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Review

Prevalence of *Leishmania* species in rodents: A systematic review and meta-analysis in Iran

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A R T I C L E I N F O

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A B S T R A C T

Leishmaniasis are diverse group of diseases caused by numerous species of genus *Leishmania*. Herein we have contrived a systematic review and meta-analysis on the prevalence of *Leishmania* species in rodents of Iran. For this purpose, following the general methodology recommended for systematic reviews and meta-analysis, six English databases (PubMed, Science Direct, Scopus, Ovid, Web of Science and Google Scholar) and four Persian databases (Magiran, SID, Iran Doc and Iran Medex) were explored during January 1995 till June 2015. Papers were selected based on 8 pre-defined inclusion criteria. During the years, a total number of 4485 different rodents were captured; among which 1291 cases were *Leishmania* positive. The calculated weighted prevalence of *Leishmania* species in rodents was 23% (95% CI = 18–28). Given geographical zones of Iran, the highest and lowest prevalence rate was belonged to North 50% (95% CI = 40–61) and West 11% (95% CI = 5–17), respectively. *Rhombomys opimus* (1766), *Meriones lybicus* (1258) and *Tatera indica* (488) were the three most abundant captured rodents, while the highest prevalence of *Leishmania* species was observed in *Nesokia indica* 48% (95% CI = 42–54) and followed by *R. opimus* 39% (95% CI = 30–47). Egger's regression test was performed to detect publication bias, which revealed it may not have a significant influence on overall weighted prevalence estimate ($P = 0.317$). Meta-regression analysis demonstrated that there is no significant relationship between overall prevalence with sample size ($P = 0.1$) and year of publication ($P = 0.7$). The results showed remarkable prevalence of *Leishmania* species in rodent reservoirs. In future, adopting a suitable strategy for control and combat with rodents is necessary.

1. Introduction

Leishmaniasis are one of the ancient zoonotic diseases which human being has encountered since 650 B.C. or even earlier (Akhoundi et al., 2016). Intracellular parasites of *Leishmania* genus belong to family Trypanosomatidae (order Kinetoplastida) and over 21 species cause this neglected arthropod-borne disease that based on etiological agents and clinical manifestations are classified into at least four major forms, including cutaneous, diffused cutaneous, muco-cutaneous and visceral (Akhoundi et al., 2016; Alvar et al., 2012). Leishmaniasis has been reported from over 100 countries as well as 350 million people are at risk, because of living in endemic regions. Based on recent reports, there are nearly 12 million infected persons worldwide and annual incidence of new cases of visceral and cutaneous leishmaniasis (CL) were estimated 0.2–0.4 million and 0.7–1.2 million, respectively (Alvar et al., 2012; Khademvatan et al., 2017b). Approximately 70–75% of new CL cases happen in ten countries, including: Colombia, Peru, Brazil, Costa Rica, Algeria, North Sudan, Ethiopia, Afghanistan, Iran and Syria (Alvar et al., 2012). Environmental changes resulting from man proceedings, urbanization, and migration has lead to global diffusion of CL (Alvar et al., 2012; Postigo, 2010). Despite many efforts, CL is still prevalent in some countries of the Eastern Mediterranean

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Region (EMR) (Alvar et al., 2012; Holakouie-Naieni et al., 2017; Postigo, 2010). In Iran, approximately 30.9 per 100,000 in population are infected to CL annually with the most incidence rate in Isfahan and Fars provinces and the least in Gilan province (Holakouie-Naieni et al., 2017). First-line drugs for the treatment of CL are pentavalent antimonial compounds, such as pentostam and glucantime, which have been prescribed since the seven decades ago until the present and have several limitations to use (Albakhit et al., 2016; Croft et al., 2006; Foroutan-Rad et al., 2016b; Foroutan-Rad et al., 2017; Khademvatan et al., 2016).

Two major forms of CL exists in Iran: anthroponotic cutaneous leishmaniasis (ACL) resulting from *Leishmania tropica* (*L. tropica*), rendering late ulcerative, urban, dry form with longer infection period and zoonotic cutaneous leishmaniasis (ZCL) due to *L. major*, causing early ulcerative, wet, rural form with shorter infection period (Gholamrezaei et al., 2016; Holakouie-Naieni et al., 2017; Khademvatan et al., 2017b; Saki and Khademvatan, 2012; Saki et al., 2010). Most of the sand fly species are of medical importance in virtue of playing a remarkable role as vectors of several infectious agents such as *Leishmania*. In Iran, *Phlebotomus sergenti* (*P. sergenti*) and *P. papatasi* are the predominant vectors for ACL and ZCL, respectively (Karimi et al., 2014; Kavarizadeh et al., 2017; Parvizi et al., 2012; Rassi et al., 2008b; Yavar et al., 2013). Rodents are small mammals with short reproductive cycle, having exclusive morphologic and biologic adaptations to aquatic, terrestrial and arboreal environments. The rodents are involved in the transmission and distribution of various infectious diseases such as leishmaniasis (Dehghani et al., 2013; Khademvatan et al., 2017a; Meerburg et al., 2009; Saki et al., 2016). Given that ZCL in Iran is actually a rodent-derived infection, so its distribution highly correlates to the ecology and the spread of these reservoir hosts (Akhoundi et al., 2013; Gholamrezaei et al., 2016; Hajjaran et al., 2013; Holakouie-Naieni et al., 2017; Mohebali et al., 2004). Therefore, regarding the status of CL, presence of various rodent species in different geographic regions, and the importance of surveillance of reservoir hosts in Iran, there is a need to gather information about the rodent hosts, and determine the prevalence as well as type of *Leishmania* species in these small mammals. There are many published papers about prevalence of *Leishmnaia* species in rodents of Iran, but there is lack of a comprehensive review in this case. Therefore, we designed a systematic review and meta-analysis to estimate the pooled prevalence of *Leishmania* species in different rodent species and determine their geographical distribution in Iran.

