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Time Series Model for Forecasting the Prevalence of Some Important Parasitic Infections in Slaughtered Sheep in North-Central Iran

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ABSTRACT

Uncontrolled parasitic infections in livestock can increase the potential risk of transmission between human societies. The current study aimed to forecast the prevalence of some important parasitic infections in a central slaughterhouse in Alborz Province, north-central Iran. Data from 2009 to 2018 on parasitic infections in slaughtered sheep presented at this slaughterhouse were compiled and the prevalence of these diseases was computed. The prevalence has been considered as a time series and afterward, RStudio software using the best-fitted ARIMA model was applied to forecast the monthly variation in prevalence rates. Totally, 1,339,196 sheep were slaughtered in the studied slaughterhouse. The Iranian Afshari breed was the most slaughtered sheep and, a total of 77.6% of these animals were raised under traditional farming system. In addition to the Alborz Province, slaughtered sheep were brought from five other provinces, including Zanjan, Qazvin, Qom, Kurdistan, and East Azerbaijan. The highest and lowest total prevalence of studied parasitic zoonoses in slaughtered sheep were CE (12.76%) and *T. ovis* infection (0.01%), respectively. An approximate stationary trend for fascioliasis and CE, a mild decreasing trend for dicrocoeliasis and sarcocystosis, and an increasing trend for *T. ovis* infection has been forecasted for the next 10 years. The current study was the first of predicting some important parasitic infections in sheep in a central slaughterhouse in Iran. The results provide informative data for authorities to control such infections. Vast and in-depth forecasting investigations is required to find evidence-based data about these infections for entire the country of Iran.

1. Introduction

Parasitic infections in livestock are considered an important socioeconomic burden all over the globe, especially in developing countries (Torgerson and Macpherson 2011, Harandi et al., 2012, Hajipour et al., 2021). Uncontrolled parasitic infections in livestock can increase the potential risk of transmission between human societies (Rist et al., 2015). Nationwide monitoring programs are required in slaughterhouses as the frontline of meat production to prevent the distribution of these zoonotic infections (Ebrahimipour et al., 2020). Among the causative agents of infection in livestock, parasites (helminths and protozoans) are well-known in veterinary and human medicine (Khedri et al., 2021).

Cystic echinococcosis (CE), liver fluke's infections (fascioliasis and dicrocoeliasis), cysticercosis (*Taenia ovis* infection), and sarcocystosis (a protozoan zoonotic infection) are among the most important parasitic diseases that affect the productivity of sheep across the world (Getaw et al., 2010, Morgan et al., 2013). The larval stage (metacestode) of *Echinococcus granulosus*, the causative agent of CE is formed in livestock viscera, particularly the liver and lungs. The prevalence of this infection is quite high in herbivorous animals and slaughtered livestock, especially in developing countries (Motazedian et al., 2019, Najjari et al., 2020, Vaisi-Raygani et al., 2021). Fascioliasis and dicrocoeliasis, as significant zoonotic helminth diseases are caused by *Fasciola* spp. (*F. hepatica* and/or *F. gigantica*) and *Dicrocoelium dendriticum*, respectively. These infections are important in the liver infection of herbivorous livestock and accidentally humans. They can cause economic losses by edible organs condemnation, diminution of milk and meat production, as well as some disorders such as diarrhea, weight loss, abdominal pain, anemia, and cachexia in infected animals (Mwabonimana et al., 2009, Kordshooli et al., 2017, Fthenakis and Papadopoulos 2018, Khademvatan et al., 2019, Vasileiou et al., 2019, Najjari et al., 2020).

Cysticercosis or sheep measles is a non-zoonotic infection that is mainly caused by the cestode *T. ovis*. The intermediate hosts are infected by eating the fertile eggs of parasites excreted with the feces of canids' definitive hosts. This infection threatens the sheep industry due to meat infections and condemnation of the whole carcass or trimming of a large part of the meat (Hashemnia et al., 2016, Hajipour et al., 2020). Sheep become infected with sarcocystosis by eating sporocysts of *Sarcocystis* spp. excreted in dog feces. The heart, diaphragm, esophagus, and skeletal muscles are the preferred organs for this infection. Severe infection in animals represents weight loss, anemia, abortion, and death. This infection imposes considerable economic loss throughout the world (Dehaghi et al., 2013, Dubey 2015, Shahraki et al., 2018, Anvari et al., 2020, Rosenthal 2020).

