brucellosis infection over the six-year period.

Keywords: Brucellosis, Ilam province, GIS, spatiotemporal analysis, Incidence Rate

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Introduction

Brucellosis is a prevalent infectious disease in many regions of Iran, posing a significant threat to the country's public health (1-3). Brucellosis is a facultative intracellular pathogen found in agricultural and animal husbandry societies (4, 5). Different animal species, including cattle, harbor various species of Brucella, resulting in accidental human infectionsAmong the different species of Brucella, only four are pathogenic to humans depending on their main host and pathogenicity, causing disease in the human body (7, 8). Brucella abortus and Melitensis are the most common causes of disease in humans. Seven types of Brucella have been accurately detected, including Brucella national Tennessee, Brucella abortus, Brucella suis, Brucella canis, Brucella ovis, Brucella neotomae, and Brucella maris. In Iran, Brucella national, Tennessee, is the predominant type of this disease (9-11).

Humans can contract brucellosis via several means, such as consuming raw milk and contaminated dairy products or direct contact with biological products of contaminated livestock, as well as respiratory transmission through inhalation of suspended particles from livestock (11). The disease can cause complications affecting multiple organs in the body. In acute cases, it is a febrile disease that, if left untreated or not treated promptly, can change into a chronic disease with severe complications and in some instances lead to mortality (12). In animals, the disease can cause abortion, placental abruption, and fertility disorders, along with testicular and breast inflammation, while in humans, it can result in meningitis, endocarditis, nephritis, and pancytopenia (13). The incidence of brucellosis is seasonal, peaking in spring and summer when animals are pregnant and giving birth (3). The World Health Organization defines any disease or infection that naturally transmits between vertebrates and humans as a human-animal transmissible disease (zoonosis) (3, 14). Almost 60% of emerging human pathogens are zoonotic diseases (15), making brucellosis one of the most significant zoonotic diseases worldwide. It is present in almost all countries globally (16).

In the United States, nearly 100 cases of brucellosis are reported each year, making it one of the most common human and animal diseases. It has caused the deaths of more than 500 million people globally, with an annual death rate of approximately 370 individuals (17, 18). In endemic areas, the incidence of the disease ranges from less than 0.030 to more than 200 per 100,000 people (19).

In Iran, 2010-2020, the incidence rate of brucellosis varied from 1 (per 100,000 people) in Hormozgan to 74.8 in Lorestan province. In 2020, high incidence rates were related to the Lorestan, Hamedan, and Kurdistan provinces of Iran (21 per 100,000 population) (20, 21).

GIS is an application software that can provide a spatial distribution model of certain diseases through maps, enabling the investigation of the causes as well as the quantitative/qualitative distribution of the disease (22). The province of Ilam, covering 19.086 square kilometers, comprises about 1.4% of Iran's total area and is located in the west of the Zagros Mountains (23). In the study by He et al. (24), they examined the economic burden of human brucellosis on patients in Xinjiang, China. They highlighted the significant financial strain faced by individuals from lower socioeconomic backgrounds.

Studies suggest that location plays a key role in the occurrence of brucellosis. One way to ascertain the impact of location on a phenomenon of interest is by employing a spatial information system (25). This study is among a few that have simultaneously undertaken spatial and temporal analysis.

The purpose of this study was to explore the spatiotemporal distribution of brucellosis in order to identify high-risk cities in terms of disease incidence. The use of GIS technology in establishing and distributing health services can enhance productivity in the field of healthcare and treatment.

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This can aid in implementing policies for controlling as well as preventing brucellosis, as it is a common zoonotic disease in the province. By applying information collected from relevant organizations, it becomes possible to provide services in the affected regions and effectively control the spread of this disease.

Materials and methods

Ilam province covers an area of 19.086 square kilometers, constituting roughly 1.4% of Iran's total land area. Located to the west are the Zagros Mountains (23, 26). The province's geographical location falls between 45 degrees and 44 minutes and 48 degrees and 10 minutes east longitude of the Greenwich meridian and 31 degrees and 58 minutes to 34 degrees and 15 minutes north of the equator. Figure 1 displays a visual representation of the geographical position of Ilam province.