2. Materials and methods

2.1. Search strategy

To evaluate the prevalence of *Leishmania* species in different rodent species of Iran, six English databases (PubMed, Science Direct, Scopus, Ovid, Web of Science, and Google Scholar) and four Persian databases (Magiran, Scientific Information Database, Iran Doc, and Iran Medex) were explored for relevant papers during January 1995 till June 2015 (Fig. 1). This systematic review was performed using medical subject headings (MeSH) terms such as: "Iran", "Islamic Republic of Iran", "*Leishmania*", "Rodent", "Rodentia", "Rat", "Mouse", "Reservoirs", "Epidemiology", and "Prevalence" alone or combined together with "OR" and/or "AND". To improve the search strategy and retrieving more precise citations, the scientific name of main rodent species were also searched including: *Rhombomys opimus* (*R. opimus*), *Tatera indica* (*T. indica*), *Meriones libycus* (*M. libycus*), *Gerbillus nanus* (*G. nanus*), *Nesokia indica* (*N. indica*), *Meriones hurrianae* (*M. hurrianae*), and *Meriones persicus* (*M. persicus*).

2.2. Inclusion/exclusion criteria and data extraction

During initial search, the relevant citations were recorded based on topics and abstracts of them were saved in a world file for next evaluation. Afterwards, based on primary screening the records that seem to be potentially eligible were chosen to download the full text. The full text articles were reviewed by 2 independent reviewers (M. Foroutan and S. Khademvatan) to evaluate the final eligibility and inclusion criteria. Selected articles were read carefully and contradictions among studies were resolved by discussion and consensus. The required data were extracted by one author (M. Foroutan) and rechecked by a second (S. Khashaveh). Inclusion criteria were as follows: (1) original research papers; (2) cross-sectional studies that estimated the prevalence of *Leishmania* species in different rodent species; (3) published in Persian or English; (4) published online between January 1995 till June 2015; (5) full-text articles were available; (6) those that employed at least one of the following methods including microscopy, culture, BALB/c inoculation, and molecular techniques; (7) exact total sample size and positive samples were available; (8) exact number of different rodent species and their positive samples were available. The papers were excluded if they didn't met the above-mentioned criteria. The reference list of selected full-text papers were also meticulously checked manually to find articles not retrieved by the database searching. Finally the detailed characteristics of each paper were extracted using a data extraction form on the basis of study characteristics (the first author, province, year of publication); study methodology (microscopy, culture, BALB/c inoculation and, PCR-based methods), kind of rodent species and their geographical distribution (*M. libycus*, *R. opimus*, *T. indica*, *G. nanus*, *N. indica*, *M. hurrianae*, *M. persicus*, *Rattus rattus*, *Rattus norvegicus*, *Mus musculus*, etc); total sample size; the number of positive samples and/or prevalence rate; the parasite species (*L. major*, *L. turanica, L. gerbilli*, *L. tropica* and mixed). It should be noted three papers have surveyed the rodents in several provinces (Akhoundi et al., 2013; Hajjaran et al., 2013; Mohebali et al., 2004). In this cases, we considered each province as a separate record for estimating pooled prevalence, as shown in Supplementary Table 1. The preferred reporting items for systematic reviews and meta-analysis guideline was used to report our results (Moher et al., 2010).

2.3. Meta-analysis

Each study was appraised in terms of prevalence and its 95% confidence interval (CI). Yield of meta-analysis was revealed in frame of a forest plot, indicating prevalence estimates and their dedicated condfidence intervals of each study with the summary measure. Cochran's *Q* and I^2 statistics were applied in order to analyze the heterogeneity. I^2 values of 25%, 50% and 75% were considered as low, moderate and high heterogeneity, respectively (Higgins and Thompson, 2002). Additionally, publication bias and small study effects were measured by funnel plot relied on Egger's regression test. According to results obtained from heterogeneity test, in case of pooling the estimations, either Der Simonian and Laird's random-effects method or Mantel-Haenszel's fixed-effects method were used (Foroutan-Rad et al., 2016a; Foroutan-Rad et al., 2016c). Furthermore, studies were assorted by regions of Iran country (North, South, East, West and Center) and total prevalence was estimated in these geographical foci. Meta-regression test was performed to assess the association between total prevalence, sample size and year of studies. ArcGIS software by Esri (http://www.esri.com) was employed for mapping the geographical distribution of captured rodents. Also the pooled prevalence of *Leishmania* species was depicted using this software in different provinces of Iran.