Slaughterhouses, as highly efficient facilities related to meat production, should be routinely monitored for various infections, including parasitic diseases. Continuous evaluation of sanitary conditions of these places is required to prevent the scattering of diseases. The diagnosis of parasitic infections in slaughterhouses is mainly based on traditional post-mortem examination by veterinary specialists. Routine sanitary monitoring of carcasses and viscera of livestock is essential to identify potential parasitic infections including CE, fascioliasis, dicrocoeliasis, cysticercosis (*T. ovis* infection), and sarcocystosis in these animals (Najjari et al., 2020, Esteves et al., 2021). Providing evidence-based information to authorities facilitates the control and management of infectious diseases in endemic regions. Estimating the future prevalence of infectious diseases could offer reliable information to related official institutions to combat diseases. Nowadays, mathematical modeling has been used successfully to predict the prevalence of many diseases in previous studies (Paton and Thomas 1987, Mangal et al., 2008, Fox et al., 2011, Zhou et al., 2014, Schwabl et al., 2017, Sharafi et al., 2017, Smith et al., 2017, Sofizadeh et al., 2018, Tealab 2018, Tohidinik et al., 2018, Meshgi et al., 2019). Predicting of time series has regularly been made under the assumption of linearity. As the simplest linear model, in the autoregressive (AR) it is assumed that the current value of the time series is a linear combination of its past values while, in the moving-average (MA) model the current values are considered as a function of perturbations that have affected the time series (Tealab 2018, Tohidinik et al., 2018). To minimize the limitation of AR and MA models, Autoregressive Integrated Moving Average (ARIMA) had been designed for predicting the future values of the time series. To apply various models, the series must be converted into stationary time series, initially. For this purpose, the T 1 value is subtracted from T value of the time series, and this will be continued until the stationary time series is got. This model has been successfully applied to the analysis of some parasitic diseases such as leishmaniasis, and malaria, (Hui-Yu et al., 2017, Sharafi et al., 2017) as well as fascioliasis (Molento et al., 2018, Pritsch et al., 2019) worldwide.

Owing to the socioeconomic challenges of CE, liver fluke's infections (fascioliasis and dicrocoeliasis), cysticercosis (*T. ovis* infection), and sarcocystosis (a protozoan zoonotic infection) in slaughtered sheep in Iran, the current study aimed to forecast the prevalence of these infections in a central slaughterhouse in Alborz Province, north-central Iran.

2. Materials e Methods

2.1. Area description and data collection

The evaluated slaughterhouse is in Alborz Province, the northwest neighbor of Tehran, the capital of Iran. The latitude and longitude for this area are 35.996047 and 50.928925, respectively. Its climate is varied from high temperature in summer and cold in the winter with a range from – 7°C in January to 40°C in August. The annual precipitation rate in this region is 173.2 mm. According to the latest census of the Statistical Center of Iran, the population of this province was 2,712,400 in 2016. In the current study, all data related to the number of slaughtered sheep, gender, breed, age at the time of slaughter, farming systems, breeding places, and the rate of infected carcasses with important parasitic diseases including, CE, fascioliasis, dicrocoeliasis, cysticercosis (*T. ovis* infection), and sarcocystosis was collected for the years 2009–2018.

2.2. Statistical and forecasting analysis

Descriptive analysis was used to evaluate the collected data. For calculation of the prevalence of parasitic diseases, infected organs, or carcasses (as nominator) are divided by the slaughtered cases (as denominator) in each year and/or month. The prevalence of parasitic infections is computed in excel software version 2016 (Microsoft Corporation, Redmond, WA, USA). The prevalence has been considered as a time series and afterward RStudio software version 2018 was used to fit the best ARIMA model to the given data. Eventually, the best-fitted ARIMA model was applied to forecast the monthly variation in prevalence rates of CE, fascioliasis, dicrocoeliasis, cysticercosis (*T. ovis* infection), and sarcocystosis up to the year 2027.

3. Results

During the studied period, a total of 1,339,196 sheep have been slaughtered in the selected slaughterhouse, and out of them, 90% were male with a maximum age of one year. The predominant sheep were Iranian Afshari breed and out of all slaughtered animals, 77.6% were raised under the traditional system (Table 1).