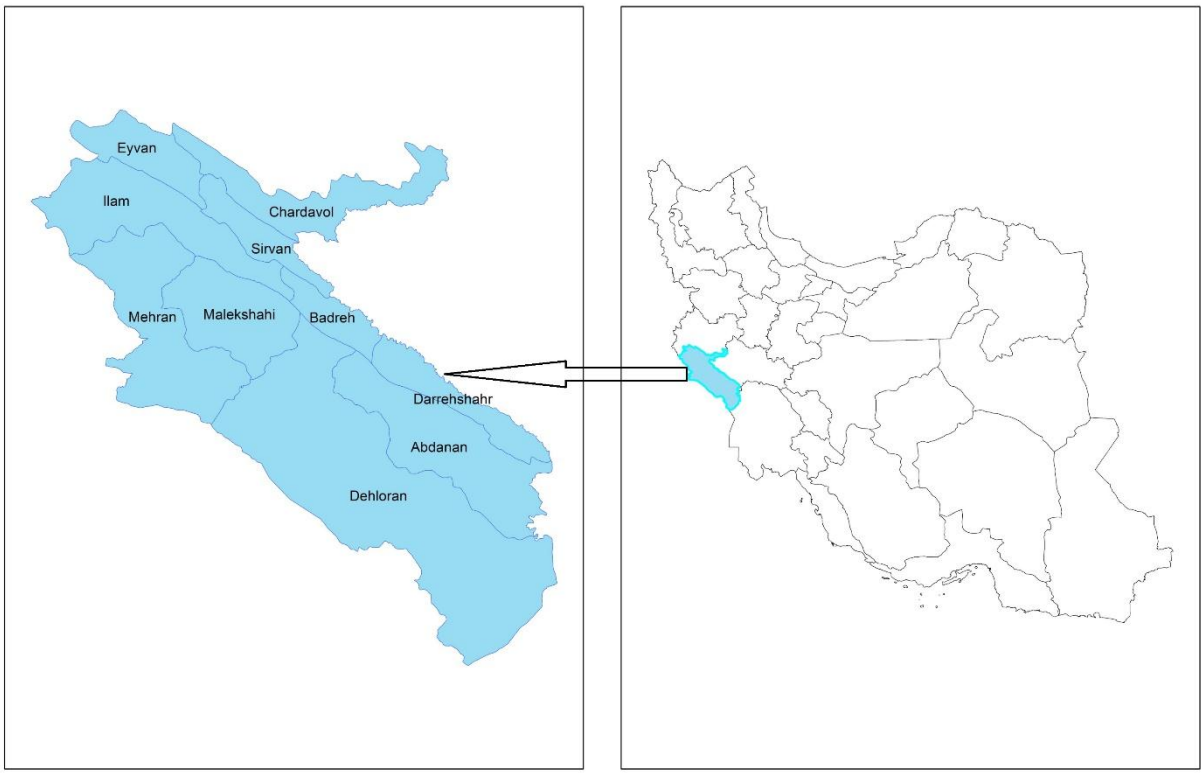


Figure 1. Location of Ilam province separated by county on the map of Iran.

Type of study

The current study is a descriptive-analytical cross-sectional study performed in the form of a census along the years 2014-2019 in Ilam Province. Initially, the information of all people suffering from brucellosis was extracted from the vice-chancellor of health of Ilam Province. Informed consent was obtained from the participants. In this study, the criteria for recruiting subjects into the study of brucellosis diagnosis were based on laboratory isolation of the agent from clinical samples at the culture site, the 2-mercaptoethanol test, and the Coombs Wright test. It was three dilutions higher than Wright's after cleaning and correcting of errors. Note that there were no patients identified by serology or other methods. Next, the incidence rate was calculated with 95% confidence limits using Stata software and based on Formula 1 by age, sex, year, and season, where the number of reported cases was equal to the number of disease cases and the total population at risk was equal to the number

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of the population, as obtained by the National Bureau of Statistics.

$$Incidence\ rate\ of\ brucellosis = \frac{Number\ of\ reported\ cases}{Total\ population\ at\ risk} * 100{,}000$$

Mapping and data analysis

The electronic map (shape file) of Ilam Province was prepared separately for the cities and imported into ArcMAP 10.4.1 software. The information entered into Excel was then joined to the map using a common field. A geographical layer was prepared through exporting the software for analysis. A choropleth map was created which would apply a range of colours to display variable changes in the layers of polygons generated at the county level both in total and by year of study. In order to classify the incidence of the disease, an equal interval was employed.