3. Results

A total of 9356 citations were found following the initial search of databases and finally 56 papers had eligibility to be included in current systematic review and meta-analysis (Akhavan et al., 2003; Akhavan

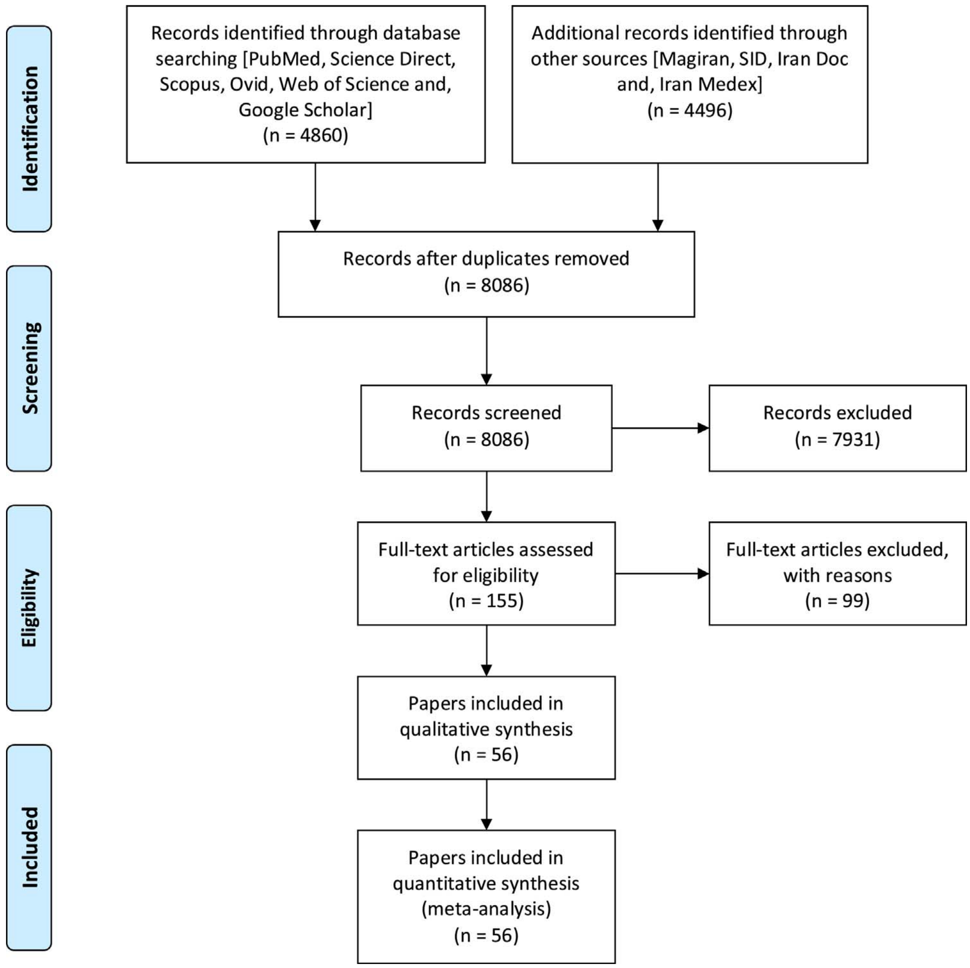

Fig. 1. Flowchart describing the study design process.

et al., 2010a; Akhavan et al., 2010b; Akhavan et al., 2007; Akhavan et al., 2010c; Akhoundi et al., 2013; Asgari et al., 2007; Azizi et al., 2011; Davami et al., 2014; Doroodgar et al., 2009; Doroudgar et al., 1997; Ghaffari et al., 2014; Hajjaran et al., 2013; Hajjaran et al., 2009; Hanafi-Bojd et al., 2006; Jafari et al., 2008; Jafari et al., 2007; Kassiri et al., 2011; Kassiri et al., 2013; Masoumeh et al., 2014; Mehrabani et al., 2011a; Mehrabani et al., 2011b; Mehrabani et al., 2007; Mirzaei et al., 2013; Mirzaei et al., 2011; Moemenbellah-Fard et al., 2003; Mohammadi Azni et al., 2012; Mohebali et al., 2004; Motazedian et al., 2010; Najafzadeh et al., 2014; Parhizkari et al., 2011; Parvizi et al., 2012; Parvizi and Hedayati, 2010; Parvizi et al., 1999; Parvizi et al., 2008; Pourmohammadi et al., 2008; Rafizadeh et al., 2014; Rassi et al., 2008a; Rassi et al., 2015; Rassi et al., 2007; Rassi et al., 2001; Rassi et al., 2006; Rassi et al., 2011; Rassi et al., 2008b; Rouhani et al., 2014; Saberi et al., 2013; Saghafipour et al., 2012; Vazirianzadeh et al., 2013; Yaghoobi-Ershadi et al., 2008; Yaghoobi-Ershadi et al., 2003; Yaghoobi-Ershadi et al., 2001; Yaghoobi-Ershadi et al., 2004; Yaghoobi-Ershadi and Javadian, 1996; Yaghoobi-Ershadi et al., 2013; Yavar et al., 2011; Yavar et al., 2013 Saberi et al., 2013; Saghafipour et al., 2012; Vazirianzadeh et al., 2013; Yaghoobi-Ershadi et al., 2008;, 2003;, 2001;, 2004; Yaghoobi-Ershadi and Javadian, 1996; Yaghoobi-Ershadi et al., 2013; Yavar et al., 2011, 2013). Flowchart describing the study design process is depicted in Fig. 1. The detailed characteristics of included articles have been inserted in Supplementary Table 1. Publication bias was checked by Egger's regression test, showed that it may not have a substantial impact on total prevalence estimate (P = 0.317) (Table 1 and Fig. 2). During January 1995–June 2015, a total number of 4485 rodents were captured, among which 1291 cases were *Leishmania* positive. The calculated weighted prevalence of *Leishmania* species in rodents was 23% (95% CI = 18%–28%) (Table 1). Given geographical zones of Iran, prevalence of *Leishmania* species in rodent reservoir hosts was the highest in North with 50% (95% CI = 40%–61%) and lowest in West with 11% (95% CI = 5%–17%) (Table 1 and Fig. 3). Also, Table 2 shows the pooled prevalence of *Leishmania* species in different captured rodents in Iran. Using molecular methods, out of 3005 tested rodents, 765 were positive in terms of *Leishmania* species and most of the animals were found to be infected with *L. major* (580 cases) and *L. turanica* (84 cases) (Table 3). Distribution of various captured rodents in Iran are illustrated in Fig. 4.