A total of 30% of slaughtered sheep in this slaughterhouse were native and raised in Alborz Province and the rest were brought from other provinces including Zanjan, Qazvin, Qom, Kurdistan, and East Azerbaijan (Figure 1). Among surveyed parasitic infections, the highest and lowest total prevalence belonged to CE (12.76%) and *T. ovis* infection (0.01%), respectively (Figure 2).

The prevalence trend of studied parasitic diseases from 2009 to 2018 has been depicted in Figure 3. In this study, the best-fitted ARIMA model has successfully been used to predict the prevalence of surveyed parasitic infections. The results indicated stationary, increasing, and/or mild decreasing trends for considered parasitic infections for the years ahead. An approximate stationary trend for fascioliasis and CE and a mild decreasing trend for dicrocoeliasis and sarcocystosis has been forecasted. Forecasting the prevalence of cysticercosis (*T. ovis* infection) showed an increasing trend. Figure 4 displayed the predicted prevalence of considered parasitic infections up to the year 2027.

Characteristics	*Sheep*	
	Male	*Female*
Slaughtering rate (%)	*90*	*10*
Age at slaughter	*1 ≤*	*4-5*
Breed	*Afshari (50%), Fashandi (45%), and Makoei (5%)*	
Farming system	*Traditional (77.6%), Industrial (22.4%)*	
Breeding places	*Alborz Province (30%), Zanjan, Qazvin, Qom, Kurdistan, and East Azerbaijan provinces (70%)*	

Table 1 *– Characteristics of slaughtered sheep in the studied slaughterhouse from 2009 to 2018 in Iran.*

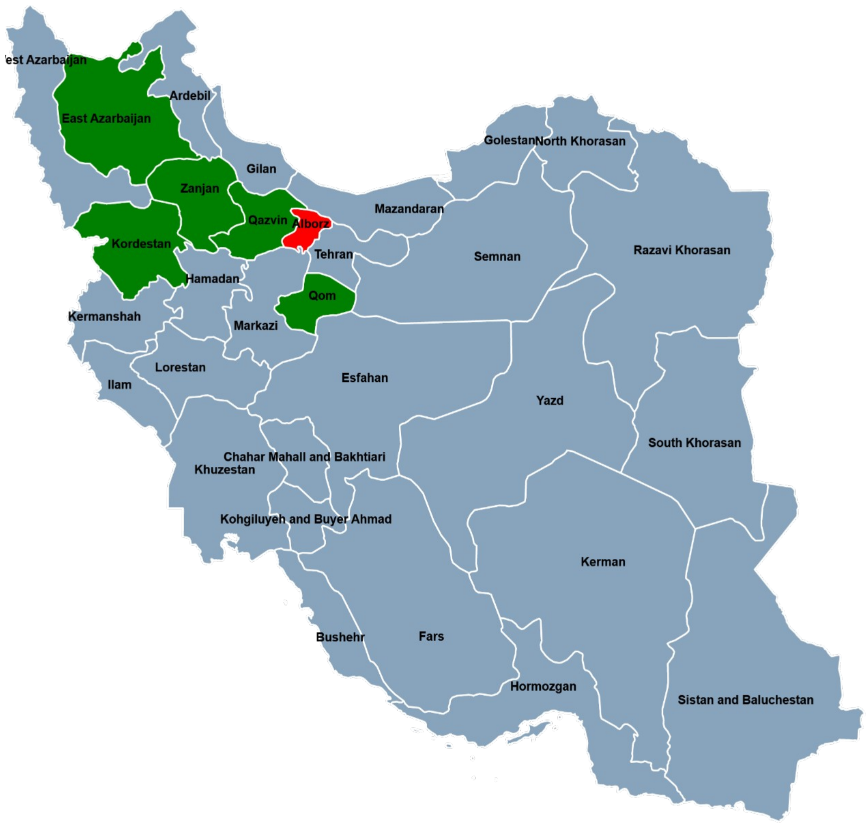

Figure 1 *– Depiction of the sources and/or breeding places of slaughtered sheep in the evaluated slaughterhouse in Iran. (Red color); the location of the studied slaughterhouse. (Green color); other five sources/breeding places of slaughtered sheep*