Moran's I index

The Moran index is a tool of spatial autocorrelation utilised in this study. The value of the Moran index ranges from -1 to +1. A Moran's I value greater than zero represents positive spatial autocorrelation; less than zero reflects negative spatial autocorrelation, and zero indicates no spatial autocorrelation (27). The value of this index was calculated using the following formula:

$$\boldsymbol{I = \frac{N}{\sum_{i=1}^{N}\sum_{j=1}^{N} W_{ij}} \times \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} W_{ij} Z_{ij}}{\sum_{i=1}^{N}(Z_i)2}}$$

Map hot spots

The disease hotspots were identified using the Getis-Ord Gi* statistic. The hotspot analysis was calculated using Formula 3, where B_i denotes the incidence of brucellosis for the city, w_{ij} represents the spatial weight between cities I and J, and n equals the total number of cities. The result of the statistic calculates a score for each city based on which it is possible to indicate high or low accumulation of disease in one place, calculated by considering the occurrence of the disease in neighboring cities.

A county with a high incidence of brucellosis was considered to be a statistically significant hotspot, especially when surrounded by counties with high incidence. The value belonging to a particular county was compared proportionally to that of the rest of the counties. If the local value was far different from the expected local sum and the difference was too large to be the result of random chance, a statistically significant score would be obtained. On the contrary, a cold spot county was one in which a low incidence of brucellosis was detected and which was also surrounded by counties with low incidences.

For hotspot analysis, we employed the fixed-distance band method to calculate spatial weight. Using this method, each county was analyzed within the context of neighboring counties. The neighboring counties located within the specified critical distance were given a weight of one and affected computations for the target county. The counties located outside the critical distance were given a weight of zero and had no impact on the target county's computations. For determining the critical distance, we utilized the Euclidean distance method, which calculates the straight-line distance between the centroids of two polygons. In other words, it refers to the minimum distance between the centers of two polygons. The center of each polygon was determined using the centroid method. Note that the standardization was not utilized in the weighting process.

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$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} - \bar{x} \sum_{j=1}^{n} w_{i,j}}{s\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}}$$

Test for time trend

The Cochran-Armitage test was employed to ascertain trends in the incidence rate of the disease over the study period. Specifically, this statistical method was utilized to identify linear trends in monthly incidence rates, as well as to determine whether these trends were statistically significant.

Results

In 2014-2019, there were a total of 703 reported cases of brucellosis. The incidence of the disease was analyzed based on different variables, as listed in Table 1.

Table 1. Brucellosis incidence rate (with %95 confidence interval) per 100,000 individuals, characterized by age group, occupation, gender, year and season.

Variable		Number of people	Number of cases	Incidence (% 95 C.I) per 100,000 people
Age Group (year)	< 20	166656	87	52.35 (41.93 to 64.57)
	21-40	238079	243	102.07 (89.664 to 115.73)
	41-60	117826	252	213.87 (188.3 to 241.94)
	> 60	61095	121	198/05 (164.36 to 236.6)
Sex	Male	296894	397	133.72 (120.89 to 147.53)
	Female	286761	306	106.71 (95.09 to 119.35)
Year	2014	573683	151	26.32 (22.39 to 30.87)
	2015	573072	139	24.26 (20.39 to 28.64)
	2016	580158	109	18.79 (15.43 to 22.66)
	2017	586450	129	22 (18.37 to 26.14)
	2018	591750	94	15.89 (12.84 to 19.44)
	2019	596821	81	13.57 (10.78 to 16.87)
Season	Spring	583656	175	29.98 (25.71 to 34.77)
	Summer	583565	233	39.92 (34.96 to 45.39)
	Autumn	583656	137	23.47 (19.71 to 27.75)
	Winter	583656	158	27.07 (23.01 to 31.64)

Among men, the incidence rate was 133.72 per 100,000 people (95%CI: 120.89 to 147.53). The age group with the highest incidence rate was 41-60 years, at 241.94 per 100,000 people (95%CI: 213.87 to 270.01), whereas the lowest incidence rate was found in the age group of 1-20 years, at 52.35 per 100,000 people (95%CI: 41.93 to 64.57).

Considering study year, the highest incidence rate was witnessed in 2014, at 26.32 per 100,000 people (95% CI: 22.39 to 30.87), while the lowest incidence rate was found in 2019, at 13.57 per 100,000 people (95% CI: 10.78 to 16.87). With regard to season, the highest incidence rate was in summer, at 39.92 per 100,000 people (95% CI: 34.96 to 45.39). Further details can be found in Table 1.