Table 1
Subgroup analysis for comparison of prevalence in different geographical regions.

Region	No. of studies	Prevalence 95%CI	I^2%	Heterogeneity test		Egger test	
				Q	P	t	P
North	13	50 (40–61)	91.05	134.07	< 0.001	0.38	0.693
South	21	17 (10–25)	93.08	289.15	< 0.001	0.29	0.754
Center	21	21 (13–30)	92.34	261.26	< 0.001	−1.73	0.154
West	5	11 (5–17)	0	2.04	0.73	−0.93	0.236
East	7	14 (8–22)	59.80	14.93	0.02	0.16	0.859
Overall	67	23 (18–28)	93.99	1097.35	< 0.001	−0.38	0.317

Test for heterogeneity between sub-groups: Q: 46.04 P-value < 0.001.

Meta-regression analysis showed that there is no significant association between overall prevalence with year of publication (P = 0.7) (Fig. 5) and sample size (P = 0.1) (Fig. 6).

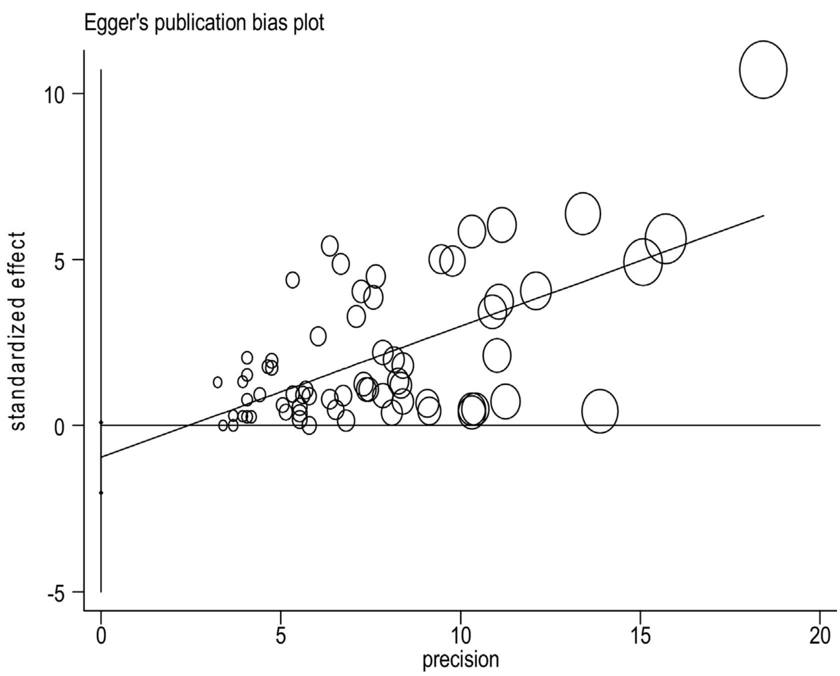

Fig. 2. Funnel plot to detect publication bias.