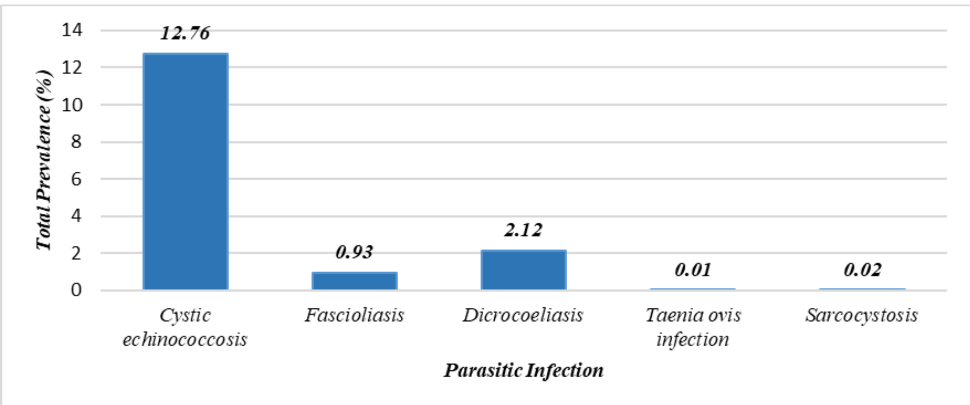

Figure 2 *– Total prevalence of parasitic infections in slaughtered sheep in the studied slaughterhouse from 2009 to 2018 in Iran.*

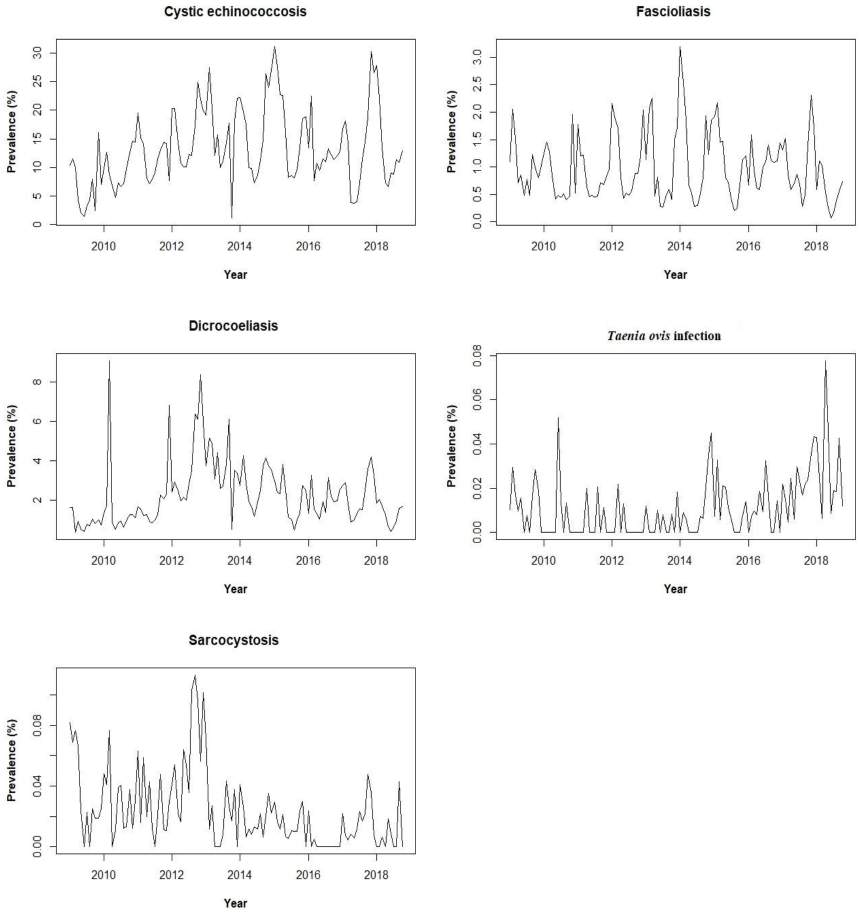

Figure 3 *– Seasonal fluctuation of the prevalence of evaluated parasitic infections in slaughtered sheep in studied slaughterhouse for the years 2009 to 2018 in Iran.*