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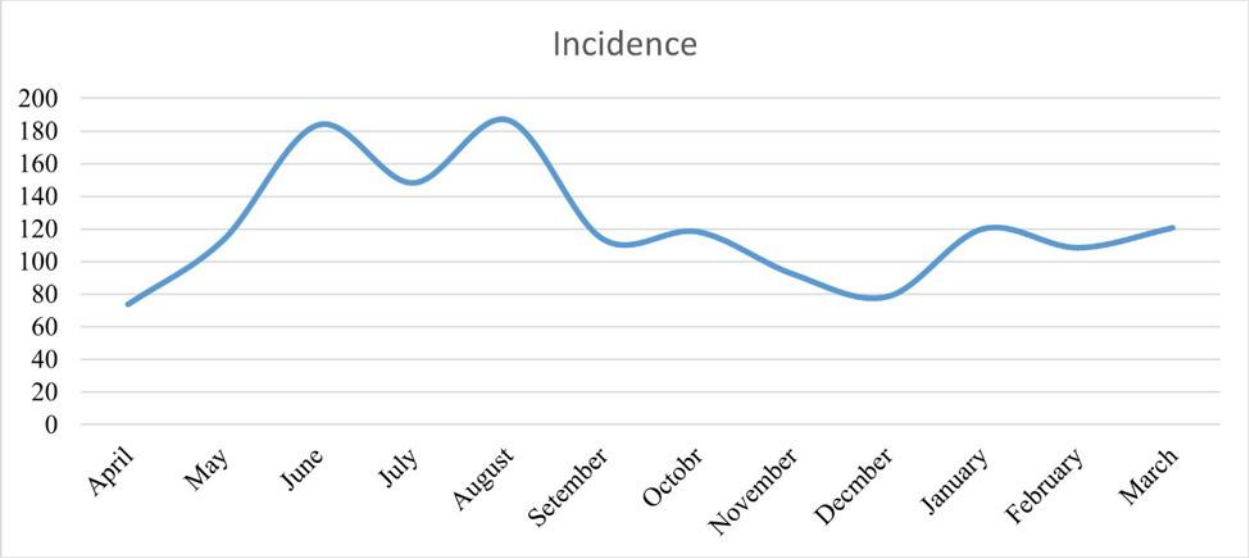


Figure 2. Time trend of brucellosis among different months of the year during 2014–2019.