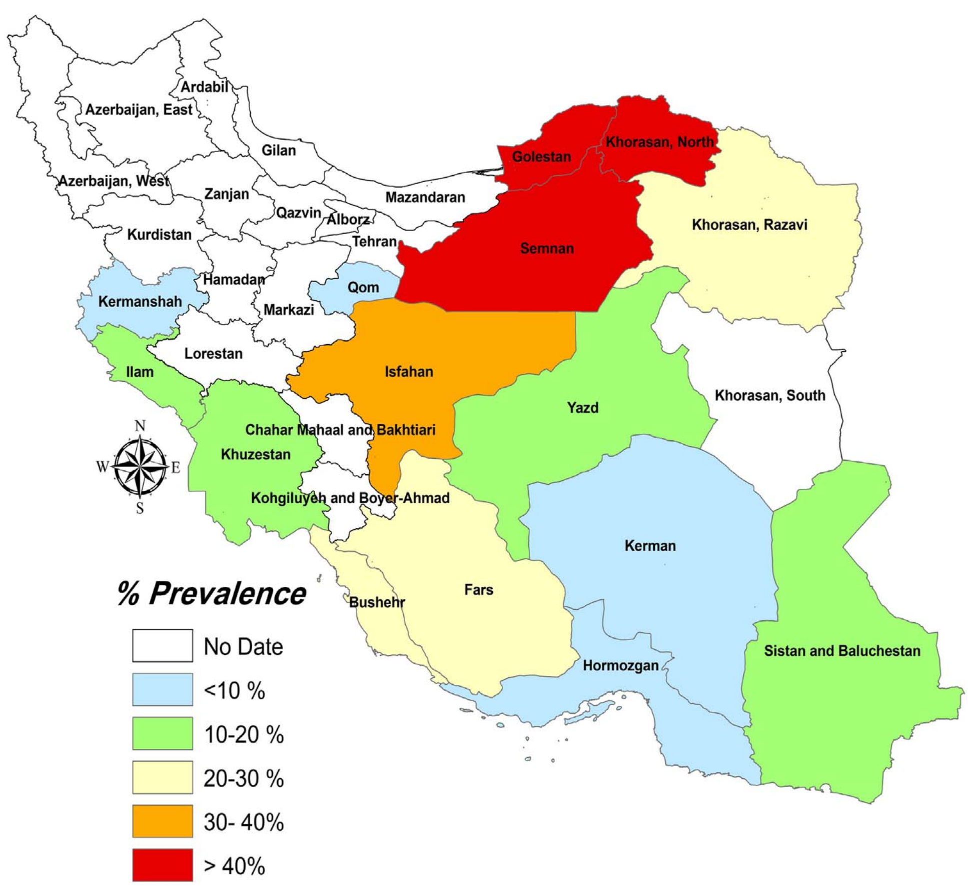

Fig. 3. Prevalence of *Leishmania* species in different geographical regions of Iran based on included papers. This map was created using ArcGIS software by Esri (http://www.esri.com).

4. Discussion

Role of rodents in spread of leishmaniasis is clearly evident. Several species of rodents have been described throughout Iran that play potential role in maintenance and establishment of *Leishmania* species life cycle (Akhavan et al., 2010b; Akhoundi et al., 2013; Gholamrezaei et al., 2016; Hajjaran et al., 2013; Mohebali et al., 2004). Unfortunately, there weren't enough papers investigating the prevalence of *L. major* in rodent hosts in other countries. A study in central Tunisia demonstrated the prevalence of *L. major* infection among *Psammomys obesus* (*P. obesus*) and *Meriones shawi* (*M. shawi*) rodents. Prevalence of *L. major* infection was 7% versus 5% for culture, 19% versus 16% for

Table 2
Subgroup analysis for comparison of prevalence according to kind of rodents.

Kind of rodents	No. of studies	No. of captured rodents	Positive (n)	Prevalence 95%CI
M. libycus	40	1258	208	9 (4–14)
R. opimus	33	1766	718	39 (30–47)
T. indica	22	488	91	14 (6–24)
G. nanus	3	20	2	2 (0–22)
N. indica	14	367	186	48 (42–54)
M. hurrianae	4	87	12	12 (5–21)
M. persicus	10	133	27	17 (2–40)
R. rattus/R. norvegicus/M. musculus	16	194	44	20 (13–27)
Others	14	172	3	1 (0–2)
Total		4485	1291	23 (18–28)

Abbreviations;: *G. nanus*, *Gerbillus nanus*; *M. hurrianae*, *Meriones hurrianae*; *M. libycus*, *Meriones libycus*; *M. persicus*, *Meriones persicus*; *M. musculus*, *Mus musculus*; *N. indica*, *Nesokia indica*; *R. norvegicus*, *Rattus norvegicus*; *R. rattus*, *Rattus rattus*; *R. opimus*, *Rhombomys opimus*; *T. indica*, *Tatera indica*.

Table 3
Subgroup analysis for comparison of prevalence in terms of *Leishmania* species.

Leishmania species	Positive (n)	Prevalence 95%CI
L. major	580	17.89% (13.06–23.25)
L. turanica	84	1.93% (0.0000–3.51)
L. gerbilli	3	0.07% (0.0000–0.11)
L. tropica	1	0.01% (0.0000–0.04)
Mixed	73	1.79% (0.0000–3.19)
Unidentified	24	0.41% (0.0000–0.91)
Total	765	23.54% (17.73–29.85)