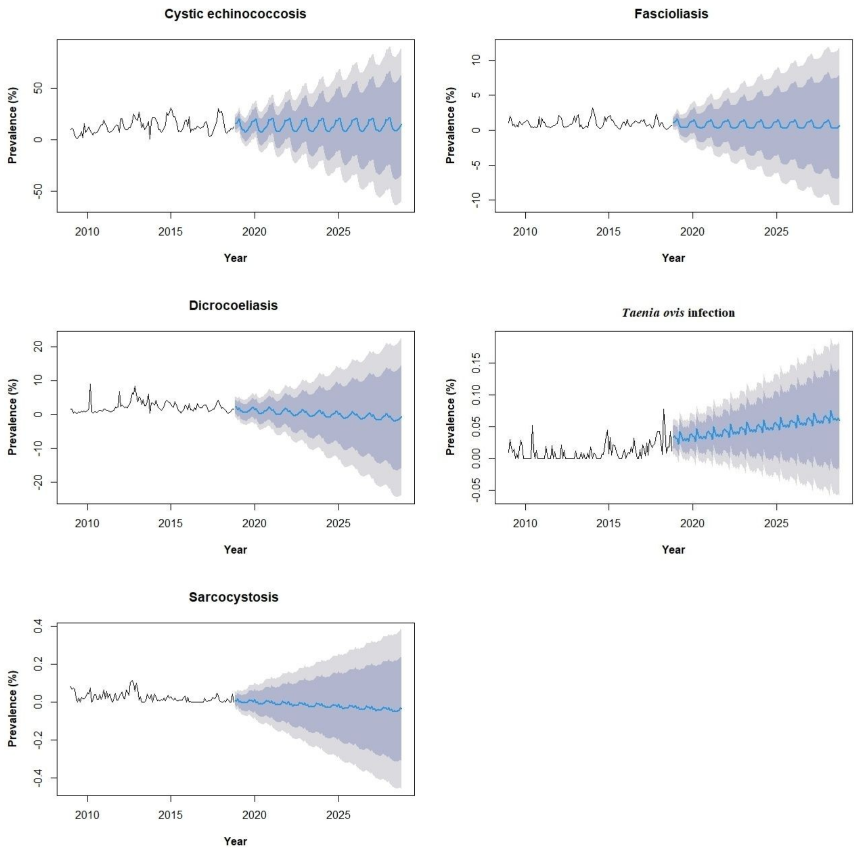

Figure 4 *– Forecasting the prevalence of evaluated parasitic infections in slaughtered sheep in studied slaughterhouse up to the year 2027. (Black line); plot for the prevalence in the studied time period (2009-2018). (Blue line); forecasted prevalence for the next 10 years. Dark and pale gray areas indicated the predictions with 80% and 95% confidence intervals, respectively.*

4. Discussion

Parasitic diseases are still among the most important challenges for animal farming worldwide, especially in low and middle-income countries (LMICs). It is necessary to pay attention to control measures to prevent the spread of diseases between other animals and human societies (Ebrahimipour et al., 2020). To the authors' knowledge, despite the reliability and common use of the time series ARIMA forecasting model, this is the first study to predict the prevalence of some parasitic infections in sheep in Iran.

As an endemic region for many parasitic infections, several previous studies have indicated the high prevalence of these infections in Iran. Studied parasitic diseases are among the most reported infections in small ruminants causing condemnation of edible parts of carcasses. The overall prevalence of CE in slaughtered livestock in Iran is reported 13.9% (95%CI: 10.7–17.7%) (Ebrahimipour et al., 2017, Mahmoudi et al., 2019, Vaisi-Raygani et al., 2021).

Previous studies in Iran demonstrated a high frequency of liver fluke infections (fascioliasis and dicrocoeliasis) in herbivorous animals across the country. (Kordshooli et al., 2017, Motazedian et al., 2019, Najjari et al., 2020). The prevalence rates of fascioliasis were reported 4.2% (95% CI = 3.8%–4.5%) in sheep, 9% (95% CI = 8.0%–9.9%) in cattle, and 3.1% (95% CI = 2.4%–3.7%) in goats throughout Iran (Khademvatan et al., 2019). The overall prevalence of dicrocoeliasis in slaughtered livestock was 2.17% in Iran (Meshgi et al., 2019). Other infections reported with lower prevalence in small ruminants slaughtered at slaughterhouses are cysticercosis (*T. ovis* infection) and sarcocystosis (Dehaghi et al., 2013, Hashemnia et al., 2015, Hashemnia et al., 2016, Sarafraz et al., 2020).