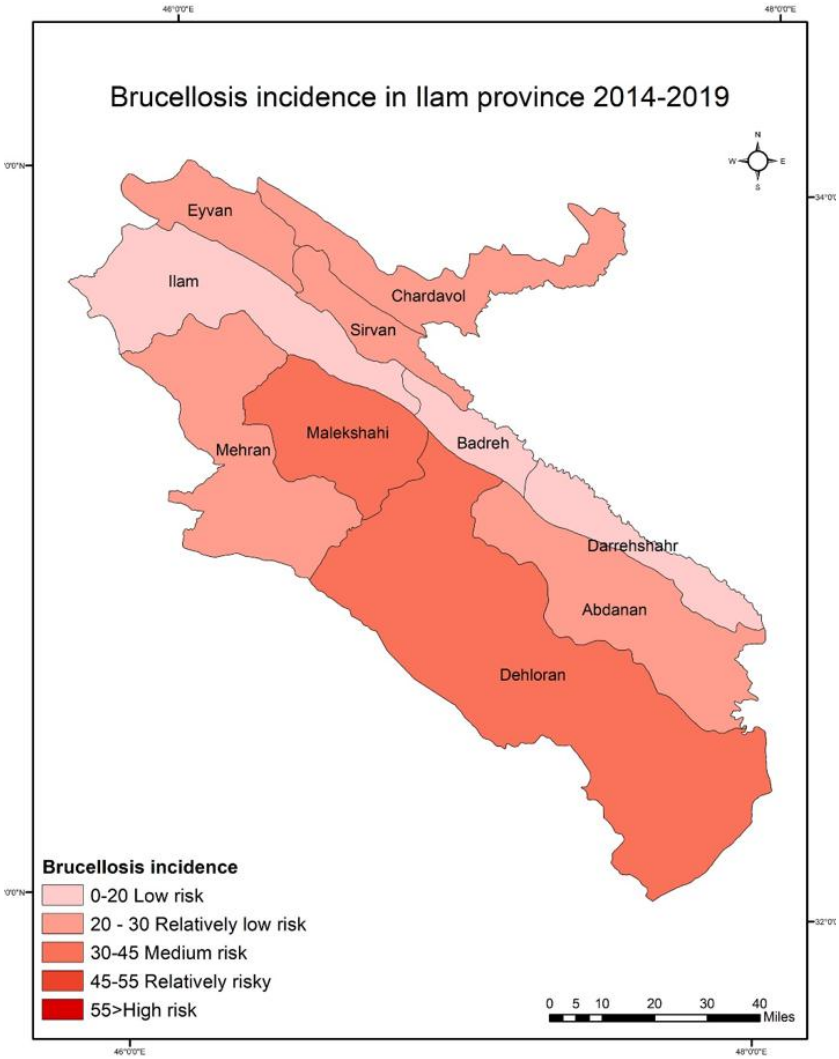


Figure 3. Choropleth map for total brucellosis incidence rate (from year of 2014 to 2019) separated by county in Ilam province.

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Figure 2 depicts the overall incidence of the disease, while Figure 3 exhibits the incidence of the disease by year across different cities. The highest incidence rates along the years 2019-2014 were observed in Malekshahi (258.97 per 100,000 people; 95% CI: 196.2 to 335.4) and Dehloran (256.93 per 100,000 people; 95% CI: 219.69 to 298.66), whereas the lowest incidence rates were found in Badra (76.18 per 100,000 people; 95% CI: 39.37 to 133.03), Darrehshahr (55.94 per 100,000 people; 95% CI: 36.2 to 82.56), and Ilam (51.6 per 100,000 people; 95% CI: 42.87 to 61.7) (see Figure 2). Figure 3 demonstrates the incidence of the disease by year at the county level. Figure 1 in the supplementary file displays the hot-spot & cold-spot map at the county level for each year of the study. In 2015, Chardavol City was identified as a hotspot at a 99% confidence level, while in 2016, Mehran City was identified as a hotspot with the same level of confidence. According to the map, Dehloran city was a hotspot in 2018, while Darrehshahr was detected as a cold spot in 2015; nevertheless, these findings were not statistically significant (p-values > 0.05). No specific pattern was observed for the other cities along the study years (see Figure 2 in the supplementary file). The Moran results are revealed in Figure 3 in the supplementary file by study year, while the analysis output is provided in Table 2.

Table 2. Result of Moran's Index for high-low clustering of brucellosis incidence rates during 2014-2019.

Type of distribution	year	P-value	Z-score	Morans Index
Random	2014	0.73	-0.33	-0.23
Random	2015	0.37	0.89	0.22
Random	2016	0.74	-0.32	-0.20
Random	2017	0.20	-1.25	-0.52
Random	2018	0.46	0.73	0.13
Random	2019	0.30	-1.03	-0.41

The results suggest that there was no clustering pattern for the occurrence of brucellosis in any of the Ilam cities along the study period, and the distribution of the disease appeared to be random.

Analysis of disease trends demonstrated that the incidence of brucellosis was highest in August along all years of the study (2014-2019). The course of the disease exhibited several fluctuations, but no significant linear trend was observed along the months, according to the findings of the Cochran-Armitage test ($p > 0.05$)

Discussion

This study aimed to analyze the spatiotemporal patterns of brucellosis across various cities within Ilam province. These patterns can assist health decision-makers in prioritizing staffing and equipment budgeting, as well as disease control efforts in different locations and timeframes.

The results of this study revealed that the age group of 41-60 (84.35%) had the highest number and incidence of brucellosis. Conversely, the age group under 20 showed the lowest percentage. In a study performed in Kermanshah province, the largest number of disease cases was reported in the age groups of 50-59 years and 30-39 years (29). Similarly, Oliver et al. reported a mean patient age of 50 years (30). Nevertheless, another study in our country indicated that the majority of cases occurred in patients under 40 years old (31). Farahani's study, exploring the epidemiological characteristics of patients in Arak city over a ten-year period, found that the most common age group was 10-19 years (32). Qureshi et al. noted that the most affected age group was 25-29 years (7). This study included 400 participants who fulfilled the inclusion criteria. The study included 191 (47.8%) females and 209 (52.2%) males, with an average age of 35.7 (±12) years (33).