Extracted from 42 papers/No. of tested rodents (n = 3005): (Akhavan et al., 2010a; Akhavan et al., 2010b; Akhavan et al., 2010c; Akhoundi et al., 2013; Asgari et al., 2007; Azizi et al., 2011; Davami et al., 2014; Doroodgar et al., 2009; Ghaffari et al., 2014; Hajjaran et al., 2009; Jafari et al., 2007; Kassiri et al., 2013; Masoumeh et al., 2014; Mehrabani et al., 2011a; Mehrabani et al., 2011b; Mehrabani et al., 2007; Mirzaei et al., 2013; Mirzaei et al., 2011; Moemenbellah-Fard et al., 2003; Mohammadi Azni et al., 2012; Mohebali et al., 2004; Motazedian et al., 2010; Najafzadeh et al., 2014; Parhizkari et al., 2011; Parvizi et al., 2012; Parvizi et al., 2008; Rafizadeh et al., 2014; Rassi et al., 2008a; Rassi et al., 2015; Rassi et al., 2007; Rassi et al., 2001; Rassi et al., 2006; Rassi et al., 2011; Rassi et al., 2008b; Rouhani et al., 2014; Saghafipour et al., 2012; Vazirianzadeh et al., 2013; Yaghoobi-Ershadi et al., 2008; Yaghoobi-Ershadi et al., 2001; Yaghoobi-Ershadi et al., 2013; Yavar et al., 2011; Yavar et al., 2013 Saghafipour et al., 2012; Vazirianzadeh et al., 2013; Yaghoobi-Ershadi et al., 2008;, 2001;, 2013; Yavar et al., 2011, 2013).

direct examination of smears, and 20% versus 33% for indirect fluorescent antibody test (IFAT) among *P. obesus* and *M. shawi*, respectively (Ghawar et al., 2011). Echchakery et al. (2015) declared that "in Morocco, the order Rodentia is represented by 7 families and 32 species of which *R. norvegicus*, *P. obesus*, *Mastomys erythrolecus*, *M. shawi*, *Meriones crassus* and *M. libycus* are considered reservoirs of leishmaniasis in Asia, Midle East and Africa" (Echchakery et al., 2015). Also, some reports have indicated the infection to *L. donovani*, *L. infantum* and *L. tropica* in some rodents such as *Gerbillus*, *R. norvegicus* and *M. musculus* (Helhazar et al., 2013; Kassahun et al., 2015; Navea-Perez et al., 2015), suggesting their potential to act as reservoir for another *Leishmania* species. Rural regions and suburbia areas of Iran are considered as endemic with respect to rodent reservoir hosts and zoonotic cutaneous leishmaniasis (Gholamrezaei et al., 2016; Holakouie-Naieni et al., 2017; Sedaghat and Salahi Moghaddam, 2010). According to Table 2, more than eight different rodent species were captured, of which 3 dominant reservoirs were including *R. opimus* (1766), *M. libycus* (1258) and *T. indica* (488), respectively, while the highest prevalence of *Leishmania* species was observed in *N. indica* 48% (95% CI = 42–54), followed by *R. opimus* 39% (95% CI = 30–47). More details are presented in Table 2. Based on distribution map for *R. opimus*, *M. libycus* and *T. indica*, they altogether cover most of the country landmass except of the North and Northwest regions (Gholamrezaei et al., 2016). Distribution of the great gerbil, *R. opimus*, is mainly confined to central and northeastern realms and it has been shown to be mostly infected by *L. major* (Gholamrezaei et al., 2016; Mirzaei et al., 2014; Mohebali et al., 2004; Sedaghat and Salahi Moghaddam, 2010). *T. indica*, the Indian gerbil, is frequently observed in Southern and Southwestern territories that is accounted as principle reservoir in absence of *R. opimus* (Akhoundi et al., 2013; Dehghani et al., 2013; Gholamrezaei et al., 2016; Vazirianzadeh et al., 2013). Molecular studies have revealed the infection of this rodent species with *L. major* (Akhoundi et al., 2013; Vazirianzadeh et al., 2013; Yaghoobi-Ershadi et al., 2013). The Libyan jird, *M. libycus*, occupies broader lands than the two others and is characterized as the main reservoir in some regions (Akhoundi et al., 2013; Gholamrezaei et al., 2016; Mirzaei et al., 2014; Sedaghat and Salahi Moghaddam, 2010). Given high CL cases in humans during last three decades, it's accounted as a substantial threat in health sector, suggesting the significance of distribution pattern maps for ZCL (Gholamrezaei et al., 2016; Holakouie-Naieni et al., 2017). There's a consensus that every natural reservoir host possess its own niche for living which is overwhelmed by several factors such as vegetation, climate, and geographical topography (Dehghani et al., 2013; Gholamrezaei et al., 2016; Sedaghat and Salahi Moghaddam, 2010). In recent publication, the highest incidence rate of CL between 1983 and 2013 was dedicated to Isfahan province, followed by Fars, Bushehr, Ilam, Khuzestan provinces (Holakouie-Naieni et al., 2017). The prevalence map of *L. major* cases in Iran (Holakouie-Naieni et al., 2017; Salahi-Moghaddam et al., 2015; Sedaghat and Salahi Moghaddam, 2010) alongside above-mentioned findings are consistent with our results implicating the geographical distribution of reservoir hosts and their pivotal role in disease epidemiology.