In the current study, the total prevalence of studied parasitic infections showed the highest and lowest for CE (12.76%) and cysticercosis (*T. ovis* infection) (0.01%), respectively (Fig. 1). The results of this study are in line with previous studies in Iran that reported CE, fascioliasis, dicrocoeliasis as well as cysticercosis (*T. ovis* infection), and sarcocystosis as socioeconomic challenges in slaughterhouses.

Estimating the future prevalence of other parasitic infections has been considered in several studies in many countries (Schwabl et al., 2017, Molento et al., 2018). The next year's dirofilariasis prevalence (2015-2017) was forecasted based on the spatial-temporal conditional autoregressive model in the United States and the results indicated that canine heartworm can be predicted accurately (Bowman et al., 2016). The high-risk regions for soil-transmitted helminths and *Schistosoma mansoni* in Rwandan schoolchildren were predicted using conditional random fields (CRF) method. This model predicted a risk map of co-infection (*A. lumbricoides* and *T. trichiura*) with more than 300 children infected per km^2 in some western and northwestern regions. The results showed a prevalence for hookworms and *S. mansoni* lower than 20% throughout the country (Clark et al., 2020).

The prevalence of *Trypanosoma cruzi* in related hosts and vectors was predicted in some countries in the Americas. The results indicated the importance of reservoir hosts as supplementary types of agents in the model. The authors presented an agent-based model (ABM) as a good method in the parasitology modeling (Devillers et al., 2008). As reliable tools to combat forthcoming epidemics and outbreaks of parasitic infections, various models have been applied to predict these diseases (Mangal et al., 2008, Magalhães et al., 2011, Zhou et al., 2014, Funk et al., 2018).

Several previous studies have stressed the forecasting of parasitic diseases in Iran. In one study in Fars Province, the incidence and effect of climate variables on zoonotic cutaneous leishmaniasis (ZCL) were evaluated using the Seasonal Autoregressive Integrated Moving Average (SARIMA) model. The results showed that the incidence of ZCL could be estimated by the number of cases in a given month (Tohidinik et al., 2018). The higher presence possibility of *Leishmania* vectors was predicted and the areas with a higher chance were categorized. The results could be reliable in the decision for the disease control (Mollalo et al., 2018, Sofizadeh et al., 2018). Environmental suitability assessment and geographical distribution of *D. dendriticum* are analyzed at the coast of the Caspian Sea, Iran. The considerable prevalence of this infection and the climate variables as effective predictive factors were emphasized in this study (Meshgi et al., 2019).

In the studied slaughterhouse, slaughtered sheep were brought from Alborz Province and other 5 provinces in Iran. In these breeding places, predominant traditional husbandry (77.6%), semi-arid climate, frequent mountain, agro-pastoral areas, and abundance of definitive hosts facilitate the transmission of these infections. The results of this study showed a mild decreasing trend for dicrocoeliasis and sarcocystosis, while for fascioliasis, cysticercosis (*T. ovis* infection), and CE, approximate stationery and/or increasing trends have been expected.

Although the current study is the first to forecast the prevalence of some important parasitic infections in Iran, it has several limitations. The most prominent limitation is the restriction of data to just one slaughterhouse and the results of this study could not be a reflection of entire country. With the investigation in vast geographical areas and more data from other slaughterhouses, the results could be more defensible. Another important restriction is conducting the study just based on parasitic infections prevalence without considering in-depth assessment of effect the environmental factors and climate change on these diseases. Nevertheless, the 10 years of data on parasitic zoonoses prevalence in selected slaughterhouse could be a highly reliable basis for predicting assay.

5. Conclusion

The current study has demonstrated for the first time the predicting of some important parasitic infections in sheep in Iran. The data revealed a mild decreasing trend for dicrocoeliasis and sarcocystosis, and stationery and/or increasing trends for fascioliasis, cysticercosis (*T. ovis* infection), and CE, for the studied slaughterhouse. Vast and in-depth forecasting investigations is required to find more defensible evidence-based data about these infections for entire the country of Iran.

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Declaration of interest: The authors declare that they have no conflict of interest.

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