In conclusion, it can be inferred from these studies that brucellosis affects all age groups, with a higher incidence in those under 40 years old. On average,

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the disease occurs more frequently in the active and efficient sections of society. The variations in disease incidence among age groups in different studies can be attributed to disparities in age group classifications and age ranges of subjects.

The results of the study demonstrated that the incidence of brucellosis in men was 133.72 per 100,000 and in women was 101.71 per 100,000. When expressed as a percentage, 56.47% were men and 43.52% were women. In Sudjani et al.'s study undertaken in Shahrekord, 27.3% were women and 72.7% were men (34). Likewise, in Fard Azar's study conducted in 2012-2013, the prevalence of the disease was 52.55 per ten thousand in men and 43.11 per ten thousand in women (35). Farahani Solar's study in Arak for nine years reproted the highest percentage of patients was male (32). In most studies, including those by Honarvar et al., the incidence of the disease was higher in men (36-38). This could be attributed to the higher likelihood of men to have more contact with livestock owing to their occupations. Nevertheless, few studies such as the Mohammadian study reported the highest incidence in women (35). The study performed by Honarvar and colleagues in Fars reported 59% of cases were women and 41% were men (39). This could be because women have greater involvement in animal husbandry practices and therefore have higher exposure to contaminated dairy products.

The present study also found that the highest incidence of brucellosis as well as the highest percentage of patients occurred in spring with an incidence of 29.98 per hundred thousand people and in summer with an incidence of 39.92 per hundred thousand people. Conversely, the minimum incidence of the disease was witnessed in autumn and winter. Hosseini et al.'s epidemiological study undertaken in Quchan city in 2013 also concluded that the lowest prevalence of the disease was observed in autumn and the highest in spring (40).

Elsewhere, according to Moosazadeh et al., the highest number of patients with brucellosis occurred during spring (41). In a study by Dadar et al.(42), they presented the meta-epidemiology of brucellosis across Iranian livestock. The most afflicted livestock animal in Iran was the cow, with a 14.7% total frequency. Further, brucellosis was more common in women (10.9%) than in men (8.2%), with blood and semen being the most researched and polluted samples, respectively.

The results of almost all studies reveal that the highest incidence of brucellosis occurs during spring and summer. Thus, based on these studies, it can be inferred that the peak incidence of brucellosis typically occurs during these two seasons, with some studies presenting higher rates during spring and others during summer. Overall, these two seasons are considered to be the most contaminated. This may be owing to the increased birth of livestock and contact with calving secretions, which elevates the risk of contracting brucellosis.

Limitations and Strengths

In spite of its significant contributions, the study had limitations, such as probable underreporting of cases because of symptom overlap with other febrile illnesses, as well as a failure to account for socioeconomic factors that may influence disease transmission. Future research could fill these gaps by capturing a larger variety of characteristics, such as healthcare access and socioeconomic position, to improve our understanding of brucellosis transmission dynamics across geographies. Further, expanding the study to include other regions may provide a more comprehensive picture of the epidemiological aspects of brucellosis in Iran.

Conclusion

Overall, this study presented a complete analysis of the incidence and spatiotemporal trends of brucellosis in Ilam province from 2014 to 2019. The findings indicated significant seasonal fluctuations, with the highest rates occurring in spring and summer. It also pointed to a higher frequency of the condition in men, especially in the 41–60 age range.

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This is consistent with earlier research conducted in Iran, suggesting that the disease surges during the calving seasons, most likely in response to increased contact with infected animal products and livestock. The results also demonstrate that disease incidence varies by area, with certain cities harboring much higher rates. This information could help health authorities allocate resources and implement targeted interventions.

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CRediT authorship contribution statement

Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Software, Data Curation, Writing–Original Draft Preparation, Writing–Review & Editing, Visualization, Supervision, Project Administration: FM, PV, AA, AN, KS, AK.

Declaration of Generative AI and AI-assisted technologies in the writing process

We did not use artificial intelligence programs in this article.

Conflict of interest

All authors declare that they have no conflict of interest.

Ethical considerations

Ethical concerns included acquiring the ethics code (IR.MEDILAM.REC.1399.282), ensuring integrity in library collection and data reporting in accordance with the Declaration of Helsinki.

Data availability statement

All data of this study can be in access by email with corresponding Author.

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