Four different types of diagnostic methods were utilized to estimate *Leishmania* species in rodent reservoirs from Iran are including: smear method, BALB/c inoculation, culture, and molecular tools; the most applied examinations were smear method followed by molecular tools, parasite culture and BALB/c inoculation. PCR-based techniques are more sensitive to detect the parasite and are also able to discern *Leishmania* species, comparable to other experimental methods, and have been successfully evaluated (Akhavan et al., 2010a; Akhavan et al., 2010b; Akhavan et al., 2010c; Akhoundi et al., 2013; Azizi et al., 2011; Davami et al., 2014; Mirzaei et al., 2013; Mirzaei et al., 2011; Motazedian et al., 2010; Najafzadeh et al., 2014; Rouhani et al., 2014; Yaghoobi-Ershadi et al., 2013 Yaghoobi-Ershadi et al., 2013).

Our systematic review and meta-analysis is subject to 2 limitations: 1) different diagnostic methods with different sensitivities and specificities were used to detect the parasite in rodents; and 2) there are certain knowledge gaps in some regions of Iran in terms of prevalence of *Leishmania* species (especially *L. major*) in rodent reservoirs in those areas. Thus, these limitations implicate more accurate epidemiological experiments with a unique, highly sensitive method in order to determine the prevalence of *Leishmania* species in small mammal reservoirs in Iran and to improve more elaborated picture for their ecology and control programs.

In conclusion, to the best of our knowledge, this was the first systematic review on the prevalence of *Leishmania* species in different rodent hosts of Iran, which showed high prevalence of infection. The nationwide control programs have to take into account the obtained results from this study to confront ZCL and to lower the incidence of clinical cases in Iran annually. In particular, some points should be exerted in case of constant surveillance of ZCL infection status in rodent species by using sensitive molecular approaches, decreasing the number of animal reservoirs and confining their traffic around human societies, elevated health practice and improved public awareness about disease consequences, regular monitoring of travelers and immigrants coming from endemic nations, skin protection from sand fly bites by spraying

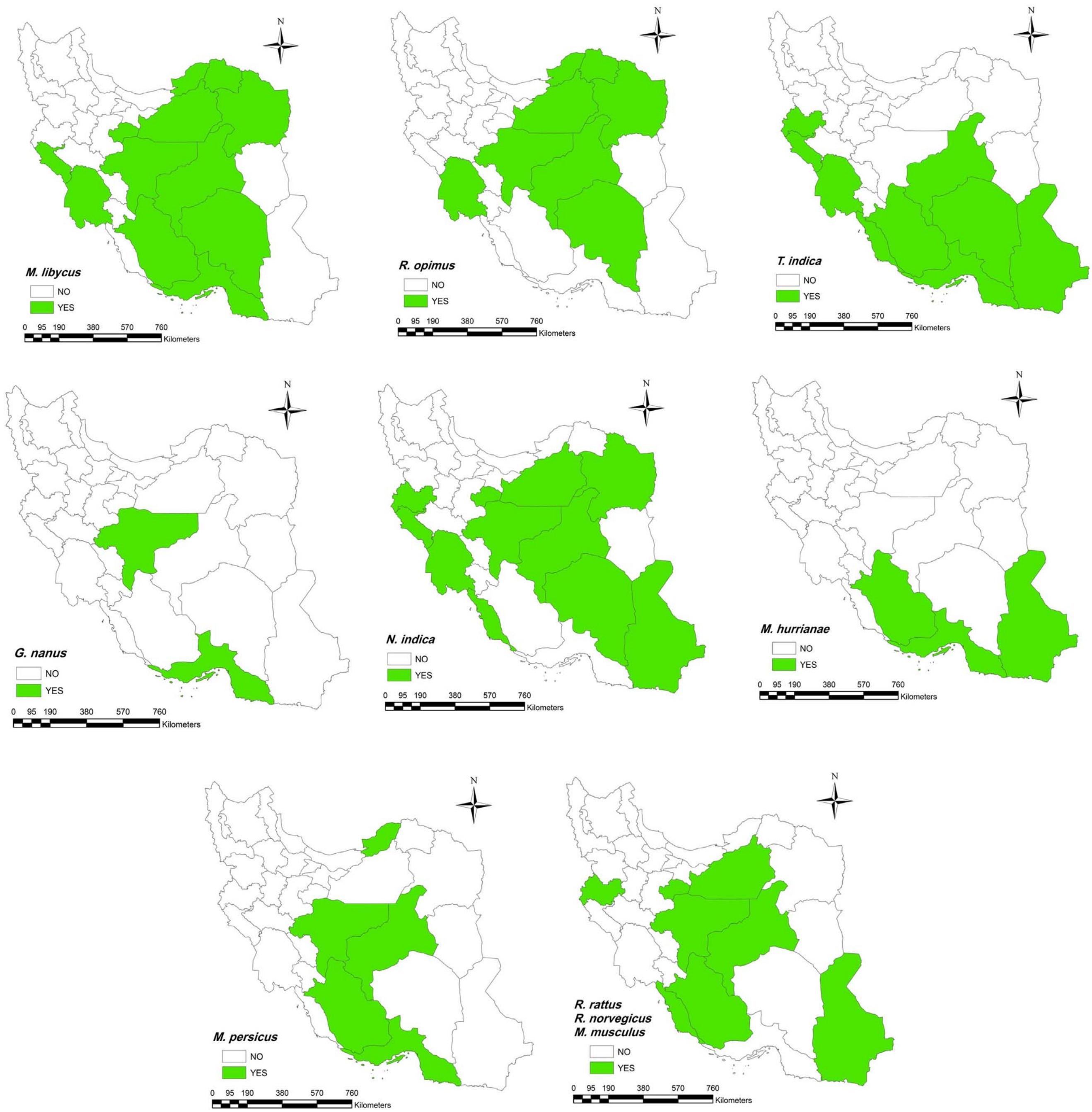

Fig. 4. Distribution of various captured rodents in Iran based on included papers. Yes indicates the presence of rodent in region; No indicates lack of the presence of rodent in region.Abbreviations: *G. nanus*, *Gerbillus nanus*; *M. hurrianae*, *Meriones hurrianae*; *M. libycus*, *Meriones libycus*; *M. persicus*, *Meriones persicus*; *M. musculus*, *Mus musculus*; *N. indica*, *Nesokia indica*; *R. norvegicus*, *Rattus norvegicus*; *R. rattus*, *Rattus rattus*; *R. opimus*, *Rhombomys opimus*; *T. indica*, *Tatera indica*.

insecticides and bed nets as well as destruction of rodent habitats to interrupt the transmission of this chronic infection.

Authors' contributions

M. Foroutan conceived the study; M. Foroutan and S. Khademvatan designed the study protocol; M. Foroutan and S. Khademvatan searched the literature; M. Foroutan and S. Khashaveh extracted the data; H. Khalkhali analyzed and interpreted the data; F. Hedayati-Rad prepared the maps using ArcGIS software; H. Majidiani and M. Foroutan wrote the manuscript; M. Foroutan, S. Khademvatan, H. Majidiani, and H. Mohammadzadeh critically revised the manuscript. All authors read and approved the final manuscript. Ethical issues (Including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Competing interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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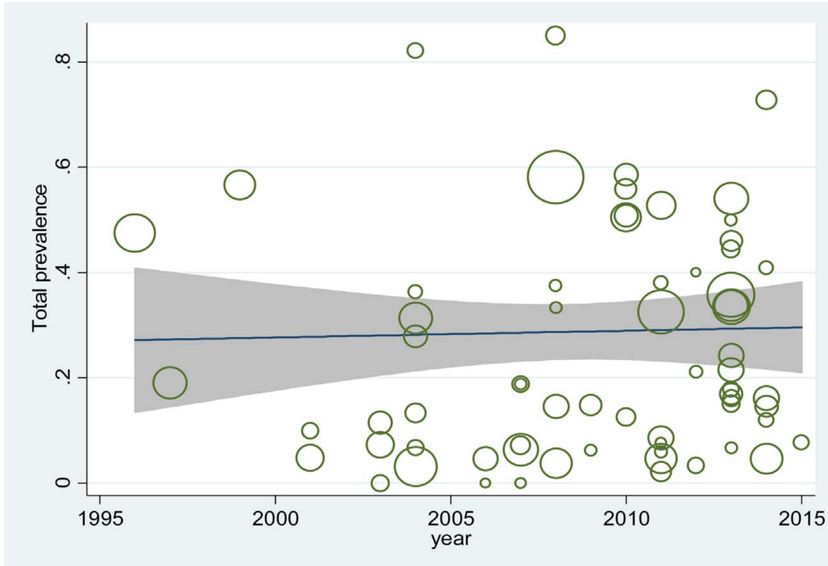

Fig. 5. Meta-regression plot of prevalence of *Leishmania* species according to the year of the study.

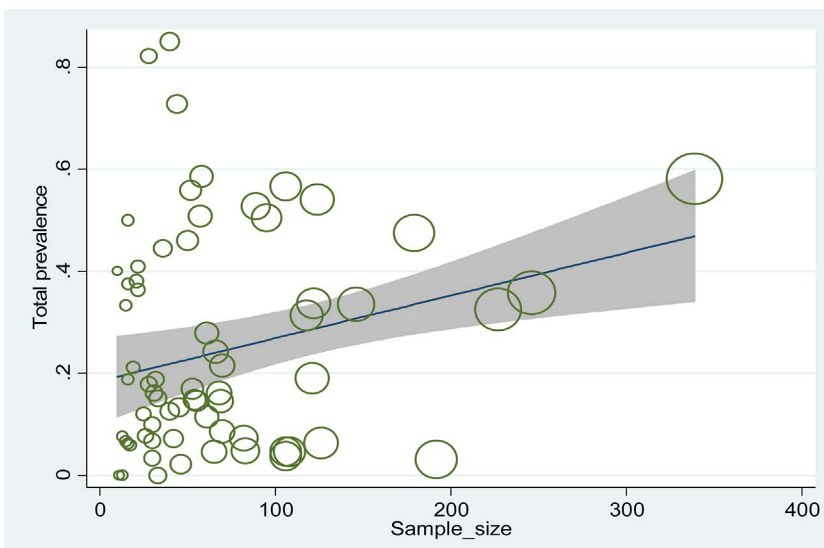

Fig. 6. Meta-regression plot of prevalence of *Leishmania* species according to the sample size.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.actatropica.2017.04.022.

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